CIE **COMMISSION INTERNATIONALE DE L'ECLAIRAGE**
ROMANIAN NATIONAL COMMITTEE ON ILLUMINATION CNRI

UNIVERSITATEA TEHNICĂ DIN CLUJ-NAPOCA
Centrul de Ingineria Iluminatului

International Conference
ILUMINAT
2 0 0 9
20 February, Cluj-Napoca

The 5th International Conference ILUMINAT 2009

PROCEEDINGS

20 February 2009
Cluj-Napoca, Romania

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The responsibility for the content and the English language of each paper in the Proceedings rests solely with its author.

Additional information of this Conference Proceedings are available from the President of the Organising Committee

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Editura MEDIAMIRA Cluj-Napoca
C.P. 117, O.P. 1, Cluj
ISBN 978-973-713-232-1

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The Proceedings of the ILUMINAT 2009 International Conference
Sponsored by S.C. EnergoBit SCHREDER Lighting S.R.L.

COMMISSION INTERNATIONALE DE L'ECLAIRAGE
INTERNATIONAL COMMISSION ON ILLUMINATION
INTERNATIONALE BELEUCHTUNGSKOMMISSION

Central Bureau: Kegelgasse 27 – 1030 Wien – Austria

To: Romanian National Committee on Illumination
Attention: Prof. Florin Pop

Esteemed members of the Romanian National Committee and delegates to the ILUMINAT 2009 CONFERENCE

On the occasion of your upcoming conference, allow me to convey to you the best wishes of the CIE. Your conference comes at a trying time for international trade and many national economies. This global crisis has an impact, which affects nearly everybody, including international organizations like the CIE. Several of our important National Committees find it difficult to pay their CIE dues because of an erosion of their traditional membership base, exchange rate fluctuations and other factors.

For this reason, the CIE Board at its last meeting in October 2008, decided to approach the National Committees at the next General Assembly in May 2009 in Budapest (Hungary) to approve wide-ranging changes in the structure and functioning of the organization. These are aimed at further lightening the financial burden of National Committees with regard to membership fees and generating more income through the operations of the CIE Central Bureau in Vienna. While it is not possible to talk about the detailed proposals in this regard before the General Assembly has had a chance to consider them, it is clear that the CIE, like other organizations, has to continually adapt to changing circumstances and cannot afford to be complacent and inflexible.

The subject of your conference, energy issues and the environmental impact of lighting are receiving our close attention at present and remain an important strategic focus.

Other current developments include a shift from the traditional hands-on management role of the CIE Board to a greater role for the professional staff at the CIE Central Bureau in running the day to day activities of the organization under a new, very active and motivated General Secretary. The Board's active involvement in the running of the organization comes from a time, when there was no or only a rudimentary Central Bureau and the Board members in their honorary capacity were forced to make their scarce time available to provide continuity and keep the organization afloat. By leaving the day to day affairs firmly in the hands of the professional staff at the well established Central Bureau in Vienna, the Board will have more time available to do strategic work and for its statutory supervisory role under the guidance of the General Assembly.

It is a further focus of my presidency to formalize the CIE's existing relationships with other international organizations as much as possible. Recent agreements with the International Committee for Weights and Measures (CIPM) and the Professional Lighting Designers' Association (PLDA) are examples of this.

With this short summary of present strategic CIE objectives, I wish you a successful conference and everything of the best for 2009.

Pretoria, 27 January 2009

Franz Hengstberger
President

MESSAGE

Through time, through the competence of its builders, the City of Cluj became more and more important for science and culture, for spiritual freedom and free enterprise, and the most important decisions left in the memory of generations tell us that the contemporary scenery is a creation of the human genius perfected by request, with the appearance of nature, as the spirit of the things in the human spirit.

That is, to see, to feel, to think, to innovate, to build, and, obviously ... to light.

Thinking in this way, our meeting, dedicated to the ILUMINAT 2009 International Conference, is a lesson of scientific honesty, not only a problem of expression but of conception in an effort to convert a present reality for the future through a plan of intuition that mixes the field of light and shadows with the energetic and aesthetic argument.

Currently, the market of lighting systems is extremely dynamic, with a lot of new players, in continue change, and the designers of lighting systems have to adapt to requirements of EU norms and to the competition in this field. UTC-N is implying itself through the formation of lighting specialists and through delivery of know-how to professional companies. By means of different research and design contracts, UTC-N has involved itself in development of studies concerning the rehabilitation of the public lighting system in Cluj-Napoca and Dej, in the design of new representative buildings of the city: the desired building of the Cluj-Napoca Philharmonics, the new stadium, etc.

The engineering education and formation in the fields of light and lighting teaches us not to abandon the efforts by thinking at the destiny, and such a philosophy reveals an important conclusion. The way someone accepts his/her destiny may be more important than the destiny itself, and You have already proven this.

This very moment is a manifest of our science, speaking a language anyone may understand, because it means to embed, as much as possible, the dream inside reality, and the reality inside the dream. Because the eternal dream of mankind is the light.

The Technical University of Cluj-Napoca is organizer of this conference, through the Lighting Engineering Center, coordinated by Prof.Dr. Florin Pop, involved for more than 20 years in the field lighting, coordinator of a prestigious specialty journal, “Ingineria Iluminatului” and partner or initiator of more European or national research programs. Currently at its fifth edition, this international conference ILUMINAT has started in 2001 and runs every two years, this year being its first jubilee. We use this opportunity to underline the involvement of UTC-N in two recently finalized research programs, a European one: EnERLIn – Energy Efficient Residential Lighting Initiative -, Intelligent Energy-Europe program, and a national one: CREFEN – Information system energy efficiency in residential sector”.

Thus, the Cluj technical area is a mixture of signs, and a mirror where everybody is looking at its own face, to know oneself better.

We have to have confidence in the times to come, even if more are doubtful about it.

Let us not forget that we pass through the fast-running present, connecting the past to the future, and conferring them a unique and unrepeatable identity.

Certainly, life is always an opportunity to ask ourselves “who are we, where are we coming from and where are we going to?” ... and Your results answer to all these questions.

Looking insistently towards the world, we understand better than anytime that we live in a permanent change, where the independence of our spirit and the overpass of paradigms lead to innovation, and innovation is more important than the value of tradition. This is, in fact, what You have proved in the last 10 years.

I like to mention that it is an honor to have among us the former eminent President of the International Lighting Committee, Prof.dr. Wout van Bommel, the Presidents of the National Lighting Committees in Romania - Prof.dr. Cornel Bianchi, Germany – Honorary Professor Axel Stockmar, Slovenia - dr. Grega Bizjak, as well as academic personalities in Europe and Romania.

In this sense, we show that the Technical University in Cluj-Napoca ensures the development of cognitive services in the European education area, through a process that has become transnational.

We are concerned by the internationalization of education, the flexibility of academic career through the articulation of the educational system with the other systems, but the future must be designed through the availability of international resources and cooperation.

It is not by accident that at this prestigious conference we have participants from abroad, and the topic is interesting and rich, defining actual fields of scientific research by original papers of clear value.

The Technical University in Cluj-Napoca declares itself a host with the vocation of openness towards the world, underlying, not only for the participants, that we have lines of engineering studies in English, German and French.

We may certainly remember many other things, because memory is like the wind that invents the clouds, or like a rose from the same branch with the reality, but with no thorns.

If the subtle laws of hope push us always towards confession, we will probably understand that we are not going to discover life in libraries, but the books help us understand it, and the scientific research brings progress.

In the framework of the Technical University of Cluj-Napoca we may be capable of scientific dialogue, learning the languages of other nations, which will change the cultural politics of mentalities and will help us become better Europeans.

This homage and scientific event reveals once again that engineering sciences to progress, because they manifest admiration for the success and they know what they owe to the past.

I consider that it is a privilege for me to use this opportunity to congratulate once again Prof.dr. Florin POP on his celebration of 65 years of age and I wish him a long and happy life, together with his family and loved ones.

This make us look towards our colleagues with admiration and respect, but then to turn our looks back towards us with the hope that we will become what we deserve to be!

Finally, I wish this conference success and I assure the participants of my high consideration, showing in the same time that the engineer knows that without dark there can be no light!

Prof.Dr.Eng. Radu Munteanu

Rector of the Technical University of Cluj-Napoca

20 February 2009

Ladies and Gentlemen,
Honored Audience,

It is a great pleasure for me and the C.N.R.I. members to participate at the 5-th edition of the International Conference ILUMINAT-2009, organized by the Lighting Engineering Center of the Technical University of Cluj-Napoca, under the patronage of CIE-CNRI, starting with year 2000.

I have to underline that all the events developed here have represented a real success, both considering the exchange of ideas and information in

THE FIELD of LIGHT AND LIGHTING,

and, as well, considering the participation of some international top personalities.

Certainly, these conferences could not take place without the involvement and the management spirit of the CNRI vice-president Prof.Dr. Florin POP and the important support of the Academic Leadership of the Technical University of Cluj-Napoca.

The current conference brings a new opportunity to present and discuss the current problems of ELECTRIC and NATURAL LIGHTING, the quality and maximal energy efficiency, extremely important, especially today, in the context of the global crisis.

We have to search and find the best solutions to ensure a light environment of high quality with constant parameters, in rooms aimed to different activities, with the reduction of the energy consumption!

As well, there is a need to ensure a day and/or night urban lighting environment, to achieve, especially today, the security of auto and pedestrian traffic in the capital city and the large cities, without light pollution, which generates discomfort aesthetically and visually.

Finally, I underline the special character of this conference, organized in connection with the anniversary of 65 years of age of Prof.Dr. Florin POP, to whom I wish, on my behalf and on behalf of C.N.R.I.,

MANY HAPPY YEARS, WITH A LOT OF LIGHT, FULL HEALTH
AND IMPORTANT ACHIEVEMENTS TO FOLLOW!

I take the opportunity of this festive moment to transmit him

THE EXCELLENCY DIPLOMA
on behalf of C.N.R.I.,

for all his remarkable achievements
IN THE FIELD OF LIGHT AND LIGHTING!

Prof.Dr. Cornel BIANCHI
President of C.N.R.I.
Honor member of the Romanian Technical Sciences Academy

Ladies and Gentlemen,
Distinguished participants,
Dear friends and colleagues,

I would like to welcome you to the 5th International Conference ILUMINAT 2009. This is a short half day, but very intensive in information, with Invited Lectures of high professionals in lighting from abroad and Romania.

The Conference is honored by the presence of European national lighting schools. Interesting scientific papers were submitted both by research teams or professionals from Canada and from national universities. The participation of young researchers, Ph.D. students, contributes to the success of the conference and to the enhancement of their knowledge.

The Lighting Engineering Center of the Technical University of Cluj-Napoca, Romania was recently involved in two programs for promoting lighting energy efficiency and energy saving measures in residential buildings: EnERLIn – European Efficient Residential Lighting Initiative, an EIE-SAVE program to promote Compact Fluorescent Lamps in the residential sector, and CREFEN – Integrated software system for energy efficiency and saving in the residential sector, a Romanian CEEX (Excellency in Research) program.

We are sure ILUMINAT 2009 Conference is an interesting and useful FORUM of the international lighting community. Some members of the Scientific Board expressed their regrets for not being able to attend the conference, wishing the participants great success.

During the last 20 years, I was honored by the kind support and friendship of the members of this amazing world of lighting professionals. Through these relations, many young researchers from our university were able to visit lighting laboratories in European countries, to perform very useful research stages, to participate at the lighting international conferences, to join research programs. Our gratitude is due to all our European friends.

Related to this moment, of celebrating 65 years of life in 10 February, and the arrival of retirement, I am glad to hand the assumed professional duties in lighting fields to younger people devoted to Light and Lighting. Of course, I will remain closed to this wonderful Lighting World.

Wishing to realize the promotion of the lighting knowledge, to provide developments in lighting field, to enhance our friendship relations, I would like to welcome all of you, hoping that you will remain with enjoyable memories of this special day in Cluj.

Dr. Florin POP, Professor
Vice-president of the CIE National Committee of Romania

The Proceedings of the ILUMINAT 2009 International Conference

Messages

Franz HENGSTBERGER, Dr., President of the CIE
Radu MUNTEANU, Professor, Rector of the Technical University of Cluj-Napoca
Cornel BIANCHI, Professor, President of the CIE National Committee of Romania
Florin POP, Professor, Chairman of the International Conference ILUMINAT 2009

L1 **The CIE President presentation**
Dr. Franz HENGSTBERGER
The role of the CIE as an International Standards Organization

Invited Lectures

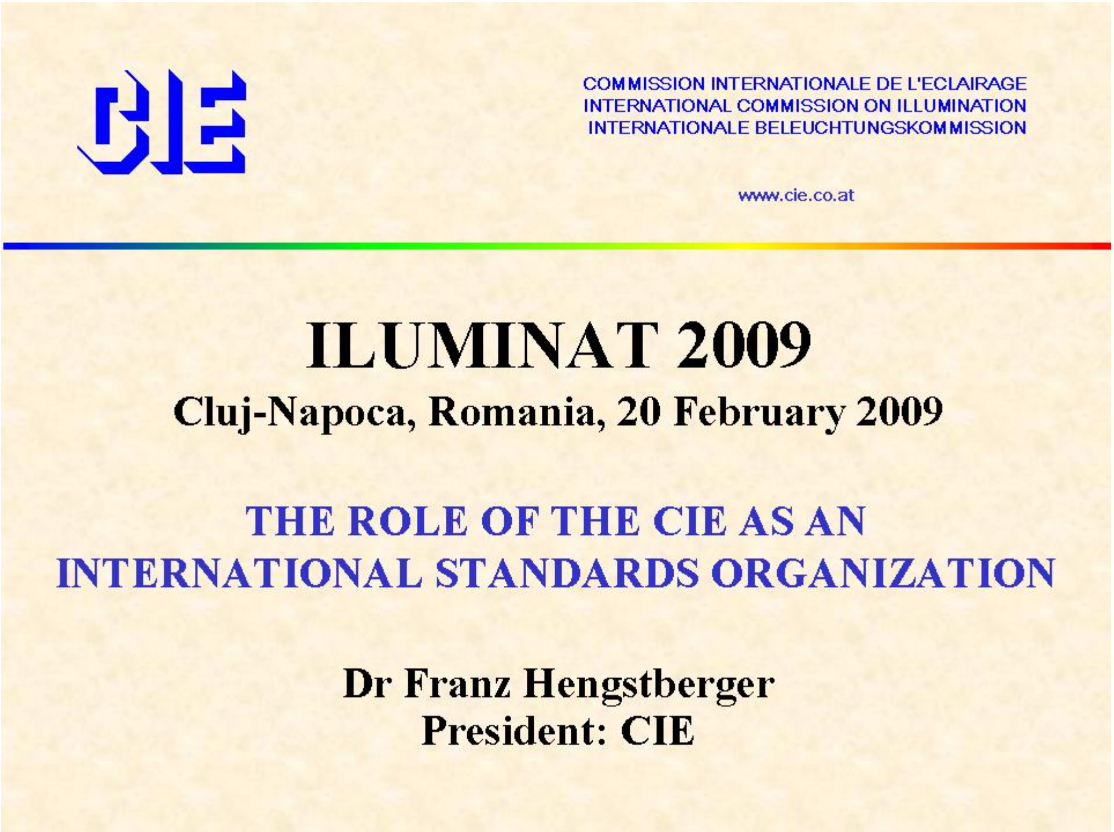
L2 **Honorary Professor Axel STOCKMAR**
President of the CIE National Committee of Germany
Energy efficient railway lighting according to the European standard EN 12464-2
HP Axel STOKMAR has participated at all International Conferences ILUMINAT 2001-2009
L3 **Professor Cornel BIANCHI**
President of the CIE National Committee of Romania
Modern structures of using natural light for natural-electric integrated, efficient and quality lighting systems (in Romanian)
L4 **Dr. Grega BIZJAK, Dr. Matej KOBAV,** University of Ljubljana, Slovenia
President of the CIE National Committee of Slovenia
Consumption of Electrical Energy for public lighting in Slovenia
L5 **Professor Ir. Wout van BOMMEL**
Philips Lighting, Eindhoven, The Netherlands, Fudan University, Shanghai
Road lighting in the light of the future
L6 **Dr. David CARTER, Reader,** University of Liverpool, UK
Hybrid lighting systems
L7 **Professor Cătălin D GĂLĂȚANU, Ass. Professor Dorin D. LUCACHE**
Technical University „Gh. Asachi” of Iasi, Romania
Point of view: quality in lighting education
L8 **Professor Liisa HALONEN,** Head of the Lighting Laboratory
Dr. Eino TETRI
Helsinki University of Technology, Finland
Lighting Efficiency and LED Lighting Applications in Industrialized and Developing Countries
L9 **Professor Virgil MAIER, Professor Sorin PAVEL,** Head of the EPS Department
Technical University of Cluj-Napoca, Romania
Flicker dose in the road lighting
L 10 **Dr. Janos SCHANDA, Professor emeritus** of the University of Pannonia, Hungary
Katalin GOMBOS
Photometry of Solid State Lighting in theory and practice
L 11 **Şerban ȚIGĂNAŞ,** President of the Order of the Romanian Architects, Transylvania Branch
Dana OPINCARIU
Technical University of Cluj-Napoca, Romania
What the architects are expecting from the artificial light?
L12 **Professor Florin POP,** Head of the Lighting Engineering Center
Dr. Dorin BEU, Reader
Technical University of Cluj-Napoca, Romania
Ten years of sustainable lighting in Transylvania

Proposed papers

P1 Albu, H.O., Pop, F., Technical University of Cluj-Napoca, Romania
Power Quality analysis of buildings lighting installations
P2 Barb, D.C, Pop, F., Technical University of Cluj-Napoca, Romania
KNX and DALI – Controlling the light
P3 Barb, D.C., Ştefănescu, S., Martineac, Corina, Technical University of Cluj-Napoca, Romania
Rehabilitation of Lighting Installation of Central University Library - Energy Efficiency Case Study
P4 Bindiu, R., Cziker, A., Pop, G.V., Technical University of Cluj-Napoca, Romania
Optimum Tariff Selection for Public Lighting Systems
P5 Bucur, Gh.D., Sarchiz, D., University "Petru Maior" Târgu Mureş, Romania
Optimization of reliability electric supply of hospital emergency lighting
P6 Bucur, Gh.D., Sarchiz, D., University "Petru Maior" Târgu Mureş, Romania
Evaluation and optimization criteria of reliability electric supply of emergency lighting
P7 Ciugudeanu, C., Pop, F., Technical University of Cluj-Napoca, Romania
Tubular daylight guidance systems - Energy Saving Potential in Residential Buildings in Romania
P8 Cziker, A., Chindriş, M., Miron, Anca, Technical University of Cluj-Napoca, Romania
Implementation of Artificial Intelligence Techniques in Lighting Systems
P9 Dumitru, Cr., Gligor, A., University "Petru Maior" Târgu Mureş, Romania
Renewable Energy Laboratory for Lighting Systems
P10 Gecan, C.O., Chindriş, M., Bindiu, R., Technical University of Cluj-Napoca, Romania
DC Voltage Lighting Systems
P11 Grif, H.Şt., University "Petru Maior" Târgu Mureş, Romania
Neutral daylight control system
P12 Grosuleac, D., Philips Romania
Design principles for cove lighting
P13 Ignat, J., Technical University "Gh. Asachi" Iaşi
Considerations regarding the supply solutions of the safety illumination system – type 2a (in Romanian)
P14 Martineac, Corina, Ştefănescu, S., Hopîrtean, M., Technical University of Cluj-Napoca, Romania
Dealing with light pollution
P15 Pop, G.V., Chindriş, M., Gecan, C.O., Technical University of Cluj-Napoca, Romania
Oportunities to Reduce Consumption of Electricity in Lighting Systems
P16 Rosemann, A., Şuvăgău, C., BC Hydro, Canada
Model to Determine Lighting Energy Savings in Commercial Buildings
P17 Ştefănescu, S., Martineac, Corina, Barb, D.C., Technical University of Cluj-Napoca, Romania
Photovoltaic Architectural Lighting - Central University Library Case Study
P18 Szabó, Erzsébet, Buzura, Anca, Mocan, Al., S.C. Pieme S.R.L., Cluj-Napoca, Romania
Problems and proposals for sustainable lighting solutions for special areas of historical monuments, according to EU directives to reduce energy consumption
P19 Țicleanu, C., "Transilvania" University of Braşov
Approach on modelling of horizontal daylight transfer by light-pipes and anidolic ceilings

THE ROLE OF THE CIE AS AN INTERNATIONAL STANDARDS ORGANIZATION

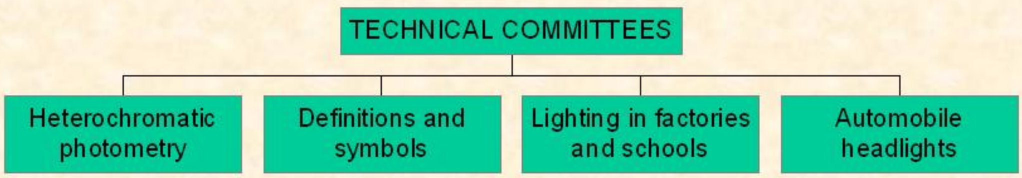
Dr. Franz HENGSTBERGER
CIE president



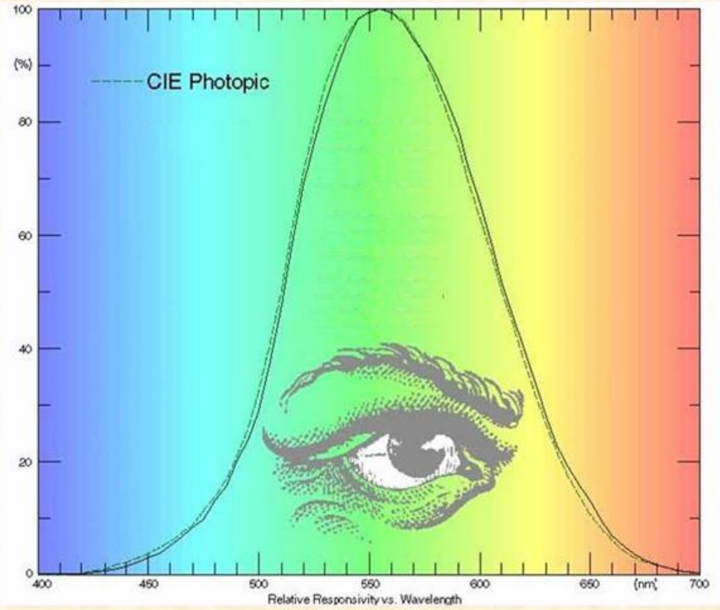
HISTORICAL ORIGINS

- The CIE owes its origin to the development of gas lighting and electric lighting around the beginning of the 20th century
- It started out in 1900 as the International Commission on Photometry (CIP) and became the International Commission on Illumination (CIE) in 1913.

CIE TECHNICAL COMMITTEES 1921, PARIS

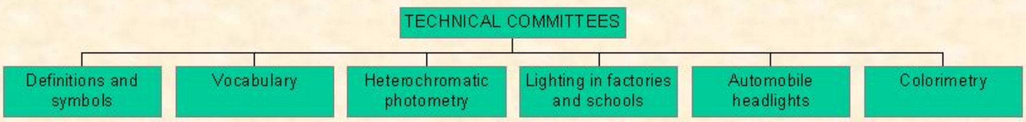


CIE STANDARD OBSERVER (PHOTOPIC)
1924, GENEVA

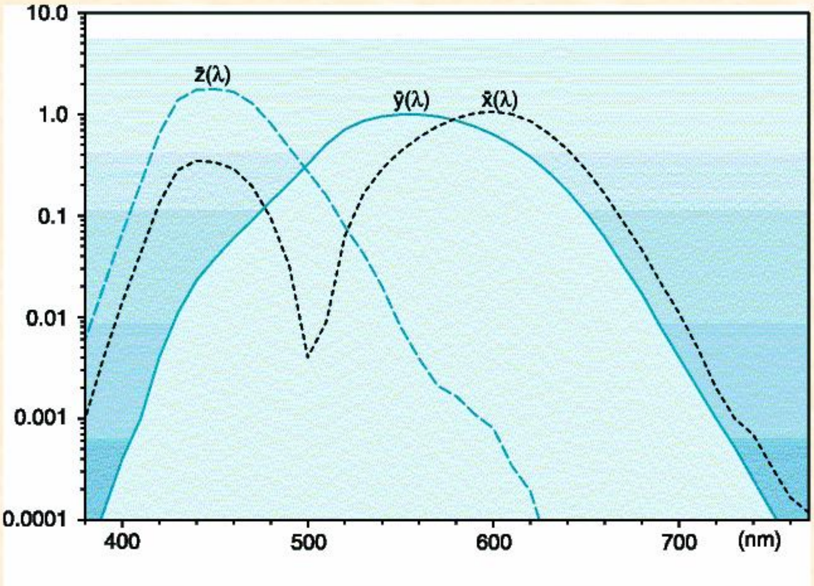


CIE S 010/E:2004
ISO 23539:2005(E)

CIE TECHNICAL COMMITTEES
1924, GENEVA



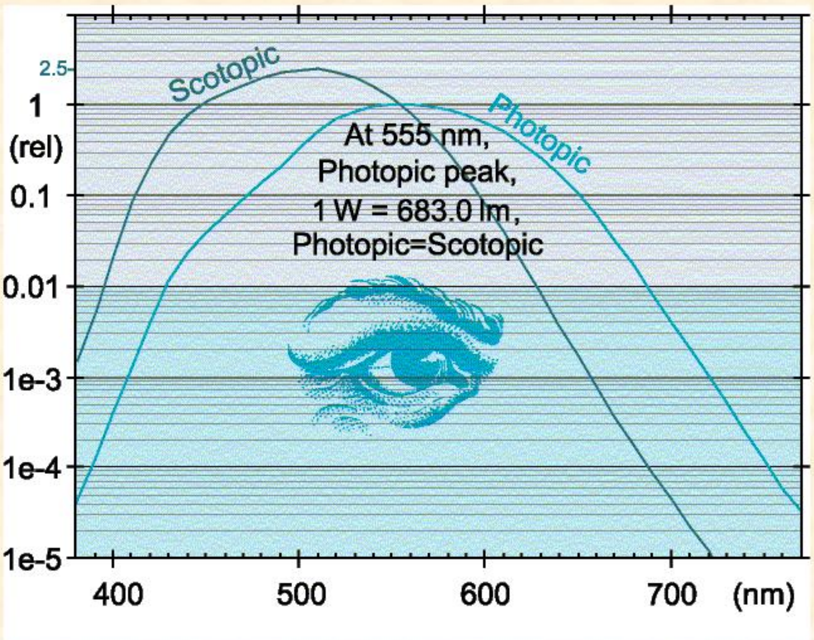
CIE STANDARD COLORIMETRIC OBSERVER (1931, CAMBRIDGE)



Colour matching functions

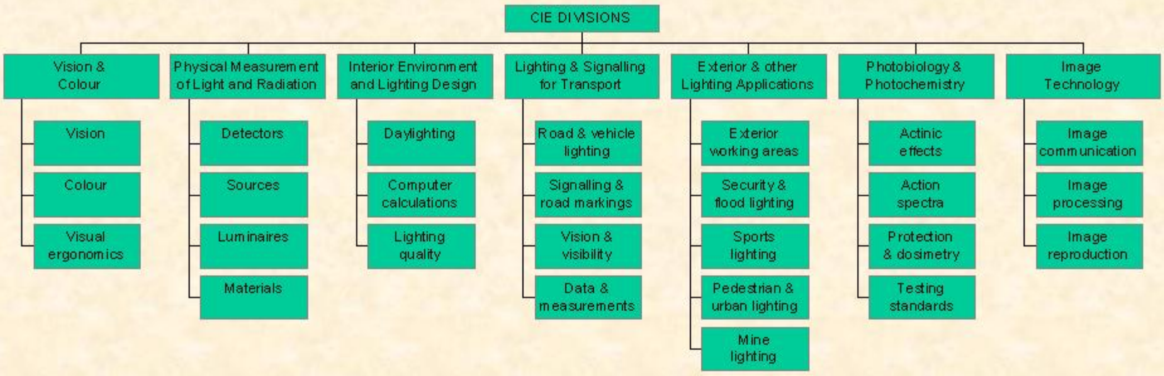
CIE S 14-1.2/E:2006

CIE STANDARD OBSERVER (SCOTOPIC) 1951, STOCKHOLM



CIE S 010/E:2004
ISO 23539:2005(E)

THE CURRENT CIE DIVISIONAL STRUCTURE



EXTRACT FROM CIE STATUTES

CIE OBJECTIVES

4.1 To provide an international forum for the discussion of all matters relating to the science, technology and art of light and lighting* and for the interchange of information in these fields between countries. To achieve these goals the Commission organizes scientific educational events and holds CIE Sessions normally every four years.

4.2 To develop basic **standards** and procedures of metrology in the field of light and lighting.

4.3 To provide guidance in the application of principles and procedures in the development of international and national **standards** in the fields of light and lighting.

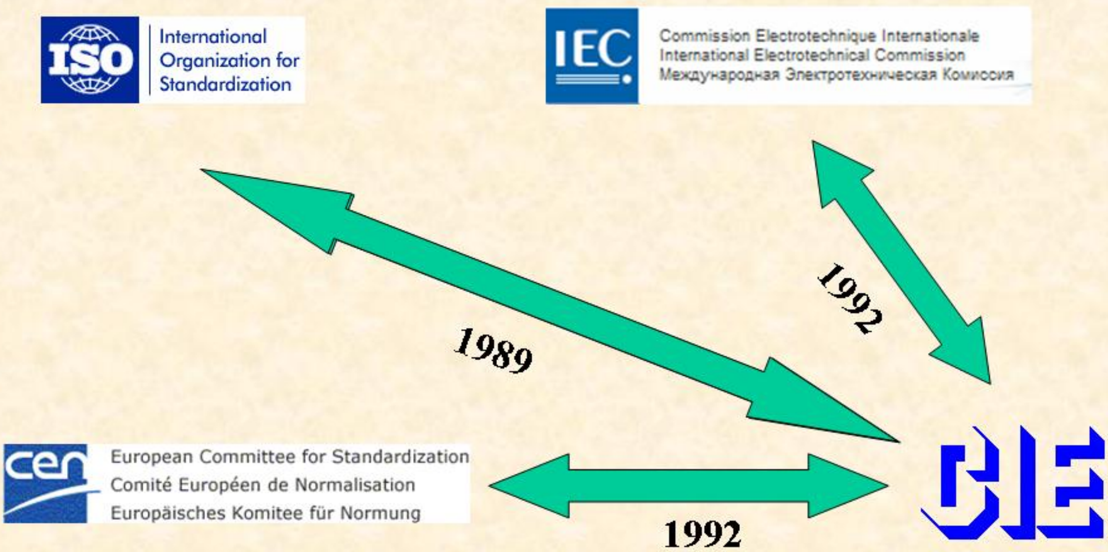
4.4 To prépare and publish Proceedings, **Standards**, Technical Reports and other publications concerned with all matters related to the science, technology and art of light and lighting.

4.5 To maintain liaison and technical interaction with other international organizations concerned with matters related to the science, technology, **standardization** and art in the fields of light and lighting.

EXTRACT FROM CIE STATUTES
OBJECTIVES (FOOTNOTE)

** Light and lighting in these objectives is to be understood in the broad sense of embracing such fundamental subjects as vision, photometry and colorimetry, involving natural and manmade radiation over the UV, the visible and the IR regions of the spectrum, and application subjects covering all usage of light, indoors and out, including environmental and aesthetic effects, as well as means for production and control of light and radiation.*

RECOGNITION BY ISO, IEC AND CEN



TEXT OF ISO RECOGNITION

International Organization for Standardization

*"Council, deeming that the International Commission on Illumination (CIE) fulfils the prerequisites laid down in 1.1 and 1.2 of Council resolution 19/1984, **accepts the International Commission on Illumination as an international standardizing body** for the purpose of Council-resolution 19/1984 with a view to CIE documents being processed as ISO International Standards following the procedure set out in Council resolution 19/1984".*

EXCERPT FROM IEC RECOGNITION

Commission Electrotechnique Internationale
International Electrotechnical Commission
Международная Электротехническая Комиссия

The IEC undertakes to:

3.1 Recognize the CIE as a competent authority for submitting its approved standards to IEC for direct endorsement and issue as an IEC/CIE standard in accordance with the provisions of the IEC/ISO Directives.

3.2 Effect joint development of standards in those areas where the domains overlap or complement each other.

3.3 Where mutually acceptable, publish the approved standards produced under items 3.1 and 3.2 above as joint IEC/CIE "double-logo" standards.

EXAMPLE OF DOUBLE-LOGO STANDARD WITH IEC


NORME INTERNATIONALE
INTERNATIONAL STANDARD
CEI
IEC
62471
CIE S 009:2002
Première édition
First edition
2006-07

Sécurité photobiologique des lampes et des appareils utilisant des lampes

Photobiological safety of lamps and lamp systems

IEC CIE

CODE PRIX
PRICE CODE X

EXCERPTS FROM CEN RECOGNITION

European Committee for Standardization
Comité Européen de Normalisation
Europäisches Komitee für Normung

CEN recognises that the development and consultation methods used in CIE, its commitment to compliance with relevant legislation and the public availability of CIE documents, facilitate the reference to CIE documents and satisfy the major requirements of the CEN Technical Board policy for normative reference…….

As identified by technical bodies of CEN and CIE, both organisations can decide to endorse each other's publications, using their own internal regulations, procedures and practices, taking into account the needs for doing so and the nature of the publications………

COOPERATION WITH THE ORGANS OF THE METRE CONVENION

Cooperation Agreement with the International Committee for Weights And Measures (CIPM) - 2 April 2007

CIE

EXCERPT FROM CIPM - CIE COOPERATION AGREEMENT (2007)

Recognizing that the CIPM's responsibility for the definition of the photometric units in the SI[1] and the standardization of the action spectra of the human eye[2] by the CIE are the interlinked cornerstones of practical physical photometry worldwide, the Parties undertake to inform each other whenever either Party is contemplating a change in any of these foundations of physical photometry. If considered necessary by both Parties, a joint, temporary, ad-hoc task group, reporting to the CCPR and the relevant CIE Division, would be formed to discuss the specific topic in more detail.

[1] Le Système International d'Unités (The International System of Units)

[2] The CIE action spectra for the human eye in various states of adaptation (photopic, mesopic and scotopic), for various field sizes (2°, 10°) and various other conditions (visual environment, age of observer, etc) as the CIE may decide to standardize.

CIE

EXCERPT FROM CIE – PLDA COOPERATION AGREEMENT (2008)

AGREEMENT BETWEEN
THE INTERNATIONAL COMMISSION ON ILLUMINATION
AND THE PROFESSIONAL LIGHTING DESIGNERS' ASSOCIATION
Article I

1. The International Commission on Illumination (CIE), referred to hereinafter as "the Commission", and the Professional Lighting Designers' Association (PLDA), referred to hereinafter as "the Association", agree that with a view to facilitating the implementation of their objectives, set out respectively in the Statutes of the CIE and the PLDA, they will act in close cooperation with each other and consult each other regularly in regard to matters of common interest.

2. The Association takes note of the objectives of the Commission in the fields of vision and colour, measurements of light, interior environment and lighting design, lighting and signalling for transport, exterior lighting and other application, photobiological effects, and imaging technologies as set forth in the Statute of the Commission and in particular that the Commission has the expertise and role to standardize action spectra for photobiological and photochemical quantities, including those related to Human vision[1], and to ensure that data obtained in the course of its work is accurate and reliable.

3. The Commission recognizes the responsibilities and role of the Association as set forth in the fields of recognition of the profession of architectural lighting design and the strengthening of the ties between lighting designers, clients and the architecutral world. ……………..

USE OF CIE STANDARDS BY NATIONAL STANDARDS BODIES

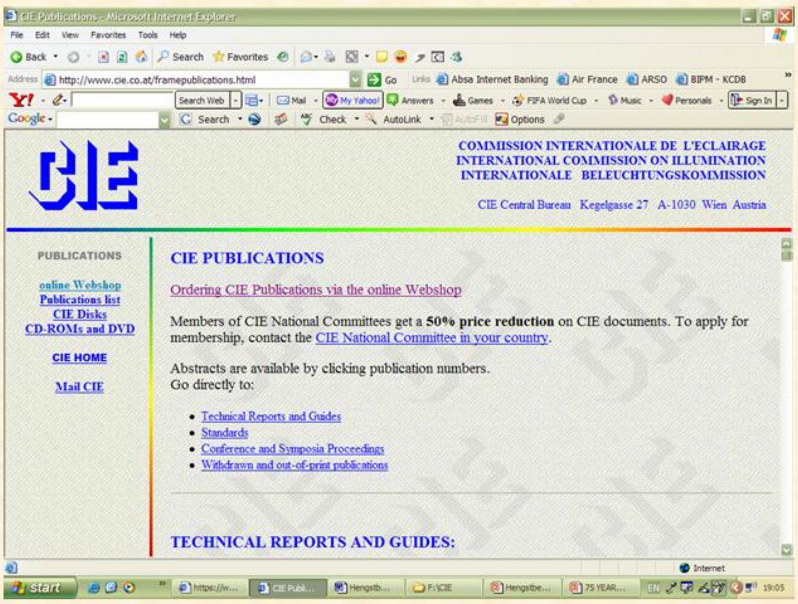
Adoption of CIE Standards as national standards (in translation, if appropriate)

- If a national standards body wishes to (translate and) adopt an ISO/CIE Standard as a national standard, it can do so according to the regulations valid for all other ISO standards (i.e. free of charge), provided that proper reference is given to the original ISO/CIE document.
- If a national standards body wishes to (translate and) adopt a CIE Standard that will not be adopted by ISO as joint standard, as a national standard, it may do so, provided proper reference is given to the original CIE document (including CB address), that the CIE CB is informed and gets a copy of the national standard for its files. No fee to be paid.
- If a national standards body wishes to adopt a CIE Draft Standard as national standard, they should wait until the CIE Standard is published, because the draft might still change, and then there exists a national standard based on an international draft, and an international standard which is different.

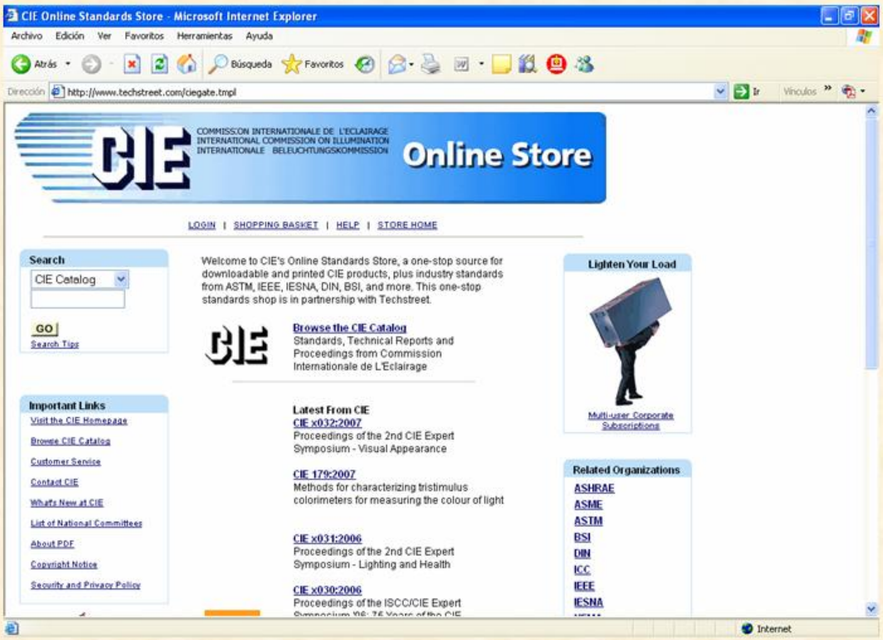
CIE STANDARDS AND DRAFT STANDARDS

CIE S 004/E:2001	Colours of light signals
ISO 16508/CIE S 006.1/E	Road traffic lights – photometric properties of 200 mm roundel signals (1999)
ISO 16508/CIE S 006.1/F	Feux de circulation – Caractéristiques photométriques des flux de signalisation avec un diamètre de 200 mm (1999)
ISO 10527/CIE S 007/E	Erythema reference action spectrum and standard erythema dose (1999)
ISO 10527/CIE S 007/F	Spectre d'action érythémale de référence et dose érythémale normalisée (1999)
CIE S007/D	Erythemale Referenzwirkungsfunktion und standardisierte Erythemdosis (1998)
ISO 8995-1:2002(E)/CIE S 008E:2001	Lighting of work places – Part 1:Indoor
CEI/IEC62471/CIE S 009/E:2006	Photobiological safety of lamps and lamp systems
CIE S 009/F:2002	Sécurité photobiologique des lampes et des appareils utilitsant les lampes
CIE S 009/D:2002	Photobiologische Sicherheit von Lampen und Lampensystemen
ISO 23539:2005(E)/CIE S 010/E:2004	Photometry - The CIE system of physical photometry
ISO 15469/CIE S 011:2003	Spatial distribution of daylight - CIE standard general sky
ISO 23603/CIE S 012/E:2004	Standard method of assessing the spectral quality of daylight simulators for visual appraisal and measurement of colour
CIE S 013:2003	International standard global solar UV index
ISO 1164-1:2008(E)/CIE S014-1/E:2006	Colorimetry - Part 1: CIE standard colorimetric observers
ISO 1164-2:2008(E)/CIE S014-2/E:2006	Colorimetry - Part 2: CIE standard illuminants
CIE S 015:2005	Lighting of outdoor work places
ISO 8995-3:2006(E)/CIE S016/E:2005	Lighting of outdoor work places - Lighting requirements for safety and security
ISO 28077:2006(E)/CIE S01494/E:2006	Photocarcinogenesis action spectrum (Non Melanoma Skin Cancers)
ISO 30061:2007(E)/CIE S020/E:2007	Emergency Lighting
ISO 1164-4:2008(E)/CIE S014-4/E:2007	Colorimetry - Part 4: CIE 1976 L*a*b* Colour Spaces

CIE STANDARDS AND DRAFT STANDARDS



CIE WEBSHOP



CIE NEWS

NUMBER 83

COMMISSION INTERNATIONALE DE L'ECLAIRAGE
INTERNATIONAL COMMISSION ON ILLUMINATION
INTERNATIONALE BELEUCHTUNGSKOMMISSION

4 / 2007

CIE Australia Inc. • CIE - Austria • Belgian Inst. on Illumination (IBE-BIV) • CIE - Brazil • Bulgarian National Committee on Illumination • Canadian National Committee of the CIE • Chinese National Committee - CIE • Croatian National Committee of the CIE • Czech National Committee of the CIE • National Illuminating Committee of

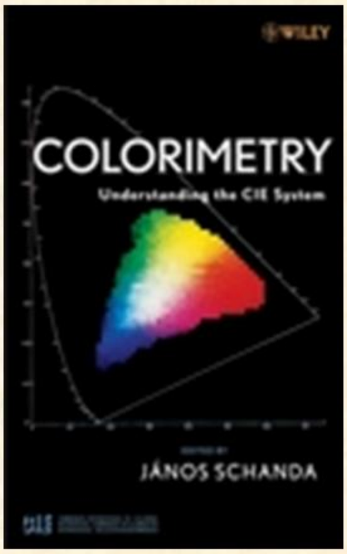
CIE ADRESSES THE ISSUE OF ENERGY CONSERVATION

The issue of energy conservation in lighting was present in most debates during our Quadrennial Session held in Beijing in July 2007. It was brought to the General Assembly by the Finnish National Committee, and its concern was largely shared by the delegates which approved the following resolution:

ENERGY CONSERVATION REQUIRES SMART LIGHTING

A worldwide consensus is evolving to reduce electrical energy consumption because of concerns about global climate change. Recognizing that lighting consumes substantial energy, the International Commission on Illumination (the CIE) which held its XXVIth Session in Beijing, China 4-11 July (about 800 delegates from 42 countries), called for a worldwide effort to reduce energy consumed for lighting. This is possible through intelligent use of new technology and a scientific understanding of the varied human needs for

COLORIMETRY
Understanding the CIE System



Book edited by Prof. J Schanda. Published by Wiley-Interscience, August 2007. Endorsed by the CIE. Contributions and chapters by many international experts.

CIE

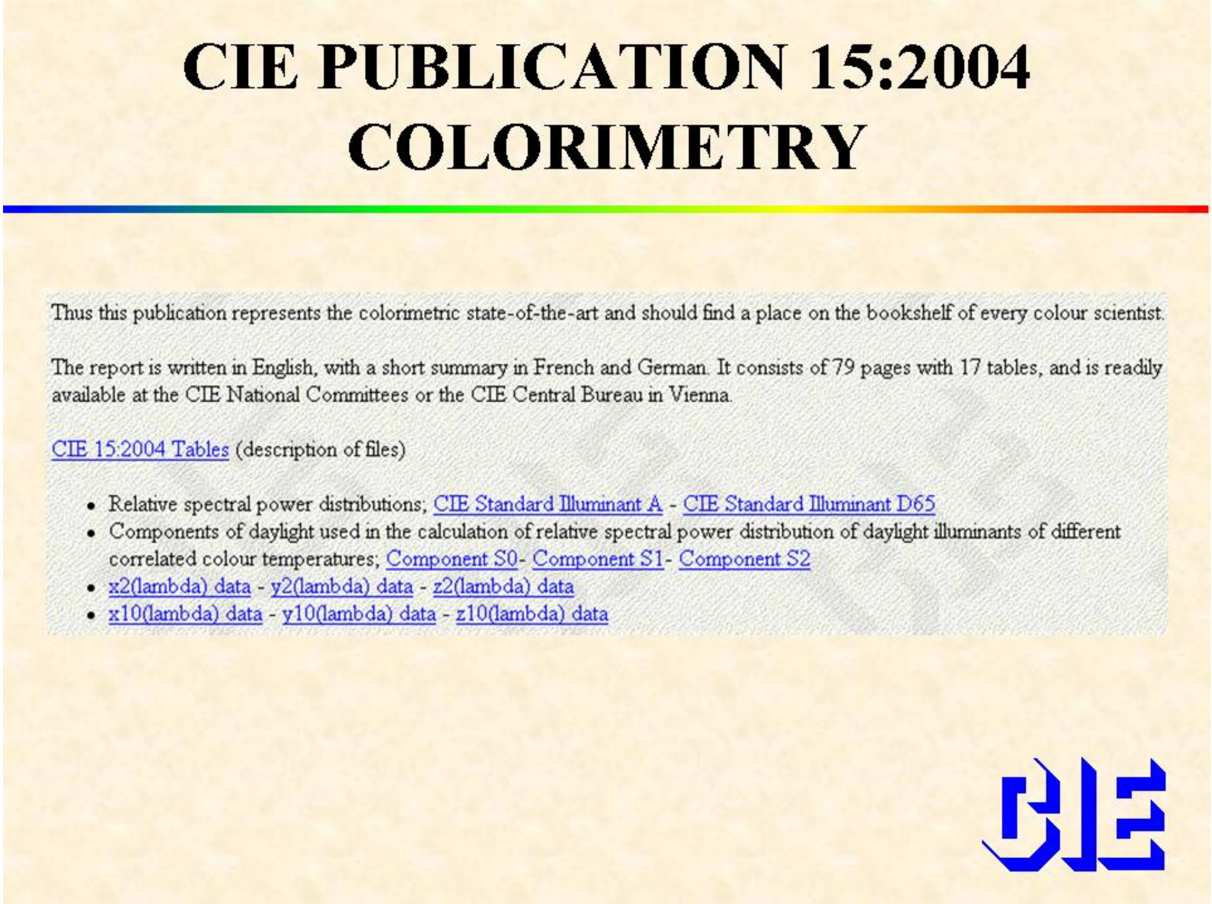
CIE PUBLICATION 15:2004
COLORIMETRY

For over 70 years the International Commission on Illumination (CIE) has provided recommendations about the precise way in which the basic principles of colour measurement should be applied. CIE Publication 15:2004 "Colorimetry" represents the latest edition of these recommendations and contains information on standard illuminants; standard colorimetric observers; the reference standard for reflectance; illuminating and viewing conditions; the calculation of tristimulus values, chromaticity coordinates, colour spaces and colour differences; and various other colorimetric practices and formulae. This publication is consistent with the fundamental data and procedures described in the CIE Standards on Colorimetry.

This publication, which replaces CIE Publication 15.2 (and is not to be known as 15.3!), includes details of the CIE DE2000 colour difference equation; spectral power distributions for sets of halophosphate lamps, DeLuxe type lamps, three-band lamps, multi-band lamps, high pressure sodium lamps and high pressure metal halide lamps. The nomenclature for the recommended geometries has changed, and there are even changes to the equations defining the parameters of the CIELAB colour space!

The publication is accompanied by CD-ROM that contains all the tables of standard and recommended spectral distributions and a program (for Windows operation systems) to perform interpolation of spectra related to reflection or absorption measurements.

CIE



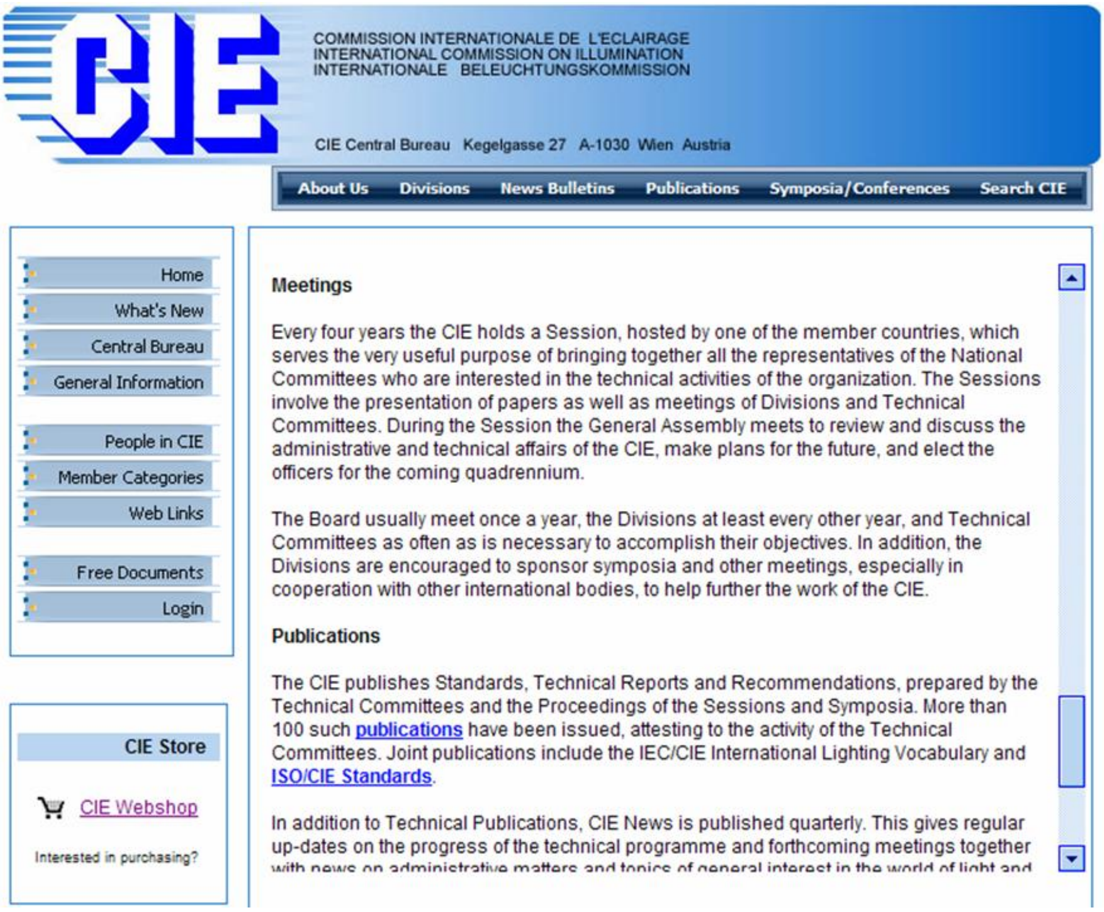
CIE PUBLICATION 15:2004
COLORIMETRY

Thus this publication represents the colorimetric state-of-the-art and should find a place on the bookshelf of every colour scientist.

The report is written in English, with a short summary in French and German. It consists of 79 pages with 17 tables, and is readily available at the CIE National Committees or the CIE Central Bureau in Vienna.

CIE 15:2004 Tables (description of files)

- Relative spectral power distributions; CIE Standard Illuminant A - CIE Standard Illuminant D65
- Components of daylight used in the calculation of relative spectral power distribution of daylight illuminants of different correlated colour temperatures; Component S0- Component S1- Component S2
- x2(lambda) data - y2(lambda) data - z2(lambda) data
- x10(lambda) data - y10(lambda) data - z10(lambda) data



COMMISSION INTERNATIONALE DE L'ECLAIRAGE
INTERNATIONAL COMMISSION ON ILLUMINATION
INTERNATIONALE BELEUCHTUNGSKOMMISSION

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Meetings

Every four years the CIE holds a Session, hosted by one of the member countries, which serves the very useful purpose of bringing together all the representatives of the National Committees who are interested in the technical activities of the organization. The Sessions involve the presentation of papers as well as meetings of Divisions and Technical Committees. During the Session the General Assembly meets to review and discuss the administrative and technical affairs of the CIE, make plans for the future, and elect the officers for the coming quadrennium.

The Board usually meet once a year, the Divisions at least every other year, and Technical Committees as often as is necessary to accomplish their objectives. In addition, the Divisions are encouraged to sponsor symposia and other meetings, especially in cooperation with other international bodies, to help further the work of the CIE.

Publications

The CIE publishes Standards, Technical Reports and Recommendations, prepared by the Technical Committees and the Proceedings of the Sessions and Symposia. More than 100 such **publications** have been issued, attesting to the activity of the Technical Committees. Joint publications include the IEC/CIE International Lighting Vocabulary and **ISO/CIE Standards**.

In addition to Technical Publications, CIE News is published quarterly. This gives regular up-dates on the progress of the technical programme and forthcoming meetings together

CIE SESSIONS

YEAR	VENUE
1979	Kyoto (Japan)
1983	Amsterdam (Netherlands)
1987	Venice (Italy)
1991	Melbourn (Australia)
1995	New Delhi (India)
1999	Warsaw (Poland)
2003	San Diego (USA)
2007	Beijing (China)
2011	Sun City (South Africa)

Beijing 2007

CIE2007

The 26th SESSION OF THE CIE
JULY 4-11, 2007 BEIJING CHINA

THANK YOU
FOR YOUR ATTENTION

ENERGY EFFICIENT RAILWAY LIGHTING ACCORDING TO EN 12464-2

STOCKMAR Axel
LCI Light Consult International

ABSTRACT

The European Standard EN 12464-2 “Lighting of work places - Part 2: Outdoor Work Places” specifies the lighting requirements for the lighting of many outdoor areas, tasks and activities - including railways and tramways - and their associated surrounding areas in terms of quantity and quality. Furthermore the standard sets limits of obtrusive light for exterior lighting installations which are based on publication CIE 150:2003. Lighting levels are given in terms of average maintained illuminances of task and surrounding areas. In terms of energy efficiency this standard offers for the first time the possibility for the application of adaptive lighting as for a number of tasks the requirements are dependent on risk, duration, or passenger volume. For the calculation of illuminances and uniformities the maximum grid cell sizes can be evaluated using a formula which takes into account the actual dimensions of the area under consideration. The glare directly from the luminaires of an outdoor lighting installation is determined using the CIE Glare Rating (GR) method described in publication CIE 112:1994.

1 INTRODUCTION

The European Standard EN 12464-2 “Lighting of work places - Part 2: Outdoor work places” [1] specifies the lighting requirements for the lighting of many outdoor areas, tasks and activities and their associated surrounding areas in terms of quantity and quality. In a comprehensive table requirements are given for the exterior lighting of railways and tramways. For the lighting of open and covered platforms the lighting requirements are specified dependent on the type of train services and on the number of passengers [1] which offers the possibility to introduce adaptive lighting systems [2].

The standard specifies lighting requirements for outdoor work places which meet the needs for visual comfort and performance; they do not specify lighting requirements with respect to safety and health of workers at work, although the lighting requirements as specified usually fulfil these safety needs.

2 LIGHTING DESIGN CRITERIA

The main parameters determining the luminous environment are the luminance distribution, the illuminance level and uniformity, the limitation of glare, the directionality of light (modelling), the colour appearance and colour rendering, and the degree of flicker [1]. The luminance distribution in the field of view controls the adaptation level of the eyes. A well balanced luminance distribution (sudden changes should be avoided) is needed to increase the visual acuity, the contrast sensitivity, and the efficiency of the ocular functions. The illuminance and its distribution (on task and surrounding area) have a great impact on how quickly, safely, and comfortably a person perceives and carries out a visual task. The illuminance values specified in the standard [1] are maintained illuminances over the task area on the reference surface, which may be horizontal, vertical or inclined. The task area is defined as the partial area in the work place in which the visual task is carried out. For places where the size and/or the location of the task area are unknown, the area where the task may occur is considered as the task area. The maintained illuminance of the surrounding area shall be related to the maintained illuminance of the task area and should provide a well-balanced luminance distribution in the field of view. For task area illuminances of 100 lx or above the illuminances of the surrounding area are specified as four steps down on the recommended scale of illuminances which was taken from the European standard EN 12665 “Basic terms and criteria for specifying lighting requirements” [3]. The surrounding area is regarded as a strip surrounding the task area in the field of view. The width of this strip should be at least 2 m, but this is usually of no importance for railway or tramway lighting.

Alongside the average maintained illuminances specified for a large number of areas, tasks and activities there are also requirements given concerning uniformities (minimum/average) - and in particular for railway and tramway lighting diversities (minimum/maximum) - [1] for task and surrounding areas. For the calculation and verification of illuminance values (minimum, average, maximum) a grid system has to be used which is based on a formula giving the maximum grid cell size dependent on the area dimensions. This formula is equivalent to the equation given in the European standard EN 12193 "Sports lighting" [4].

The colour qualities of near-white lamps are characterised by the colour appearance of the lamp (warm, intermediate, cool) and the colour rendering capabilities expressed in terms of the general colour rendering index R_a. This methodology is the same as used for the lighting of indoor work places [5]. For the recognition of safety colours the light sources shall have a minimum colour rendering index of 20; for specific tasks, areas or activities including railways and tramways minimum general colour rendering indices are given in the schedule of lighting requirements [1]. To highlight objects, to reveal textures or to improve the appearance of people (modelling), directional lighting may be suitable. Modelling is the term used to describe the balance between diffuse and directional light; too directional lighting will produce harsh shadows. Lighting from specific directions may reveal details within a visual tasks, increase their visibility and making the task easier to perform. Unfortunately there are no measures given in the standard [1], only verbal descriptions.

3 EVALUATION OF GLARE

Glare is the sensation produced by bright areas within the field of view and may be experienced either as discomfort or disability glare [1]. The glare directly from the luminaires of an outdoor lighting installation shall be determined using the CIE Glare Rating (GR) method according to CIE publication 112:1994 [6]. For a given observer position and a given viewing direction (2º below the horizontal) the degree of glare is dependent on the equivalent veiling luminance produced by the luminaires and the equivalent veiling luminance produced by the environment in front of the observer. The veiling luminance caused by the lighting installation is calculated according to the Holloday formula. The veiling luminance of the environment is approximated; i.e. it is assumed to be 3,5 % of the average luminance of the area under considerations [6]. If no particular observer positions and viewing directions are specified, the glare rating should be computed at the illuminance grid positions at 45º intervals radially about the grid points with the 0º direction parallel to the long axis of the task area [1]. On platforms observers should be positioned in a regular grid covering one or several luminaire spacings with viewing directions along the platform and at ±15° / ± 30° against the long axis.

Regarding the disability glare possibly experienced by vehicle drivers there are no limits specified in the standard [1]; it only states 'avoid glare for vehicle drivers'. If the situation of a train driver e.g. entering a station is considered to be similar to the position of a car/lorry driver moving along a road, the threshold increment concept - usually applied in road lighting - could be used to evaluate the disability glare. For a given train driver position (midst of a track at a specified height) the veiling luminance can be calculated, and using the average track luminance as the adaptation luminance (next to a platform as 10% of the average platform luminance) the threshold increment could be determined. It has been proven that installations with luminaires suitable to minimize also the light pollution will produce threshold increments smaller than 15% [7].

4 OBTRUSIVE LIGHT

Obtrusive light is defined as light, outside the area to be lit, which, because of quantitative, directional, or spectral attributes in a given context, gives rise to annoyance, discomfort, distraction or a reduction in the ability to see essential information. The time after which stricter requirements (for the control of obtrusive light) will apply, often a condition of use of lighting applied by a government controlling authority, e.g. the local government, is called curfew [1][8]. To safeguard and enhance the night time environment it is necessary to control obtrusive light which can present physiological and ecological problems to surroundings and people. To evaluate the effects of obtrusive light from outdoor lighting installations the methods described in CIE Publication 150:2003 [8] have been included in the standard [1] for the lighting of outdoor work places. For the different environmental zones E1 to E4, i.e. natural, rural, suburban, and urban, limits are specified for pre- and post-curfew hours in terms of maximum vertical illuminances on properties, of maximum luminous intensities of individual light sources into potentially obtrusive directions, of maximum average luminances of facades and signs, and of maximum upward light ratios. Furthermore the maximum values of threshold increments for users of nearby roads are considered.

Railway stations are located in all of the different environmental zones E1 to E4. Using luminaires for direct illumination at relatively low mounting heights (and no high pole lighting) will not cause problems in terms of vertical illuminances on buildings, of luminous intensities in potentially obtrusive directions, and of the proportion of the luminous flux emitted above the horizontal. The possible reduction of light levels dependent on passenger volume [1][2] - sometimes even switching off during hours of guaranteed non-operation of trains - is a further measure to reduce light pollution particularly in dark (natural zone E1) or low brightness (rural zone E2) areas. Application of energy efficient lighting systems using lamps with higher efficacy, ballasts with lower losses, and luminaires providing higher utilization factors platform will also help to reduce pollution, obtrusive light, and sky glow.

5 LIGHTING REQUIREMENTS FOR RAILWAYS AND TRAMWAYS

In the schedule of the lighting requirements a large number of areas, tasks, and activities are listed including airports, building and industrial sites, harbours, parking areas, petrochemical industries, power and water plants, railways, saw mills, and shipyards [1]. The requirements for railways and tramways are specified in part 12 of table 5: “Lighting requirements for areas, tasks, and activities”. For the specific areas, tasks, and activities requirements are given in terms of average maintained illuminances, uniformities, glare rating limits, and colour rendering indices. For open platforms e.g. there are three different levels of requirements dependent on the type of train or services and on the number of passengers, with a fixed minimum colour rendering index R_a of 20; for covered platforms there are two different levels of requirements dependent on the type of train or services and on the number of passengers, with a fixed minimum colour rendering index R_a of 40. In addition special attention has to be paid to the edge of the platform and to the avoidance of glare for train drivers. The listed minimum values of illuminance, uniformity and diversity [1] are a kind of harmonized average values reflecting current European practice. The dependence of the lighting requirements on the type of train or service and passenger volume gives great flexibility and allows e.g. for a reduction of the illuminance level at night time when only a small number of passengers are expected under nominal condition. As the recommended illuminances for the tasks are given as maintained illuminances the design should take into account an appropriate maintenance factor. The maintenance factor to be applied depends on the characteristics of the lamp and control gear, the luminaire, the environment, and on the maintenance programme. For the elaboration of a maintenance schedule it is recommended to follow the methods described in the CIE guide on the maintenance of outdoor lighting systems [9].

6 ENERGY EFFICIENCY OF PLATFORM LIGHTING

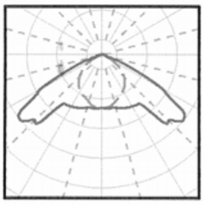
Lighting requirements in general concern the quality criteria illuminance level, luminance distribution, glare limitation, modelling, colour appearance, and colour rendition. Besides these photometric criteria special attention is paid to the costs of acquisition, installation, maintenance, and operation of the lighting system. Here it is of particular interest to what extent the total costs could be reduced by utilizing lamps with higher efficacy, ballasts with lower losses, and luminaires with higher light output ratios and/or more appropriate luminous intensity distributions The ratio of the achievable illumination level, expressed in terms of an average illuminance on a reference surface (the platform), to the necessary electric power depends on the selected lamps, ballasts, and luminaires as well as on the luminaire layout. For lamps and ballasts there are appropriate measures, efficacy and ballast-lamp circuit power respectively, which serve as a basis for the evaluation of energy efficiency. However, for luminaires the obvious measure, the light output ratio, is not a suitable quantity, as there exists no relationship to the achievable illumination level [10]. The energy efficiency of a particular luminaire in a given layout can be evaluated using the utilization factor platform (UFP). The utilization factor platform is defined as the ratio of the total flux received by the reference area of a platform to the total lamp flux of the installation. If the value of the utilization factor platform is close to the light output ratio of the luminaire there is the risk that the uniformity limits are not met and/or the illuminance along the platform edge is insufficient. Values of the utilization factor platform small compared with the light output ratio of the luminaire indicate not only a poor performance but also the tendency to a higher light pollution as a larger amount of the luminous flux is spread around and not concentrated on the area to be lit. For the selection of appropriate luminaires – covering all requirements concerned – a comprehensive platform lighting design table could be regarded as a useful design tool (figure 1).

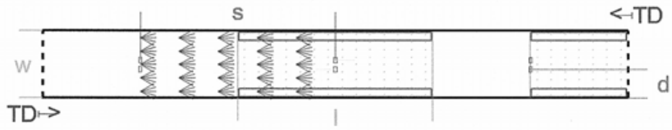
7 ADAPTIVE PLATFORM LIGHTING

For the lighting of open and covered platforms the lighting requirements are specified dependent on the type of train services and on the number of passengers [1]. This means firstly, the lighting levels could be different for a number of platforms of just one station, and secondly, the illumination levels could be reduced during some of the hours of darkness when only a small number of passengers is being expected [2]. According to the internal recommendations of the German Railways a small number of passengers is defined as less than 500 passengers per day per station [11]. It is important to note that - while reducing the average illuminance levels - the other quality criteria, especially the uniformity and the diversity (as given in table 1), have to be observed and fulfilled. According to the specified average maintained illuminances it is possible to reduce the lighting level between 25 % and 50 % and the electrical power between 15 % and 50 % depending on the type of the adaptive lighting system. If the lighting installation of a covered platform consists of e.g. two roof mounted rows of fluorescent luminaires along the edge of the platform, it is possible to reduce the lighting level (from 100 lx to 50 lx) by simply switching off every second lamp or luminaire. Depending on the luminaire layout it may be impossible to meet the even less strict requirements concerning uniformity and/or diversity. This could be overcome by switching off every second luminaire in a zigzag mode. To double-check the different options, the platform lighting design table could be used again (table 1). A similar procedure could be applied to HID installations of covered platforms. For open platforms, where a reduction from 50 lx to 20 lx or from 20 lx to 15 lx is envisaged, is seems to be impossible to achieve the required uniformities and/or diversities using a switching off method; here adaptive lighting systems with dimming facilities should be applied using e.g. additional ballasts or electronic control gear. All in all the condition dependent requirements for platform lighting specified in the new European standard EN 12464-2 [1] offer the possibility to introduce adaptive lighting systems which, utilizing intelligent controls, could help to save energy and to protect our environment.

Table 1 Lighting requirements for platforms according to EN 12464-2 [1]

Type of Platform	E_m	U_o	U_d	GR_L
Open platforms, **rural and local trains, small number of passengers**	15 lx	0.25	0.125	50
Open platforms, **suburban and regional trains with large number of passengers** or **inter-city services with small number of passengers**	20 lx	0.40	0.20	45
Open platforms, **inter-city services**	50 lx	0.40	0.20	45
Covered platforms, suburban or regional trains or **inter-city services with small number of passengers**	50 lx	0.40	0.20	45
Covered platforms, **inter-city services**	100 lx	0.50	0.33	45





Platform Lighting Design Table (EN 12464-2)

Lamp SON-T PLUS PIA 50W (4400 lm) Mounting height h = 6.0 m Tilt of luminaire 10º Maintenance factor = 0.67

w (m) d (m)	s (m)	reference area / central							reference area / endwise			
		Eav (lx)	Uo	Ud	ER (%)	GR	UFP (%)	TI (%)	Eav (lx)	Uo	Ud	ER (%)
5.00 2.00	15.0	28.2	0.77	0.65	91	40	36	7.2	23.5	0.63	0.45	90
	18.0	23.6	0.69	0.50	91	39	36	8.2	21.5	0.46	0.30	90
	20.0	21.2	0.50	0.32	91	39	36	8.8	20.0	0.31	0.19	90
	22.0	19.2	0.36	0.21	90	41	36	9.4	18.6	0.23	0.13	90
	25.0	16.9	0.20	0.10	91	44	36	10	16.7	0.12	0.06	90
6.00 2.50	15.0	27.2	0.71	0.58	85	40	42	6.9	22.6	0.60	0.42	83
	18.0	22.7	0.67	0.47	85	40	41	7.8	20.7	0.47	0.30	84
	20.0	20.4	0.50	0.31	85	39	42	8.4	19.3	0.33	0.19	84
	22.0	18.6	0.36	0.21	85	41	42	9.0	18.0	0.23	0.13	84
	25.0	16.3	0.21	0.10	85	44	42	10	16.1	0.13	0.07	84
7.00 3.00	15.0	26.0	0.70	0.55	78	41	46	6.4	21.6	0.57	0.38	76
	18.0	21.7	0.65	0.44	78	40	46	7.3	19.8	0.47	0.29	77
	20.0	19.5	0.50	0.30	78	39	46	7.9	18.4	0.34	0.19	77
	22.0	17.7	0.35	0.19	78	42	46	8.4	17.1	0.23	0.12	77
	25.0	15.6	0.22	0.10	78	45	46	9.3	15.3	0.14	0.07	78
8.00 3.50	15.0	24.9	0.65	0.49	72	41	51	6.1	20.5	0.53	0.34	70
	18.0	20.7	0.62	0.40	72	41	51	6.9	18.8	0.44	0.26	71
	20.0	18.6	0.49	0.29	72	40	51	7.5	17.5	0.33	0.18	71
	22.0	17.1	0.35	0.19	72	42	51	8.0	16.4	0.23	0.12	71
	25.0	15.0	0.22	0.10	72	45	51	8.7	14.7	0.15	0.07	72
9.00 4.00	15.0	23.8	0.60	0.44	66	42	54	5.7	19.5	0.49	0.30	64
	18.0	19.8	0.60	0.37	66	41	54	6.4	17.9	0.42	0.24	64
	20.0	17.8	0.49	0.27	66	40	54	6.9	16.8	0.33	0.17	65
	22.0	16.3	0.35	0.18	66	43	55	7.4	15.7	0.23	0.11	65
	25.0	14.2	0.23	0.11	66	46	54	8.1	13.9	0.17	0.07	66
10.0 4.50	15.0	22.5	0.56	0.39	61	42	57	5.2	18.5	0.47	0.27	58
	18.0	18.8	0.58	0.34	61	42	57	5.8	17.0	0.42	0.22	58
	20.0	17.0	0.47	0.25	61	41	58	6.2	16.0	0.32	0.16	59
	22.0	15.4	0.35	0.17	61	43	57	6.7	14.8	0.25	0.12	59
	25.0	13.5	0.23	0.10	61	46	57	7.3	13.3	0.16	0.07	60

s ... luminaire spacing (m)
w .. width of reference area, width of platform (m)
d ... distance of luminaire row from edge of platform (m)
h ... mounting height of luminaires (m)
l .... length of reference area (m)
TD. position of train driver
average reflectance of platform surface 0.15
Adaptation luminance has been set equal to one tenth of the average platform luminance

CEN Flux Code 43 86 99 100 77 0 50 75 0

Eav .. average illuminance (lx), maintained value
Uo .... uniformity Emin/Eav
Ud .... diversity Emin/Emax
ER ... ratio (%) of average illuminance of strip at edge of platform (1 m) to average illuminance of reference area (width of platform) in percent
GR ... maximum glare rating
UFP.. utilisation factor platform (%)
TI ..... threshold increment (%)

Figure 1 Platform lighting design table

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STRUCTURI MODERNE DE UTILIZARE A LUMINII NATURALE PENTRU SISTEME DE ILUMINAT INTEGRATE NATURAL – ELECTRIC, EFICIENTE ŞI DE CALITATE

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1 INTRODUCERE

Prezenta lucrare tratează iluminatul integrat electric-natural, o structură deosebit de importantă pentru prezent şi viitor, capabilă să asigure o eficiență energetică ridicată, cu respectarea calității mediului luminos interior.

În lucrare vor fi prezentate accesul luminii naturale de la structurile clasice (ferestre) la cele moderne, atât prin sistemele de prelucrare moderne la ferestre cât şi prin transferul prin structuri spațiale (centrale, laterale sau mixte). De asemenea, vor fi prezentate şi structurile moderne compactizate precum tubul de lumină (monovalent şi bivalent) şi tubul solar (mono-, bi- şi trivalent) recomandate de experiența internațională precum şi unele soluții originale de utilizare eficientă şi confortabilă.

Desigur că pentru obținerea unei eficiențe maxime a sistemului integrat este necesară şi utilizarea de surse de lumină moderne de eficacitate maximă şi calitate spectrală corespunzătoare cerințelor mediului luminos. Componentele mediului luminos interior, alese corerspunzător destinației încăperii, sunt determinante în realizarea confortului vizual optim care asigură desfăşurarea activității umane intelectuale sau fizice. Structura mediului luminos interior este determinată de aspectele cantitative şi calitative şi de interconexiunile specifice. Într-un sistem de iluminat exclusiv electric, echilibrul componentelor este constant, ceea ce va conduce, evident – dacă este corect conceput, la confort optim, funcționalitate şi estetică a mediului luminos, în condiții de seară/noapte. În varianta clasică, cele două sisteme erau concepute separat: cel natural pentru zi, cel electric pentru seară-noapte, echilibrarea la variația zilnică a luminii naturale realizându-se prin comenzi manuale facultative.

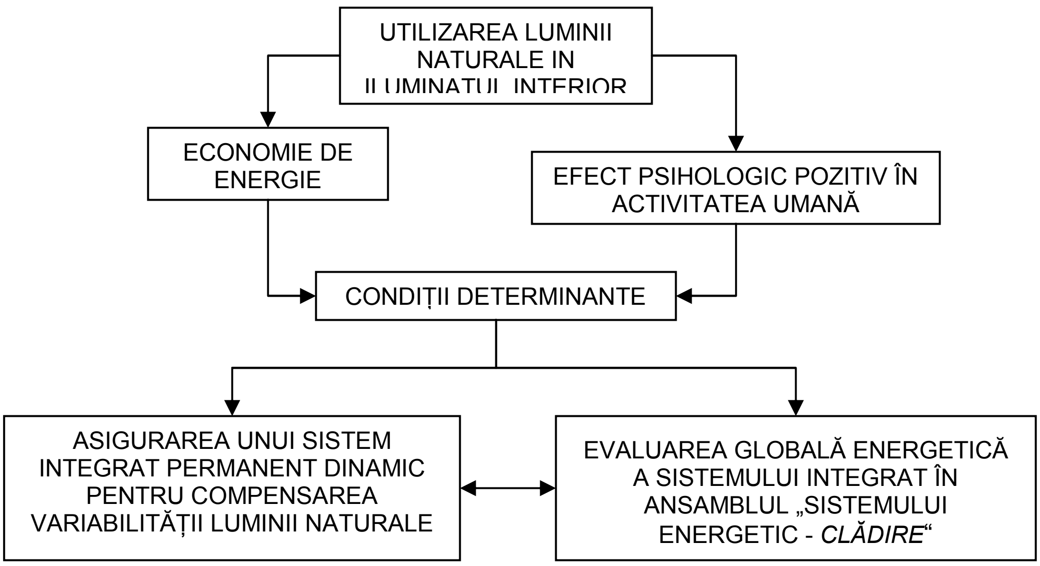


Figura 1 Efectele pozitive ale luminii naturale în iluminatul interior al clădirilor

Structura modernă a integrării iluminatului electric cu cel natural implică o dificultate de concepție, realizare şi funcționalitate, datorită variației permanente a luminii naturale, determinată de variația diurnă şi de orientare, anotimp şi de variația vremii (însorită, înnorată total/parțial ş.a.). Apare astfel necesitatea variației simultane a componentelor cantitative (în special nivelul de iluminare) ale iluminatului electric, pentru a realiza un confort vizual permanent constant.

O problemă dificilă o reprezintă sincronizarea culorii aparente a surselor de lumină cu variaţia permanentă a culorii aparente a luminii naturale (lumină cer albastru, cer înnorat, lumină soare, schimbare de culoare dimineaţă, zi, seară). Soluţia optimă este variaţia culorii aparente a surselor electrice în funcţie de variaţiile luminii naturale, dezavantajele fiind însă dificultăţile de implementare şi costul extrem de ridicat. Practic, această soluţie este utilizată azi pe plan internaţional în foarte puţine locaţii destinate activităţii intelectuale, din cauza complicaţiilor de implementare a sistemului, în special la clădirile existente. Practic, pentru sistemele de iluminat integrate actuale curente, se utilizează sursele de lumină de culoare aparentă neutră şi neutră-caldă în funcţie de destinaţie, acces de lumină şi program de activitate, având în vedere şi reacţia umană la culoarea aparentă în zona climatică temperată (culoarea alb-caldă – stimulativă, culoarea alb-rece – liniştitoare, iar cea neutră fiind atât medie ca reacţie vizuală, cât şi cea mai armonizată la variaţiile permanente ale luminii naturale). Utilizarea eficientă a luminii naturale a devenit azi un aspect deosebit de important în tratarea modernă a concepţiei sistemelor integrate.

În concluzie, lumina naturală, extrem de variabilă, prezintă efecte pozitive în activitatea umană şi poate conduce la economie de energie (Figura 1), cu condiţia unei armonizări cu cea electrică, care trebuie să realizeze permanent compensarea variabilităţii printr-un sistem integrat dinamic "inteligent", capabil să asigure mediul luminos interior confortabil, funcţional şi estetic.

2 TRANSFERUL LUMINII NATURALE ÎN INTERIORUL CLĂDIRILOR

În general accesul luminii naturale în clădire se poate realiza clasic prin ferestre sau prin structuri interioare moderne, de regulă centrale, atrium-uri, vitrate la partea superioară şi care oferă posibilitatea transferului luminii naturale către zona centrală cât şi către încăperile tangente amplificând şi echilibrând transferul prin ferestrele uzuale. Sunt practicate şi structuri centrale înguste de transfer al luminii către zonele adiacente prin oglinzi care dirijează şi concentrează „jetul luminos".

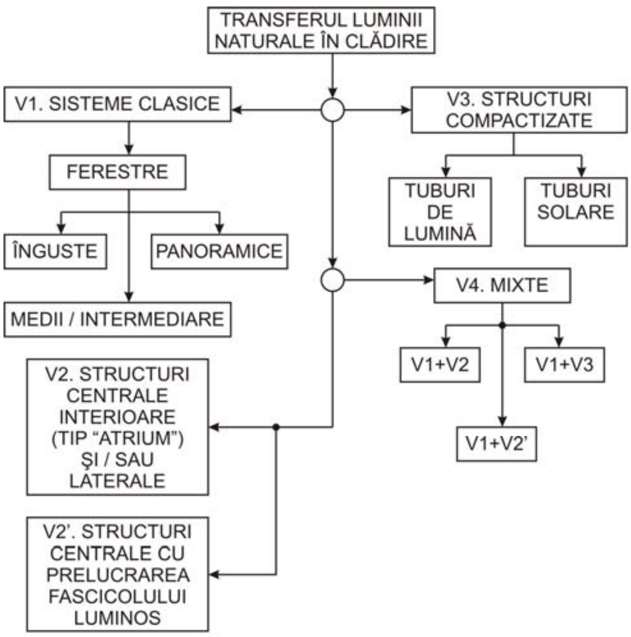


Figura 2 Transferul luminii naturale în clădire

Există posibilitatea, deocamdată mai rar aplicată, de utilizare a structurilor compactizate, „tuburi de lumină" şi tuburi solare, pentru realizarea transferului luminii, soluţie extrem de eficientă şi uşor de aplicat. În Figura 2 sunt prezentate schematic sistemele de acces ale luminii naturale. Tendinţa actuală pentru clădirile destinate activităţilor umane (muncă intelectuală, fizică sau mixtă), este utilizarea variantei V2 şi V2', care, pe de altă parte, elimină şi dezavantajul birourilor adânci cu structuri clasice, care necesitau un sistem de iluminat electric interior, suplimentar şi permanent- PSALI (Permanent Suplimentary Artificial Lighting of Interior). Se transformă astfel zona centrală "neagră" într-o zonă de acces a luminii naturale. Accesul luminii naturale în clădire poate fi realizat atît prin sistemul clasic de ferestre cu lumina prelucrată şi controlată sau/şi prin intermediul structurilor interioare centrale, care oferă posibilitatea transferului luminii naturale prin zonele vitrate laterale către încăperile adiacente.

3 SISTEME DE TRANSFER INTEGRATE CU FERESTRE ŞI PLAFOANE / ZONE DE PLAFON

Sistemul de transfer al luminii naturale prin ferestre nu este practic decât o deschidere în structura clădirii. Fereastra este şi astăzi sursa predominantă de lumină naturală. Datorită distribuției neuniforme de iluminări/ luminanțe în adâncimea încăperii, un sistem vertical de iluminat natural nu este o sursă corespunzătoare de lumină azi (la o adâncime a încăperii de 2,5-3 înălțimea sa, nivelul iluminării ajunge la aproximativ 1/10 față de cel de lângă fereastră). Lumina solară directă este adeseori o sursă necorespunzătoare într-un spațiu interior datorită intensității şi direcției sale, care produc orbirea ocupanților încăperii. Pe de altă parte, lumina difuză fie de la cerul descoperit sau acoperit, sau de la lumina solară difuzată de structuri de protecție (jaluzele/ draperii), nu pătrunde în adâncimea spațiilor interioare prevăzute cu ferestre clasice. Astfel, dacă adâncimea încăperii față de zona de acces a luminii naturale (ferestre clasice), este mare față de înălțimea încăperii ($l \geq 2.5h$), atunci se impune în zona opusă ferestrelor un iluminat suplimentar permanent pentru menținerea unui mediu luminos, echlibrat şi confortabil (Figura 3). Se poate observa în figură realizarea echilibrului distribuției nivelului de iluminare global natural+ electric (curba 3), prin funcționarea în trepte a sistemului de iluminat electric (curba 2), pe şiruri: şirul I (cel mai apropiat de ferestre- 0%), şirul II (50%), şirul III (100%). Soluția optimă constă în realizarea unui sistem de control automat al iluminatului electric suplimentar, capabil să compenseze permanent variabilitatea aportului de lumină naturală (curba 1).

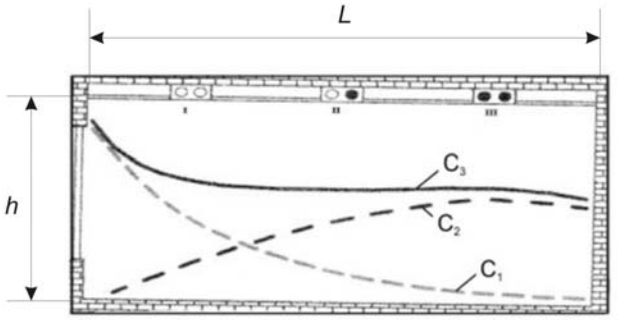


Figura 3 Compensarea scăderii aportului de lumină naturală prin funcționarea în trepte a iluminatului electric suplimentar : şirul I - 0% ; şirul II - 50% ; şirul III - 100% ;
C1 – variația iluminării naturale; C2 – variația iluminării electrice; C3 = C1 + C2 (suma iluminării naturale şi electrice)

Prelucrarea luminii naturale accesată prin ferestre şi plafoane a devenit azi o preocupare care s-a transformat în soluții de la bune la foarte bune, în funcție de structurile studiate şi care au fost brevetate în Italia, Elveția şi Germania. Variantele optime recomandate, care realizează o iluminare aproximativ constantă, sunt prezentate din Figurile 4 şi 5.

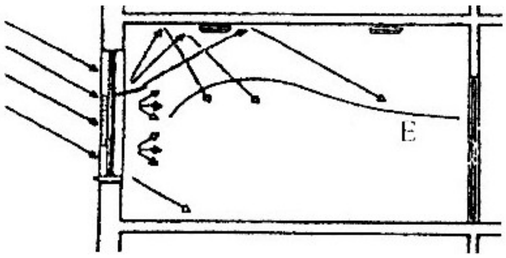


Figura 4 Acces protejat, dirijat şi prelucrat al luminii naturale (controlat) cu ecran cu trei regiuni:
1 – microoglindă superioară care dirijează lumina naturală către plafon;
2 – material difuzant în zona medie;
3 – acces direct în zona inferioară.

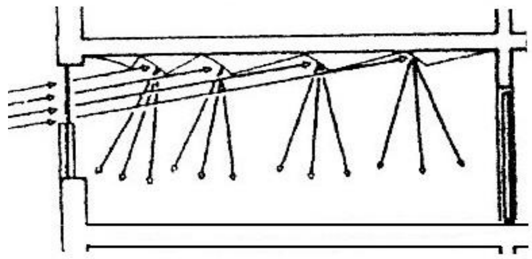


Figura 5 Acces prelucrat (controlat) al iluminării naturale cu ecran refractant superior şi plafon reliefat; se obține o uniformizare foarte bună a iluminării transversale şi un echilibru bun al luminanțelor, fiind cea mai bună variantă din cele trei (6,7,8)

Se obține astfel: Emax~Em şi Emin~Em

Aportul luminii naturale prin plafoane sau prin zone ale plafonului, atunci când această soluție este posibilă, sau în variante mixte (plafon şi ferestre) cu prelucrare şi control corect sunt soluții benefice pentru reducerea consumului de energie în clădire. În Figura 6 se poate urmări un sistem mixt cu iluminat parțial prin plafon şi prin fereastră, lumina naturală fiind prelucrată, dirijată şi controlată

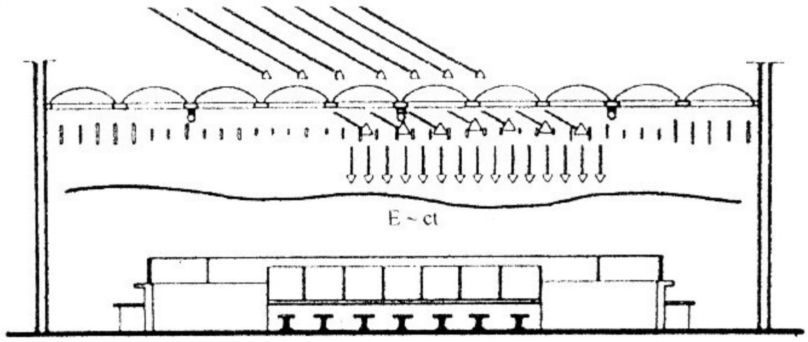


Figura 6 Accesul luminii naturale prin plafon transparent şi dirijat şi prelucrat (controlat) cu ecran cu lamele reflectante

4 STRUCTURI CENTRALE ŞI LATERALE MODERNE PENTRU TRANSFERUL LUMINII NATURALE ÎN CLĂDIRI MEDII ŞI MARI

Structurile centrale de transfer al luminii naturale s-au realizat şi se realizează azi în trei-patru moduri (Figura 7).

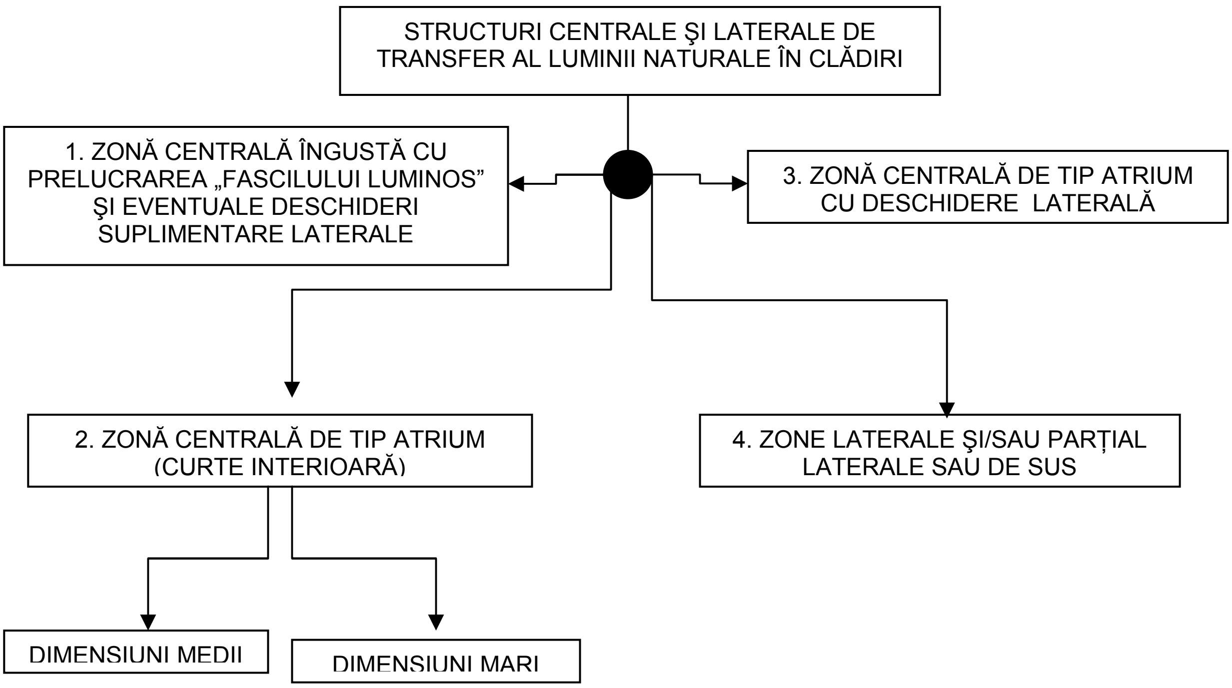


Figura 7. Moduri actuale de transfer al luminii naturale în interiorul clădirilor

─ Zonă centrală relativ îngustă şi cu transmisie a luminii naturale prin fascicule concentrate şi dirijate prin oglinzi de la un captator exterior orientabil automat către sursa solară sau cu mai multe captatoare fixe pentru diversele poziții ale incidenței solare.

─ Zonă centrală medie ca dimensiuni de tip atrium (curte interioară), dacă clădirea nu are multe/foarte multe niveluri, fără prelucarre specială a luminii naturale.

─ Zonă centrală mare ca dimensiuni (de tip atrium mare) când sunt multe/foarte multe niveluri şi fără prelucrarea specială a luminii naturale.

─ Zona centrală mare cumulat şi cu o zonă laterală vitrată (rar două) la multe/foarte multe niveluri şi de asemenea fără prelucrare specială a luminii naturale.

─ Zone laterale la clădiri mari sau parțiale pe anumite zone de interes.

În Figura 8 poate fi urmărită o structură de tipul 1 la o clădire modernă realizată în deceniul trecut la Zoug-Elveţia (ILR – PHILIPS Lighting nr. 4/1993) destinată birourilor administrative şi care utilizează o structură centrală octogonală, echipată pe acoperiş cu un sistem de captare, deschisă prin vitrare nesimetrică (funcţie de orientare în timpul desfăşurării activităţii) pe ultimele două etaje şi suplimentar încă un etaj deasupra ultimului nivel.

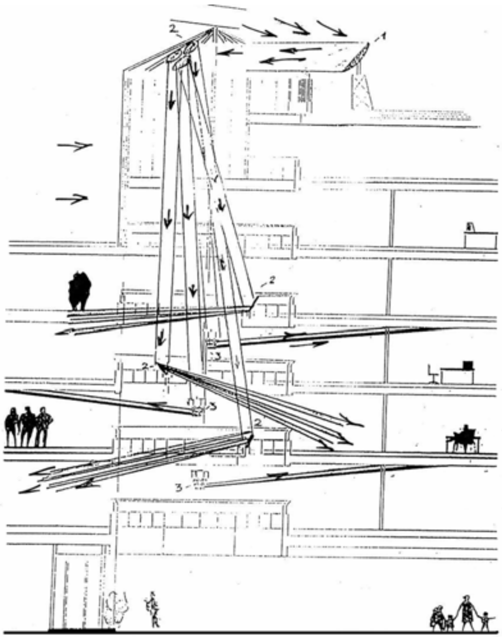


Figura 8 Secţiune prin clădirea cu zona centrală iluminată natural

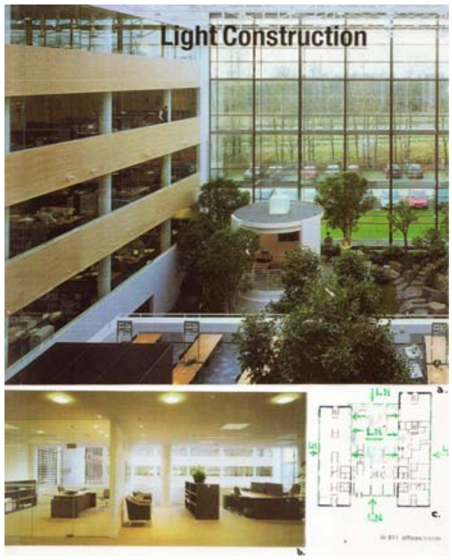


Figura 9 Clădire cu aport mare-foarte mare de lumină de sus şi lateral:
sus - vedere ansamblu; jos - vedere birou

Sistemul de captare este dotat şi cu heliostat cu oglindă (1), care urmăreşte radiaţia solară şi o transmite prin reflexie la o serie de oglinzi (2) şi prisme (3), ce transmit lumina în zonele de interes din interiorul spaţiilor de circulaţie şi birouri. Deci, practic, în afara avantajelor enumerate, zona centrală de circulaţie şi utilitară care trebuia iluminată permanent electric, devine o zonă iluminată natural. De menţionat că utilizarea prismelor (3) conduce la dispersia luminii, fiind un element decorativ (la care se poate renunţa).

În Figura 9 se poate urmări o structură modernă realizată de curând de PHILIPS cu aport de lumină prin zona centrală dar şi laterală la o clădire mare-foarte mare destinată birourilor. Structurile şi exemplele prezentate pun în evidenţă modul benefic de utilizare eficientă şi confortabilă a luminii naturale în clădirile moderne, care conduc la o creştere substanţială a confortului vizual şi la o scădere importantă a energiei electrice consumate pentru iluminatul electric.

5 NOUA GENERAŢIE DE STRUCTURI COMPACTIZATE PENTRU SISTEMELE DE ILUMINAT INTEGRATE AFERENTE CLĂDIRILOR MODERNE

Chiar dacă tubul de lumină a fost inventat în 1881, el a devenit operaţional în deceniul al IX-lea al secolului trecut datorită profesorului Whidhead (U.K.) şi companiei 3M care a dezvoltat şi fabricat produsul echipat pentru lumina electrică exclusiv cu surse de înaltă calitate PHILIPS LIGHTING.

O altă variantă recent dezvoltată în Anglia este tubul solar care realizează diferit transferul luminii, dar la dimensiuni mult mai mari şi care, în mod fericit, se poate integra şi cu o ventilare naturală pentru anumite spaţii.

În continuare vor fi tratate cele două structuri menţionate (Figura 10), care pot avea alimentare monovalentă (o singură sursă de lumină) sau bivalentă (două surse de lumină: naturală şi electrică). Menţionăm că propunerea funcţionării bivalente a tubului solar, cu sursă de lumină electrică înglobată pentru seară/noapte, este o idee originală a autorilor acestei lucrări[1]. De asemenea, o funcţie suplimentară a tubului solr poate fi o ventilare naturală controlată (v 5.2).

[1] Se pare că ideea a apărut recent şi pe plan mondial

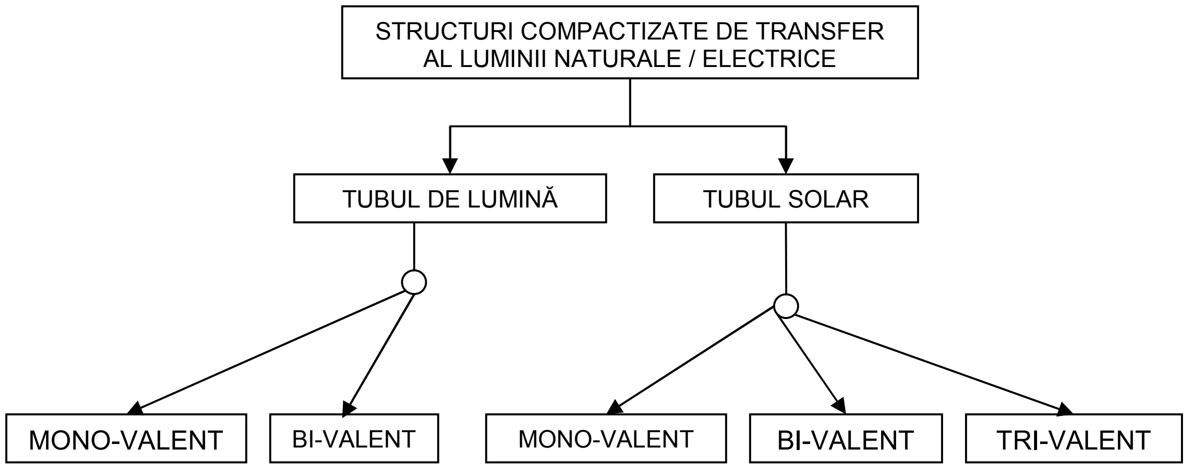


Figura 10 Structuri compactizate de transfer al luminii

5.1 Transferul luminii naturale în interiorul clădirilor prin tuburi de lumină

Tubul de lumină reprezintă o sursă secundară care transferă lumina de la o sursă primară (electrică sau naturală) fie într-o anumită încăpere, fie la un anumit obiectiv, fie pe o anumită zonă/suprafață (reflectantă sau transmițătoare) pentru realizarea sistemului de iluminat necesar desfăşurării unei activități. Transmisia luminii se poate realiza fie la capătul tubului, de unde aceasta este distribuită şi orientată, în funcție de necesitățile obiectivului, fie pe parcurs prin transfer lateral către obiectivele dorite. Tubul de lumină transmite radiația luminoasă în interiorul său pe baza reflexiei interne totale produse prin structura filmului optic de 0,5 mm grosime (SOLF – Scotch Optical Lighting Film) realizat din acril sau policarbonat transparent. Suprafața exterioară a filmului are o structură prismatică, necesară reflexiei totale, iar cea interioară este plană. Filmul optic este acoperit de un tub de protecție de 25 mm diametru ce se montează perfect pe acesta.

Structurile utilizate pentru transferul luminii pot realiza această operație în mai multe moduri şi anume:

a - la capăt (în general cu prelucrare şi dirijare); cea mai utilizată pentru lumina naturală

b - pe parcursul tubului – parțial (punctual, liniar limitat) sau pe toată lungimea tubului (pentru efecte decorative sau ghidare/dirijare);

c - prin suprafețe de prelucrare de tipul panourilor emisive de regulă dreptunghiulare.

În continuare se descrie o structură monovalentă de transfer al luminii naturale (exclusiv) într-o clădire. Principiul sistemului este prezentat în Figura 11 în care se poate urmări o schiță a unei clădiri în care lumina naturală este preluată prin captatorul 1 şi se transferă din coloanele 2 şi 3 la fiecare nivel prin tuburile 6 şi 7 în zona centrala si prin 4, 5 în zona de activitate. Astfel se satisfac, printr-un sistem mult mai comprimat fizic, cerințele de completare eficiente şi economice ale nivelului de iluminare cerut de diverse încăperi ale clădirii, pentru o uniformitate corespunzătoare asigurării echilibrului mediului luminos capabil să îmbunătățească confortul vizual necesar. Sistemul de captare a luminii naturale reprezintă unitatea funcțională de cea mai mare importanță din punctul de vedere al cantității de lumină naturală captată. Cu ajutorul unei lentile Fresnel, heliostatul este astfel construit încât să urmărească în mod eficient poziția soarelui pe cer printr-o simplă rotație în jurul axului vertical, dat fiind faptul că unghiul de captare al lentilei permite focalizarea luminii solare pentru orice unghi de înălțime solar, specific latitudinii locului unde se realizează montarea acestui sistem. Lumina focalizată este apoi reflectată de către o oglindă spre coloana verticală de transport, cât mai aproape de axul vertical al acesteia. Oglinda are o formă specială care permite şi captarea luminii difuze a cerului.

În Figura 12 se poate urmări o clasificare a sistemelor de iluminat integrate bivalente cu tuburi de lumină pe baza unei idei de integrare prin utilizarea surselor de lumină naturală şi electrică amplasate diametral opus, acționând astfel:

- când nivelul emisiei sursei naturale scade, intra în funcțiune sursa electrică cu flux reglabil şi cu rolul de menținere a nivelului de iluminare;
- când nivelul emisiei naturale a scazut la zero (seară/noapte), sursa electrică va asigura nivelul de iluminare necesar.

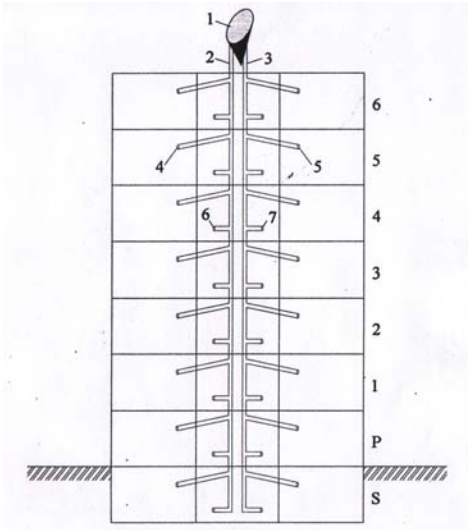


Figura 11 Principiul transferului luminii naturale în interiorul clădirilor cu ajutorul tuburilor de lumină prin zona funcțională (zona scărilor, spații utilitare), printr-o structură monovalentă:
1 - captatorul; 2, 3 - coloane verticale de transfer; 4, 5 - tuburi laterale de transfer către încăperile de lucru; 6, 7 - tuburi laterale de transfer către zona centrală funcțională a clădirii

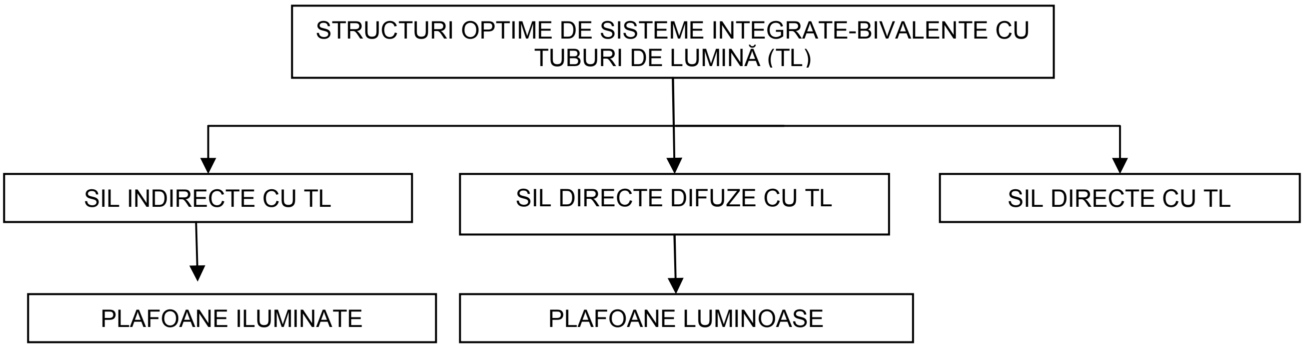


Figura 12 Structuri bivalente cu tuburi de lumină destinate iluminatului natural şi electric pentru clădiri

Ca surse de lumină electrice pot fi utilizate cele mai eficiente dintre acestea, cum sunt de exemplu lămpile cu descărcări de vapori de mercur la înaltă presiune şi cu adaosuri de ioduri metalice – MH PHILIPS, alese la o temperatură de culoare neutră/ neutru cald/ neutru rece, în funcție de destinația încăperii şi de perioada de lucru şi proporția de acces al luminii naturale prin ferestre. Astfel, se pot utiliza următoarele surse:

- MHN-TD – neutru rece (Tc=4200 K) cu redare bună către foarte bună a culorilor (Ra=85) şi eficacitate luminoasă de 70 lm/W;
- MHW-TD – cald (Tc=3000 K) cu redare bună (Ra=75) şi eficacitate luminoasă 75 lm/W şi/sau CDM cu caracteristici similare.

În 1998-1999 autorii au propus sistemul bivalent integrat indirect descris mai departe, soluție excelentă pentru interioarele destinate exclusiv activității la calculatoare personale prin evitarea reflexiei de voal şi menținerea permanentă a mediului luminos confortabil. De asemenea sistemul poate fi utilizat pentru alte încăperi care necesită acest tip de iluminat (de exemplu muzee ş.a.). În Figura 13 se poate observa schema sistemului original propus.

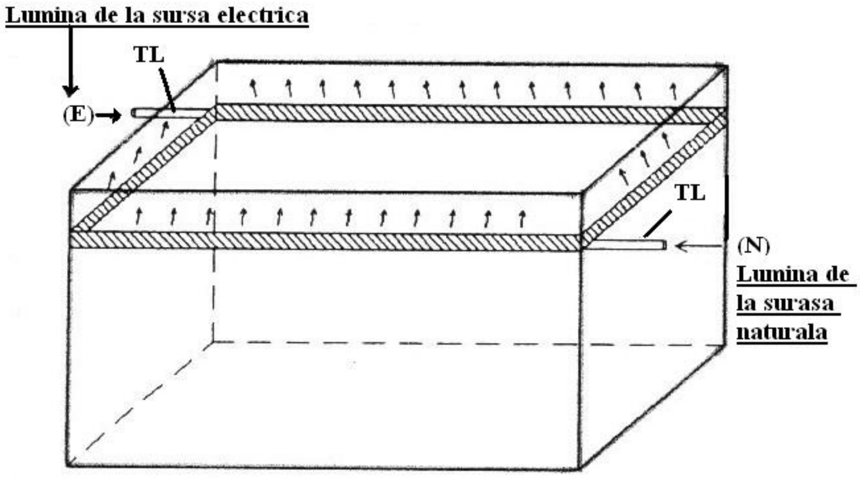
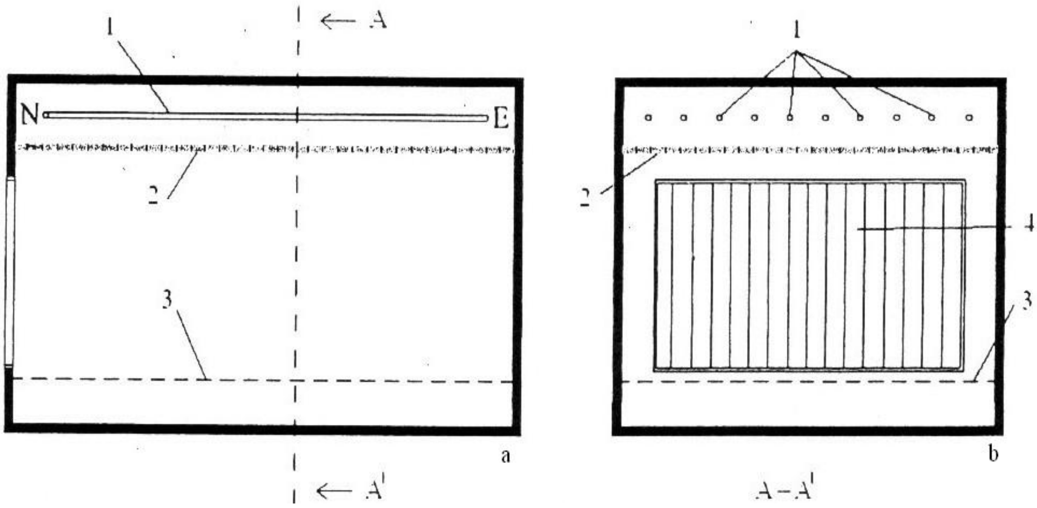


Figura 13 Schema unui sistem de iluminat integrat bivalent indirect cu tuburi de lumină, TL

Figura 14 prezintă structura unui sistem de iluminat direct-difuz cu tuburi de lumină, sub forma unui plafon luminos. Şi în acest caz s-a prevăzut o dublă alimentare cu lumină: de la sursa naturală (N) şi de la sursa electrică (E).



a – secțiune longitudinală b – secțiune transversală

Figura 14 Încăpere echipată cu plafon luminos cu tuburi de lumină:
1 – TL; 2 – plafonul difuzant transparent sau din lamele reflectorizante (preferabil); 3 – planul util; 4 - fereastră

5.2 Transferul luminii naturale în clădiri prin tubul solar

O variantă nouă a tubului de lumină a fost realizată şi promovată în Anglia, țară în care există o preocupare deosebită pentru utilzarea luminii naturale atât în interiorul clădirilor noi, cât şi a celor vechi reabilitate.

Structura noilor tuburi de lumină solară este diferită față de a tuburilor de lumină, în primul rând prin dimensiuni şi anume:

- diametre mult mai mari (~10-20 ori față de tuburile clasice prezentate);
- lungimi mult mai mici, fiind concepute în general pentru transferul luminii la clădiri de înălțime mică.

Din punctul de vedere al funcționalității tipurile utilizate pot fi:

- monovalente prin transfer exclusiv al luminii naturale solare în interiorul clădirii;
- bivalente funcțional prin transferul luminii naturale solare prin aparate de iluminat care sunt echipate şi surse de lumină electrice;
- bivalente prin transferul exclusiv de lumină naturală solară şi un sistem de ventilare naturală controlat;

- trivalente două componente de iluminat (solar şi electric) şi o componentă cu sistem de ventilare naturală controlat.

În Figura 15 se poate urmări structura unui tub solar monovalent de transfer al luminii în interior cu o structură rectilinie.

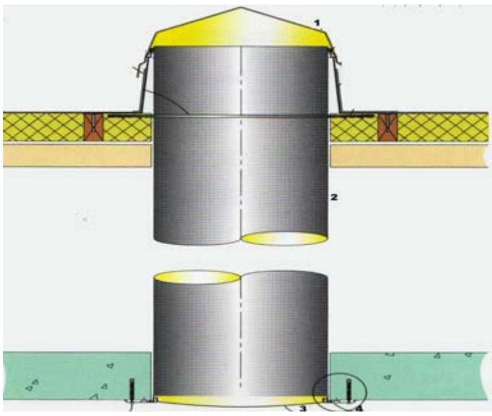


Figura 15 Tub solar monovalent rectiliniu:
1 – capac transparent din policarbonat cu protecție la radiații UV; 2 – tubul din aluminiu superargintat;
3 – panou circular difuzant; 4 – prindere sigură de structura plafonului

Trebuie menționat că tuburile solare descrise nu sunt similare cu tuburile de lumină prezentate inițial, ele având dimensiuni (diametre mult mai mari şi o structură total diferită pentru transferul luminii directe, pe porțiuni scurte, realizate cu tuburi din aluminiu supra-argintat în interior, în aşa fel încât pierderile să fie foarte reduse.

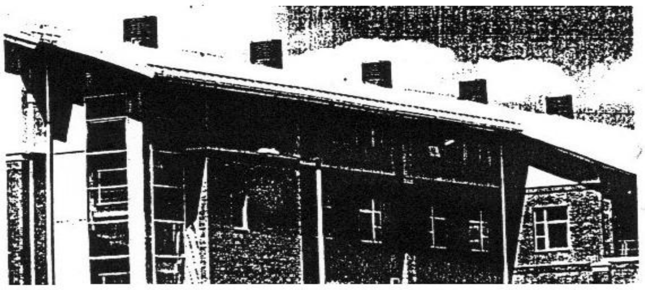
În Figura 16 sunt prezentate două clădiri echipate cu sistemele de captare a luminii solare pe acoperiş şi anume: a – locuință; b – şcoală.

Figura 16 Clădiri echipate cu tuburi solare

În Figura 17 se poate urmări un sistem bivalent realizat în Anglia cu două componente diferite, dar structurate şi coordonate în ansamblu:

- transferul luminii naturale/solare în clădire;
- ventilarea naturală de zi/noapte controlată.

Cele două sunt realizate cu un sistem integrat de transfer lumină şi aer, compactizat şi controlat. Sistemele bivalente (utilizarea pe aceeaşi structură a luminii naturale/solare şi a luminii electrice), precum şi cele trivalente (lumină naturală/solară, lumină electrică şi ventilare naturală controlată) sunt idei originale ale autorilor acestei lucrări, dar care la ora actuală se pare că au apărut şi pe plan mondial în varianta cu cele două surse de lumină.



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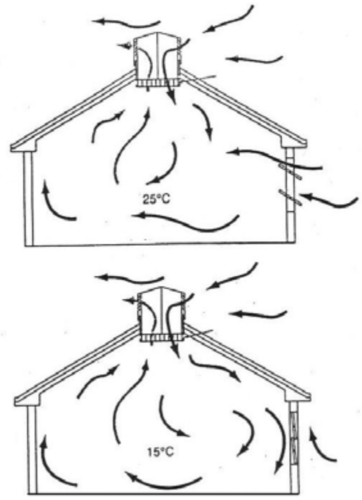
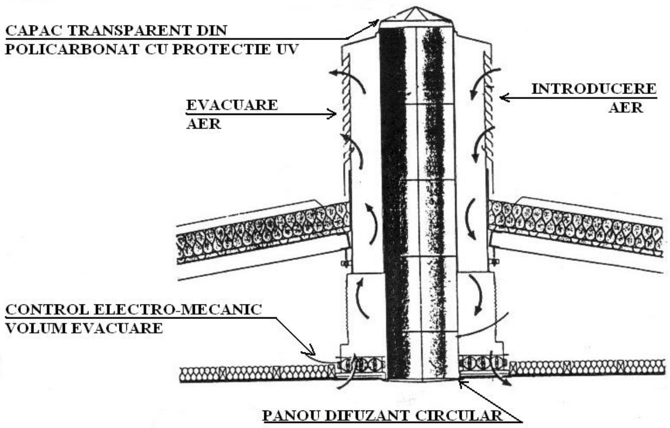
a.



Modul de operare în zi de vară:
Ferestre deschise (t≈20 ºC)

Mod de operare noaptea (vara, primăvara, toamna):
Ferestre închise (t>5 ºC)



b.

Figura 17 Structura şi modul de montare a sistemelor bivalente: transfer de lumină naturală/solară cu ventilare naturală controlată
a – vedere clădire din exterior, echipată cu tubul bivalent;
b – structura tubului bivalent

6 CONCLUZII

Lucrarea de faţă a detaliat aspecte privind eficienţa energetică a iluminatului şi calitatea sa în clădirile moderne, analizând ultimele sisteme şi structuri pentru transferul luminii naturale şi a integrării permanente dintre lumina naturală şi electrică capabile să asigure permanent şi constant un mediu luminos confortabil, indiferent de oră şi de vreme. Lucrarea a căutat să promoveze şi dezvolte aspectul necesar integrării inteligente pentru structurile prezentate. Sperăm ca în viitorul apropiat să fie introduse şi în România sistemele moderne integrate într-o structură inteligentă în aşa fel încât în fiecare clădire, indiferent de destinaţia sa, să se obţină un confort maxim, permanent constant ca parametri ai mediului luminos, cu un consum energetic minim, pe baza aspectelor determinante prezentate în cele această lucrare.

MODERN STRUCTURES OF USING NATURAL LIGHT FOR NATURAL-ELECTRIC INTEGRATED, EFFICIENT AND QUALITY LIGHTING SYSTEMS

ABSTRACT

The correct use of natural light in buildings is a special necessity, determined today not only by the positive psychological effect but also by the possibilities provided by modern structures of access. In the paper there are treated most of access ways of natural light in the buildings, including systems of treatment and permanent control, used on the international level, and original systems created by Romanian National Committee of CIE. It is also highlighted the determinant condition of visual comfort for luminances equilibrium in the central and peripheral visual field, namely the integration of natural lighting with electric lighting. An automatic control process must assure this aspect permanently in order to assure the constant and well-balanced level of illuminance and luminance in conditions of daily and weather variations. The paper proposes to structure, by analysis, the necessary framework for implementation in Romania the modern integrated lighting interior systems.

CONSUMPTION OF ELECTRICAL ENERGY FOR PUBLIC LIGHTING IN SLOVENIA

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Extended Abstract

In year 2007 the Government of Slovenia adopted Decree about limiting values of light pollution of environment. The aim of the government was to protect the living premises from the light trespassing, to reduce the energy used for outdoor lighting and also to limit the influence of the outdoor lighting installations on environment protecting so the nocturnal animals and dark sky.

In the field of public street lighting, the Decree regulates maximum allowed electrical energy consumption per capita and per year. The allowed amount of energy consumption for street lighting managed by municipalities is yearly 44.5 kWh per capita. Additional to that also yearly 5.5 kWh per capita can be used for lighting of major roads where lighting is managed by state owned companies responsible for state roads.

To be able to estimate the measures, which need to be taken to fulfil the claims in Decree until 31.12.2016, first the investigation of current consumption of electrical energy for public street lighting in Slovenia was performed. First we try to get the data about the energy consumption for street lighting from Slovenian municipalities, which are responsible for street lighting and which also pay the bills for the used electrical energy. We were able to get relevant data from 59 municipalities out of 210. The total number of inhabitants in these municipalities was around 962.000 which represent about 50 % of the total Slovenian population. From the collected data, we found out that the average electrical energy consumption per capita in this municipalities is 76.4 kWh yearly.

As the found consumption per capita was larger than the limit set in a Decree, more accurate data were needed. With the help of five distribution companies, which supply the electrical energy to the municipalities, the exact energy consumption for public street lighting for 2007 was found. The results are show in Table.

Table 1 Consumption of electrical energy for street lighting in 2007

Distribution Company	Sold el. energy [kWh]	Inhabitants	Consumption [kWh/cap.]
Elektro Celje	25,329,110	367,547	68.91
Elektro Gorenjska	13,139,097	198,301	66.26
Elektro Ljubljana	51,669,527	690,151	74.87
Elektro Primorska	26,361,525	250,282	105.33
Elektro Maribor	35,164,584	457,755	76.82
Total	**151,663,843**	**1,964,036**	
Average			**77.22**

In the same way we were also able to collect the data about energy consumption for lighting of state roads. Two state owned companies take care about that. Company DARS is taking care about lighting on highways where mostly junctions and tunnels are illuminated. The other company DDC is responsible for lighting on other (non highway) major roads. Yearly energy consumption for illumination of state roads is 6.88 kWh per capita. More detailed are these data shown in Table 2.

If we sum both values we will found out, that the yearly consumption of electrical energy for public street lighting is 84.08 kWh per capita. The number of inhabitants of Slovenia on 31.12.2007 was 1,964,036. So the total electrical power consumption for public street lighting in 2007 was 165.1 GWh.

Comparing average energy consumption for street lighting in Slovenia to some other countries one will find, that Slovenia is using more electric energy for this purpose as some other countries or as the average in European Community is. Some available data are shown in Table 3.

Table 2 Consumption of electrical energy for lighting on state roads

Company	Consumption [kWh/cap.]
DDC	1.12
DARS - tunnels	3.01
DARS - roads	2.75
Skupaj	**6.88**

Table 3 Consumption of electrical energy for street lighting in Slovenia, Germany, the Netherlands and EU25

Country	Inhabitants (mio)	Area [km^2]	El. energy for street lighting [GWh]	Density [cap/km^2]	Energy consumption [kWh/cap]	Energy consumption [kWh/km^2]
Slovenia	2.0	20,273.00	165.0	98.7	84.0	8,138.9
Germany	82.3	357,021.00	3,456.6	230.5	42.0	9,681.8
The Netherlands	16.4	41,526.00	754.4	394.9	46.0	18,166.9
EU 25	465.8	3,975,481.00	23,802.4	117.2	51.1	5,987.3

One of the reasons for that is still extensive use of rather old lighting installations (also older than 30 years) with high-pressure Mercury lamps. To show the municipalities the possibilities of energy consumption savings more energy-examinations were performed in scope of which the lamps in use were inspected and the proposition for replacements were made. The results after first replacements show that up to 50% of electrical energy can be saved. Beside that with new lighting installations also the lighting conditions are improved and the maintenance costs are lower. Some examples of successful lighting installation refurbishment will be presented in a paper.

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ROAD LIGHTING IN THE LIGHT OF THE FUTURE

Wout VAN BOMMEL

ABSTRACT

Most standards on road lighting have been developed in the eighties of last century. It is time to re-evaluate the validity of these standards especially seen in the context of changed viewpoints of experts, changed environmental circumstances and new technological developments.

In preparing new guidelines for road and street lighting all these factors have to be taken into account in the discussion about: why road lighting, quantity and quality of road lighting, where road lighting and when road lighting.

This paper gives direction to the discussion and suggestions for research.

INTRODUCTION

Today's European standards for road lighting have been drafted at the end of the nineties of last century. Standards and Guidelines must be adapted regularly to changing insights, changing priorities in society and to changing technologies. The attention for sustainability in view of global heating has led to such a change in priority. For lighting, sustainability has a special meaning when we realize that 20 % of all electricity in the world is used for lighting. New light sources like white metal halides suitable for road lighting and new solid-state light sources offer challenging new possibilities in road lighting. Especially the solid-state light sources (LEDs) give new light distribution possibilities because of their extreme compactness. Adaptable intelligent road lighting is now feasible because the newer light sources are easily dimmable and can be, in a cost effective way, controlled with electronic management systems. Technological developments in automobile lighting have led to intelligent adaptable car light beams (AFS, Advanced Front Lighting System) that put fixed public road lighting in a whole new "light". Traffic density is increased to such a high level that road lighting concepts of the last century are often not relevant anymore. The driving task of today contains different components than those of the past decennia. New discoveries about neurological aspects of lighting are also important for road lighting: first investigations are underway where neurological effects of lighting on car drivers are being studied. Last but not least crime prevention has world wide become an important issue and public lighting of course plays here an essential role.

In preparing new guidelines for road and street lighting all these factors have to be taken into account in the discussion about:

- Why road lighting
- Quality and Quantity of road lighting
- Where road lighting,
- When road lighting.

It is too early to give answers to all these questions. But this paper gives direction to the discussion and recommendations for research needed to come to final answers.

WHY ROAD LIGHTING

The functions of road lighting are, providing:

- road safety
- traffic guidance and traffic flow
- personal security
- identity and prestige to a city, village or area.

In the early years of the last century Waldram [1] defined on the basis of visibility of small objects the "silhouette principle": most objects on roads with road lighting are seen as dark silhouettes against the bright background of the lit road surface. This, in turn, has been the key to the development of the luminance concept of road lighting as still used today [2]. Already early on one realized that the combined effect of road- and car lighting is a negative combination because the vertical component of car lights reduces the silhouette effect. However, in order to limit glare from oncoming cars, car beams could not reach far ahead and thus the negative “combination effect” was limited. With the introduction of Advanced Front lighting Systems (AFS) this now is strongly changed. These intelligent and automatic car lighting systems with specific urban-, highway- and curve beams that reach far and even “around the corner”, increase visibility of objects to such an extent that often sufficient visibility can be guaranteed by the advanced car lighting system itself. IR night vision systems that display an image recorded with the aid of invisible IR radiators, on the dashboard (ADAS, Advanced Driver Assistance Systems), will further increase the importance of own car systems as far as visibility is concerned. The role of public road lighting will move much more in the direction of traffic guidance, traffic flow, neurological effects and personal security.

For traffic flow an “old” study of the eighties of Fisher and Hall [3], is today particularly interesting. In a laboratory situation, they studied the time needed to respond to a change in the angle of a "lead car”, representing the slowing down of a car driving in front of the test person. Figure 1 shows the results for an initial distance between observer and vehicle of 40 m and for two values of deceleration of the lead car. For low values of road surface luminance, Lav, the response time needed, decreases rapidly when the road surface luminance Lav increases. This research seems particularly relevant to the current traffic situation. Traffic jams on highways will be less likely to develop when drivers are able to quickly see if vehicles in front of them reduce speed before they really brake and the brake lights go on. Despite the fact that in this study, the road surface luminance is used as the criterion for the quality of road lighting, it seems likely that three-dimensional components of road lighting are key for the effect demonstrated.

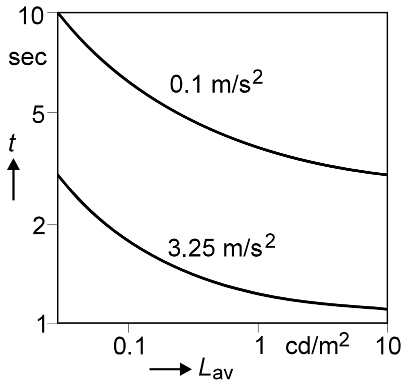

Figure 1 Time (t) required to response to a change in angle of a lead car as function od the average road surface luminance Lav. Fisher and Hall [3].

With the discovery of a third type of photosensitive cell in the retina of our eye in 2002, [Berson et.al., 4], studies into the neurological impact of road lighting are beginning to get attention as well. Figure 2 shows a car driver whose brain activity is measured during driving. The purpose of this type of research is to examine if road lighting can reduce the number of micro sleeps of night time drivers. If so, the next question to answer of course is which type of road lighting does this most effectively. To illustrate the importance of this type of research: a test where the EEC of drivers was analysed during a night time drive of 415 km motorway without lighting revealed that the cumulative duration of these micro sleeps adds up to more than 6 minutes [5].

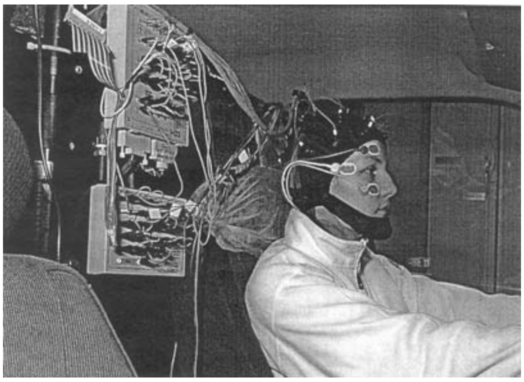

Figure 2 Equipment to measure the brain activity of car drivers while driving (photograph: A. Muzet, Strassbourg).

As stated above the role of road lighting will move more into the direction of personal security. Of course this in particular concerns lighting in areas where pedestrians are on the streets. Unfortunately this aspect becomes also more and more important for people who move in their cars from A to B. Not for nothing, nearly all modern cars have an automatic option to lock the car from the inside. Especially many women choose for their journeys in the dark those roads that have lighting, even if this means a longer detour.

QUALITY AND QUANTITY OF ROAD LIGHTING

At times when traffic density is relatively low and speeds are high, the visibility of objects and lineation is more and more taken over by the own advanced car lights as already discussed above. The traditional concept of road surface luminance lighting seems under these circumstances less relevant. It is not yet known whether neurological research, also discussed above, can indicate what kind of road lighting parameters can perhaps reduce micro sleeps.

In built-up areas but also on rural roads, personal security becomes the more determining factor in road lighting. Already in the eighties Caminada and van Bommel [6] have demonstrated that for one of the most important aspects of personal security, the recognition of faces, the three-dimensional component of lighting is essential. We came to the conclusion that the "semi-cylindrical" illuminance at face height is a good indicator for this component. Meanwhile, other measures such as the vertical illuminance on face height, semi-spherical illuminance at ground level are proposed as well.

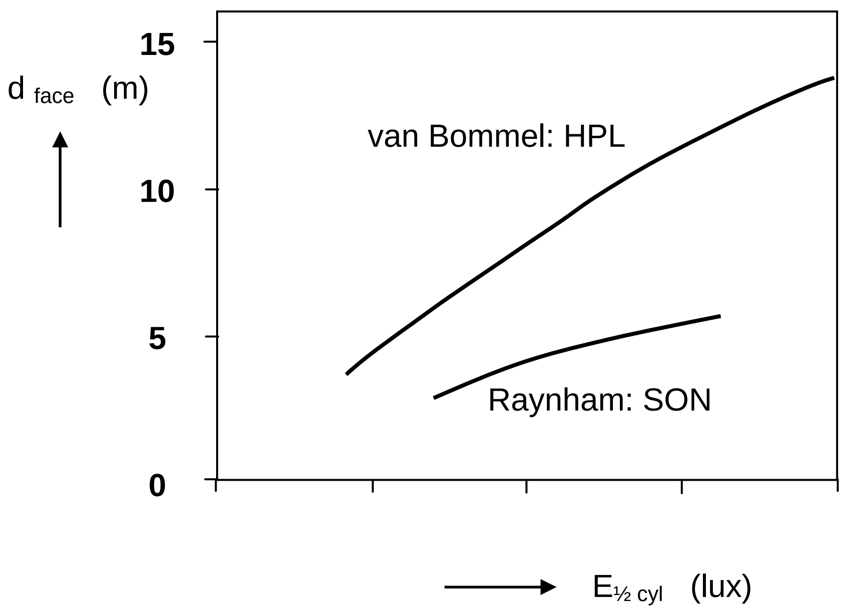

Figure 3 Identification distance d, under residential area lighting circumstances in dependence of semi- cylindrical illuminance E ½cyl, with white high pressure mercury light HPL and with yellowish high pressure sodium light. Raynham [8].

Since the introduction of the low pressure sodium lamp in 1932, many roads and streets in the world are lit with yellowish, low or high pressure sodium lamps. The contribution of colour to face recognition is neglectable with these lamps with a low colour-rendering index between 0 and 25. White metal halide light sources with a long lifetime and high efficiency and colour rendering around 80, are only just a few years available for road lighting. White LED light sources with high efficiency will rapidly become available. An investigation of Raynham compares results of his own research with that of Caminada and van Bommel. That investigation shows that white light with a colour-rendering index of at least 40 substantially contributes to face recognition and therefore allows for lower lighting levels [8]. Figure 3 quantifies the differences in terms of required semi-cylindrical illuminance.

A British directive for road lighting in residential areas permits for this reason lower light levels if that lighting uses white light. An additional advantage is that peripheral or off-line vision improves with the use of white light that has a higher blue component than yellowish light. This is because of the larger sensitivity for blue (and green) light of the mainly peripheral located rods in the retina of our eyes [9]. This offers both for pedestrians in built-up areas and for car drivers on rural roads an extra safety advantage. “Natural” white light finally also gets a more positive subjective assessment of residents than yellowish sodium lighting [10].

Given the importance of the quantity of light in the context of sustainability, the concept of “visual ergonomics” as introduced in the seventies by Vos and Padmos is today very relevant [7]. Visual ergonomics in its simplest form means that one should look for alternatives to enhance the visibility of visual tasks other than by “more light” only. There are for example traffic situations that are so complicated and confusing that a lot of light is needed to enable the driving task. Of course, a better alternative than “more light” is to simplify the complexity the driver has to deal with. Dynamic road markings (e.g. LEDs built into the road surface) to visually simplify complex situations without (extra) road lighting, is another example of applying the visual ergonomics concept.

WHERE LIGHTING

It is not the lighting expert who should determine in which areas road lighting should be present. That is a decision where politicians should play a decisive role on the basis of arguments such as cost-benefits, importance of crime prevention, importance of promotion and importance of giving identity to an area. If chosen for lighting the lighting designer is responsible where the light in the space should be. We discussed already about luminance of the road surface and thus horizontal illuminance, semi-cylindrical illuminance on face height or half-spherical illumination at ground level. It seems important that the lighting has a three-dimensional component. Here, a statement of the Dutch lighting expert Joh. Jansen in 1956 published in International Lighting Review is especially today relevant [11]:

”*A city street with dense motorized and pedestrian traffic is not much else than an elongated room. Just as in a factory hall, that street will have to receive light as to enable people to see quickly and distinctly what is happening. This no longer has anything to do with the classic luminance contrast between vehicle and bright road surface”*

The fact that the three dimensional component is important also means that extra attention is needed to avoid light in directions where it can disturbing. The direction of view of a car driver is usually downwards but a pedestrian also looks above the horizon in order to orientate himself. It is therefore not surprising that different glare systems exist for car drivers (TI) and for pedestrians ($I.A^{0,5}$). With the introduction of new compact light sources for road lighting including LEDs, it is important to note that during the development of both glare concepts, compact light sources for road lighting did not yet exist. Improved glare restriction concepts for both car drivers and pedestrians, preferably based on a same basic concept, are needed now.

Light that directly or indirectly brightens the sky and/or buildings can rightly be called light pollution. International guidelines for limiting light pollution do exist and should be followed. Restriction of light pollution may automatically improve the overall efficiency of a lighting installation because light spillage outside the area to be lit is avoided. The restriction of obtrusive light or light pollution in fact is very much a sustainability issue.

WHEN LIGHTING

The circumstances that determine whether or not lighting is needed change continuously during the dark hours. Road lighting should therefore automatically adapt itself to those circumstances. Measuring devices for circumstances like weather, traffic density, composition of traffic, traffic flow are readily available today and can be easily applied. Intelligent lighting driven by these sensors can significantly contribute to costs and energy savings. LEDs that simple can be regulated between 0 and 100% light output will accelerate putting these intelligent systems into use. In draft CIE Publication Nr. 115 (2nd edition) socalled weighting factors are defined that indicate under which circumstances road lighting levels can be reduced with one or more classes. Table 1 shows the main table from that draft publication.

On the basis of data of the total road lighting park in all European cities we come to the conclusion that general application of this system in all European cities would save some 14 TerraWatthour per year. This is the equivalent of 7 medium electricity power stations (each of 2 TWhr/year). If in this table also the earlier-mentioned advantage of white light would be built in as a weighing factor, the saving still further increases.

Table 1 Parameters and weighing factors for the selection of lighting classes for lighting in residential areas (draft CIE Publication 115 [CIE, 12].

Parameter	**Options**	**Weighting Factor**
Speed	Low	1
	Very low (walking speed)	0
Traffic volume	Very high	1
	High	0.5
	Moderate	0
	Low	-0.5
	Very low	-1
Traffic composition	Pedestrians, cyclists and motorized traffic	1
	Pedestrians and motorized traffic	0.5
	Pedestrians and cyclists only	0.5
	Pedestrians only	0
	Cyclists only	0
Parked vehicles	Present	0.5
	Not present	0
Ambient luminance	Very high	1
	High	0.5
	Moderate	0
	Low	-0.5
	Very low	-1

CONCLUSION

Given the increasing use of advanced automotive lighting and driver assistance systems in the coming years we will see a shift in the role of road lighting from visibility of objects to traffic guidance, traffic flow and personal security. The three-dimensional component of road lighting will therefore become more important. Concepts for this have been proposed but should internationally be standardized. Neurological investigations into the possible impact of road lighting to reduce nighttime micro sleeps of drivers have just been started but could also play a role in the definition of road lighting quality parameters. Application of the concept of visual ergonomics can lead to important savings in lighting, energy, light pollution and costs. General application of intelligent, adaptive automatic road lighting installations provides major savings. New, compact light sources including LEDs will play an essential role in all of this. New measures for glare restriction are required when applying these modern compact light sources. Restriction of light pollution is important to limit annoyance and to keep the skies dark for astronomers but probably even more important: it is a sustainability issue.

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HYBRID LIGHTING SYSTEMS

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ABSTRACT

This paper reviews developments in hybrid light guidance systems. In these daylight and electric light are simultaneously delivered into a building where they are combined and distributed via luminaires. The technology used in hybrid systems, both conceptual and realised, is discussed. The paper speculates as to their likely performance in terms of daylight delivery; capital and running costs; user reaction to the systems; potential impact of the systems on the building which they light; and suitable design methods.

1 INTRODUCTION

In vernacular architecture elements evolved to reflect, re-direct or control daylight. Conventional glazed windows can provide daylight some five metres into a building. But since daylight levels decrease asymptotically with distance from the window, a disproportionate amount of daylight and associated heat gain must be introduced into the front of a room to provide small amounts of daylight at the rear. Attempts to direct daylight to areas remote from the building envelope using techniques such as atriums and skylights are limited in effectiveness by contemporary technology. Over the last twenty years or so, a number of highly efficient reflective and refractive materials have been developed making possible what has become known as ‘light guidance’. Light from both daylight and electric sources may be guided. The main type of guided daylight is known as Tubular Daylight Guidance Systems (TDGS). This introduces daylight deep into electrically lit buildings, although current practice is to use the electric and daylight systems separately with minimal interaction (see Table 1).

Table1 Approaches to delivery of daylight and electric light

	Tubular daylight guidance	**Integrated lighting**	**Hybrid lighting**
Daylight sources	Skylight and sunlight	Skylight and sunlight	Sunlight
Daylight delivery	Tubular daylight guidance	Conventional glazing, beam daylighting or tubular daylight guidance	Tubular daylight guidance
Electric lighting	Conventional luminaires at point of use	Electric light may be guided as supplement to daylight.	Electric light may be guided.
Method of use	Separate daylight and electric lighting	Uses daylight as main source automatically supplemented by electric light as required.	
Control system	Usually no daylight linking	Fully daylight linked	
Output device	Separate daylight output devices and electric luminaires	Separate output devices for daylight and electric light. Electric lighting may be ‘intelligent’.	One output device is used for both lighting sources.
Quality of delivered light	Optical control of daylight by diffuser and electric light by luminaire. Source colour differences apparent	Optical control of daylight depends on particular system. Electric light control by luminaire. Source colour differences apparent	Optical control of all light by luminaire. Single source colour.

Attempts to better combine the delivery of daylight and electric light to the same space use two main approaches - ‘integrated lighting’ and ‘hybrid lighting’. Their main characteristics are summarised in Table 1. This paper reviews developments leading towards the hybrid concept and describes a number of systems, realised or otherwise. It speculates about likely issues of system performance, costs, user response, building relationship and design methods.

2 SYSTEM DESCRIPTIONS

Unless otherwise stated the performance and other data quoted in this section is from the sources cited.

2.1 Daylight guidance

Although TDGS is the only form of guidance having wide commercial application, a number of other types, notable because their technology has been adapted for use in integrated and hybrid systems, are also reviewed in this section.

2.1.1 TGDS

TDGS are cheap, simple passive devices effective under both clear and overcast skies. Their main application is in single storey buildings. Light transport is usually via a rigid tubular guide lined with a highly reflective material. A clear polycarbonate domed collector at the upper end may be horizontal or inclined at some angle to the guide axis. A diffuser at the lower end distributes light within the building. CIE Report 173 discusses system characteristics and selection and sets out standard photometry and design/analysis methods (1). Using these it is possible to estimate likely flux outputs, system efficiencies and daylight distributions of TDGS under a variety of sky conditions. The CIE Report puts forward the Daylight Penetration Factor (DPF) to quantify daylight penetration via light guidance devices. This is analogous to the Daylight Factor (DF) used for conventional glazing. Whilst DF is the illuminance received at a point indoors expressed as a percentage of the exterior skylight illuminance, the DPF is the illuminance received at a point indoors via a light guide expressed as a percentage of the global exterior illuminance. Area weighted average values of each may be calculated (ADPF or ADF respectively). Combination of the two quantities (ADPF+ADF) enables a quantitative assessment of the total daylight contribution from the various daylight providers.

Post-occupancy evaluation studies of TDGS in offices suggest that although TDGS devices are recognised as daylight providers, current design practice produces ADPF+ADF of the order of 1% on the working plane. This was not considered by users to produce a well day-lit interior, a result that led to the suggestion that a design criterion nearer 2% may be required. (2). A long term cost study showed that TDGS provided poor economic return when viewed solely in cost terms but that this needs to be balanced by consideration of the value of the daylight delivered into a working area (3).

2.1.2 Façade mounted systems

These consist of a façade mounted light gathering device oriented toward the equator, a horizontal guide system within a suspended ceiling, and output devices located deep in a building. They are used in conjunction with conventional lower windows and electric lighting systems. The light collector is a curved mirror or other device which deflects daylight into a mirrored guide. This technology is intended for office buildings but only a few systems appear to have advanced beyond the prototype stage. Courret et al. report the design, simulation and full scale testing of an ‘anidolic ceiling’ - a rectangular cross section horizontal duct using anidolic optics at each end to collect and distribute light from a predominantly overcast sky (4). Validation of the device by both simulation and measurement under overcast skies established that DF on the working plane was enhanced at the rear of a room, some 4% at depths of between 3m and 6m into the room, or approximately 1.7 times the un-enhanced value. A value of 32% efficiency for the whole system is quoted.

Façade mounted systems have been used in tropical latitudes. A proposal for an office in Kuala Lumpur uses fixed laser cut panels to deflect high angle sunlight axially into a polished aluminium duct and extractor laser cut panels inside the duct to redirect light into the room. Studies indicated that daylight levels of between 200 and 300 lux would be achieved on the working plane some 6m from the façade during working hours (5).

2.1.3 Active guidance systems

The Himawari system, developed in Japan, collects and concentrates sunlight using tracking fresnel lenses. Light may be transported up to 200m by optical fibres, and distributed using a range of custom made luminaire-like devices. For example a 15m long cable each of six fibres would deliver 1630 lumens from 98000 lux of direct sunlight on the collector (6). A major advantage of fibre optic transport is illustrated by the fact that some Himawari systems have been retrofitted to existing buildings. They have a large capital cost which is unlikely to be justified for other than specialist applications.

2.2 Integrated lighting systems (ILS)
'Integrated lighting' is a generic name for systems which deliver daylight and electric light separately but which are equipped with control that maximises use of available daylight. There are two main approaches.

2.2.1 Integrated Skylight Luminaire (ISL)
The ISL combines in one unit a skylight with a sunlight control device, an electric lighting system, and a photosensor control system to automatically dim the electric output. It delivers daylight via 1.2mx1.2m double-glazed clear roof-lights that capture both sunlight and skylight(7). This is supplemented by twelve T8 fluorescent lamps. The two light sources are linked by photosensor and luminaire controllers which automatically reduce the electric light outputs when sufficient daylight is available. A 1.2m-high daylight diffuser box is mounted below the roof-lights and distributes the sunlight via white acrylic diffusing panels.

2.2.2 Intelligent lighting systems
In essence these are an electric lighting system with enhanced controls which seek the maximum benefit from any source of daylight – guided or otherwise. A number of manufacturers market systems of this nature, some of which are based on 'open' communication protocols such as digital addressable lighting interface (DALI). All are integrated into an appropriate building management system. Luminaires are equipped with, variously, integrated network controls, occupancy sensors, personal dimming or daylight dimming. Depending on the individual circumstances of use, the combination of features listed above can yield substantial energy savings. For example a field study of a deep plan office building having luminaires with occupancy sensors, daylight linking and individual dimming control saved 69% compared to a conventional lighting system. Electric lighting substitution by daylight accounted for 20% of this total (8).

2.3 Hybrid lighting systems (HLS)
In the systems described so far light is delivered using separate output components whose optical properties may differ substantially. In 'hybrid lighting' daylight is combined with electric light prior to delivery. Optical control is more akin to that of an electric luminaire and the two sources may not appear as distinct. Table 2 summarises some features of HLS. It also includes the authors' estimates of system efficiencies for one and two storey applications. These are based on cited information on size and efficiency of individual components. Approximate flux outputs for output devices are based on the estimated one storey system efficiency and cited values of external illuminance.

2.3.1 Enhanced tubular daylight guidance
The first developments in HLS lighting were enhancements to TDGS. These use heliostats and combine electric and natural light within the guide rather than at point of use. The Arthelio study developed systems combining daylight and electric light from sulphur lamps, and culminated in the construction of two large installations – one of which was in a single storey warehouse in Milan (9) (15). This uses a single axis light capture head based on a Fresnel lens. The sunlight is then reflected via an anidolic mirror into a 13m-long, 90cm diameter circular guide lined with prismatic material. A diffuser unit located at the end of the guide delivers daylight illuminance varying between 100 and 400 lux to the working plane. This is supplemented from two two horizontal prismatic guides powered by dimmable sulphur lamps which top up or replaces the daylight as necessary.

2.3.2 Hybrid Solar Lighting (HSL)
This was developed by Oak Ridge National Laboratory for public buildings in areas of the USA where direct solar radiation is greater than 4 kWh/m^2/day and cooling is a major design concern(10). The sunlight collector is a primary 1.22m-diameter parabolic acrylic sun-tracking mirror with an elliptical secondary mirror. The latter separates the visible and infrared portions of sunlight and focuses the visible sunlight into a bundle of 127No 3mm diameter optical fibres used for transport. The optical fibre system delivers the sunlight to the end of a side emitting acrylic rod located inside a conventional 1.2m x 0.6m electric luminaire also equipped with dimmable fluorescent lamps. A control system tracks the sun; light sensors monitor daylight levels; and electronic dimming ballasts regulate the electric light

output to a pre-determined level. System losses are of the order of 50% for single-story application with an additional 15-20% for a second storey (11). One collector can power 8 to 12 fluorescent, or 30 to 40 reflector luminaires, so lighting an area of about 100m^2, and displaces about 1 kW of electrical lighting load. On a sunny day one HSL system is reported to deliver 50klm per group of luminaires.

Table 2 Hybrid system summary

Name	**Light collection method**	**Light transport method**	**Daylight output device**	**Electric sources and location**	**Daylight system efficiency at (i) 4m (ii) 8m** *(see Note 1)*	**Approx. device output (*External illuminance*)** *(see Note 1)*
Arthelio	Heliostat	Hollow light guide	Side emitting prismatic guide	Sulphur lamp in horizontal light guide	8% for 20m guide: under overcast sky 50% under direct sun	a) not measured b) 25000 lumens *(15000 lux)*
HSL	Parabolic mirror heliostat	Optical Fibres	a) Side emitting acrylic rod b) End emitting rod	a) T5 tubes in luminaire b) incandescent in luminaire	(i)50% (ii) 30%	6250 – 4170 lm *(100000 lux)*
UFO	Fresnel lens heliostat	Liquid light guide & Optical Fibre	Luminaire with acrylic diffuser	HID remote & T5 in luminaire	(i) not measured (ii)3.4%	3000 lm *(100000 lux)*
SCIS	Multiple mirrors & lenses system	Prismatic Guidance	Prismatic guide with diffusing extractor	T5 Fluorescent tubes in guide	(i) 25% (ii) 25%	25000 lm *(Not stated)*
Parans	Mini Fresnel lenses Heliostat	Optical Fibres	Diffusing luminaire with end emitting optical fibres	T5 or compact fluorescent lamps in luminaire	(i)40% (ii) 30%	7500 - 10000 lm *(75000 lux)*

2.3.3 Universal Fibre Optics (UFO)

Sunlight is collected by a roof mounted heliostat with a 1m-diameter Fresnel lens and delivered to luminaires via 10m-long 20mm-diameter liquid light guides(12). In addition light from two 150W metal halide lamps, located adjacent to the heliostat, is delivered to the luminaire via plastic fibre optic cables. The luminaires contain a coupling system linking both liquid and optical fibre guides to the edge of a 20mm thick ‘Prismex’ panel and delivers an even brightness across its emitting surface. The luminaire also has two T5 fluorescent lamps located along the edge of the emitter. The system is photocell controlled such that when daylight fails the luminaire switches to light from the metal halide lamps. A prototype, installed in Athens, had a flux output of 3060lm for a normal illuminance on the collector of 90029 lux and using 10m-long guide. The overall efficiency of the daylight system was around 3.4%, a low value presumably caused by the large number of components and optical couplings, and the inefficiency of the side emitting diffuser.

2.3.4 Solar Canopy Illumination System (SCIS)

This facade mounted system collects sunlight using an Adaptive Battery Array (ABA) - a grid of thin 16cm square mirrors located inside a weather-proof enclosure with a transparent front window (13). The façade unit is 3m wide x 1.2m high and is connected to a 1m high duct which extends some 9m into a building. The orientation of the mirrors changes with sun position and the light is concentrated and redirected by lenses and mirrors into the rectangular cross section ‘dual function prism light guide’. Electric light is from fluorescent T5 lamps located inside the guide. The guide inner surfaces are lined with multilayer optical film (MOF) which has high reflectance at all angles, and optical lighting film (OLF) which reflects light preferentially. Sunlight travels along the guide using total internal reflection within the MOF until hits an extractor material made of OLF.

HSL collector

HSL luminaire

UFO collector

UFO luminaire

SCIS

Parans collector

This diffusely reflects the light and the portion that no longer meets the angular conditions for total internal reflection exits the guide via the bottom surface. The control system uses DALI controlled ballasts, in addition to light sensors, to maintain the desired interior illumination level. A prototype at the British Columbia Institute of Technology shows that about 25% of flux incident on the mirror array arrives on the workplane extending 9m from the façade.

2.3.5 Fibre Optic Solar Lighting System (Parans)

The system, developed commercially by Parans Solar, uses roof or façade mounted $1m^2$ modular solar panels containing 64 No Fresnel lenses (14). Each lens is able to track and concentrate sunlight into a 0.75mm diameter optical fibre. Sixteen fibres are combined into a cable each of maximum length 20m. The tracking is controlled by a microprocessor which is continually fed information from a photo-sensor which scans the sky to detect sun path. The system learns and remembers the sun path at any location and thus can be moved without pre-programming. The system has five luminaire types, three of which are hybrid luminaires equipped with fluorescent lamps which dim automatically depending on sunlight conditions. Manufacturer's data for an installation with 10m optical cable and direct solar illuminance of 75klux quotes a luminaire flux output of 7500lm and 10000lm for a 4m cable. This corresponds to a system efficiency of around 30% and 40% respectively. The system has optimum collecting hours when the solar panel is within an angle of 120 degrees of the sun.

3 EVALUATION AND DISCUSSION

The above suggests that the success or otherwise of systems is related to both the nature of the technology and to the interaction of the lighting with the building. This section addresses these issues.

3.1 Light delivery

Table 2 summarises some aspects of HLS performance. Quantity of daylight delivered depends on system type, its method of use and the solar resource. Overall system efficiency is a function of the individual optical elements used and the optical processes linking them. The UFO system, which has a notably low overall efficiency, consists of two separate guidance systems for daylight and electric light, each with two optical couplings. The diffusing output device alone accounts for 25% of total losses. By comparison the HSL, which is some 20 times more efficient, has only one light guide and light output devices for both sources contained within a mirrored luminaire. Thus simplicity appears to be a virtue in system configuration. As in any lighting system the location of the hybrid output devices has a major bearing on light delivery. For working areas where good distribution of light is important, those systems having a number of discrete output devices (e.g. HSL) or large area sources (e.g. SCIS) are likely to perform better than those having large linear sources such as Arthelio. HSL and UFO use modified off-the-shelf luminaires as output devices but Parans uses a specially constructed hybrid luminaire. All have light outputs of the order of 3000- 6000 lumens – comparable to that of electric luminaires used in offices - given optimal sunlight conditions. These are all greater than those of measured discrete TDGS output devices set out in Reference 2 because, firstly, TDGS are usually smaller (typically 300 mm diameter or 600 mm square) and, secondly, the TDGS outputs quoted were largely for overcast conditions.

There are a number of concerns relating to the delivery of electric light via hybrid systems. The first is the sub-optimal optical processes within the luminaires - the optics necessary for electric sources need modification to accommodate the daylight emitters and vice versa. A second concern relates to electric lighting control. In Western Europe for example, where cloudy skies predominate, daylight illuminance may fluctuate throughout the day, placing unusual demands on the control system and potentially affecting lamp life.

The quality of light from hybrid devices, notably HSL and Parans equipped with luminaire optics is superior to that of the basic diffusers used in TDGS. Also the proximity of electric and daylight sources within the luminaire may mask gross differences in colour appearance. To extend this idea there is potential for the use of colour changing electric sources in hybrid devices to mimic changes in daylight colour, although this has not yet been realised.

TDGS have been demonstrated to work in both sunny and cloudy latitudes,but it is not evident that systems based on sun tracking will consistently deliver adequate amounts of light in, say, Northern Europe. The author measured approximate luminaire flux output on a Parans system in Southern England having a south facing collector mounted at 30^0 to vertical, and with a 20m cable. Luminaire output was 15000 lumens for direct sun (98000 lux normal to the collector), but only 50 lumens for a cloudy sky(10000 lux).

Some idea of the utility of the various systems may be gained by attempting to use each in turn for a nominally similar arbitrary task – to provide 2% ADPF+ADF across the workplane of a 12 x 12 x 3 m windowless space. Clear sky and sun were assumed and to ensure uniform illuminance discrete output devices were at 1:1 spacing to height ratio. The system configurations would be as follows:

Using daylight guidance technology:

- Sixteen 250mm-diameter TDGS each comprising collector, guide and output device.

Using HLS:

- One HSL system comprising one collector and 16 luminaires.
- Sixteen UFO systems each comprising a collector and a luminaire.

- Three Solar Canopies are enough to provide ADF of 3%, but four systems are required to provide a reasonably uniform illuminance level.
- Fibre optic solar lighting system (Parans) comprising four solar panels and 16 luminaires.
- One Arthelio system comprising one collector and two guides will provide ADF of 2.8% Using electric lighting only:

16 triple F14W/T5 fluorescent luminaires would give an equivalent illuminance.

It is clear that although the numbers of discrete luminaires/output devices are similar for many of the specifications, the number of collectors and guides differ markedly. Thus a wide range of equipment may be used to give a nominally similar result.

3.2 Cost and value

Whole life cost calculations for a lighting system include both initial and running costs. Costs may be offset by savings including reductions in electricity consumption by daylight substitution, reduction in cooling loads, and reduction in electric lighting maintenance costs. An indirect financial benefit may be the value of improvement in well-being and productivity of occupants due to daylight, although this is difficult to quantify. There is some published information on capital cost of HLS systems but there is little accumulated experience of running costs so attempts to compare system costs need to be treated with caution.

It is evident that capital costs of HLS systems are generally more expensive than electric lighting, but comparable to TDGS for two storeys or above. Before conclusions can be drawn about long term costs, the issue of running costs must be addressed. Electric lighting is dominant both visually and economically in the majority of buildings that have been equipped with daylight guidance to date, given that electricity is the major running cost. TDGS long term costs only compare with an electric-only alternative only if a series of favourable assumptions about future energy costs and system configurations are made (3). The suspicion must be that hybrid systems also will provide a poor economic return when viewed solely in cost terms. Cost needs to be balanced by value – principally the benefits of delivered daylight. This suggests that the configuration of a HLS system, notably its ability to provide a ‘day-lit space’, will have a marked impact on long term cost and benefit.

3.3 Relationship with building

The main external architectural concerns relate to collecting devices. Mirrors and lens arrays located on roofs may be visually intrusive and limit other roof uses. They may be large items – for example the Arthelio mirror is 2.5m diameter - and require protection by additional construction. Façade mounted systems may occupy considerable areas of the building envelope and present problems of appearance and integration. Furthermore systems such as SCIS require at least extra storey height and, potentially, almost dictate that the whole building be designed around them.

Internally all systems require vertical and/or horizontal paths for guides. Those delivering daylight via flexible optical fibre cables require little more space provision than electrical or communications cables and have few implications for interior spatial layout. At the other extreme, enhanced daylight guidance and SCIS require dedicated ducts, through or over several storeys occupying rentable floor area and restricting internal spatial flexibility.

Roof mounted heliostats may require additional structural work to account for wind and dead loads but these are of the same orders of magnitude as equipment such as cooling towers. Façade mounted collectors are structurally similar to cladding. Light transport and distribution elements present no more structural problems than, respectively, ventilation ductwork or luminaires.

The main unique concern of HLS components is fire resistance and to prevention of passage of smoke in both vertical and horizontal transport components. HLS based on light guides may pass through fire compartment enclosures and a range of measures including fire protected ducts, fire dampers and fire-resisting cladding may be required. Façade mounted systems will generally be within one compartment.

3.4 Human response

The literature contains nothing specifically on human reaction to HLS. Human response to TDGS gives some clues about attitudes to daylight delivered via guides or via devices similar to conventional luminaires. Evaluation of the Arthelio installation indicated a general preference for daylight; that detection of changes in exterior conditions was possible; and that it provided bright, glare free light in which the daylight contribution was discerned by its colour properties (15). User reaction in offices equipped with TDGS and a separate electric system, and some also with windows have been studied. In these the electric lighting was dominant with the guide output making only a modest contribution to task illuminance (the equivalent of 1% ADPF+ADF) (16). TDGS were considered inferior to windows in delivery of most aspects of daylight quality (notably light distribution and external communication) although satisfaction improved with increased ADPF+ADF.

Iit is possible, therefore, to speculate in general terms about likely human response to HLS systems and some desirable design features. The quantity of daylight delivered needs to be high enough to convince users that it is indeed daylight; the evidence suggesting that an ADPF+ADF in excess of 2% is required for TDGS. Spatial and diurnal illuminance variation, one of the unique properties of daylight, must be accommodated. Clearly façade based systems such as SICS have an advantage in trying to create the appearance of a ‘day-lit space’. There is a danger that automatic illuminance ‘top-up’ will create a uniformly lit space that users will perceive as dominated by electric lighting no matter how much daylight is being delivered. Similarly the perception of diurnal variation apparently requires a user view of a daylight device which is capable of mimicking external illuminance.

The nature of the output devices is important. It is clear that colour is important in user recognition of daylight and thus the proportions of daylight should be such that it is not swamped by the electric component. There is a danger that daylight from ‘luminaire-like’ devices will be considered as electric light so there is a case for making hybrid luminaires distinct from wholly electric luminaires.

3.5 Design methods

Standardised methods of design calculation, data production and exchange are universal in the lighting industry. Electric and daylight codes set out recommendations for, variously, equipment, illuminance levels and surface properties. Recent work extends this guidance to TDGS (1). Currently no independent design information exists for HLS to date and manufacturers’ websites are the main source, usually offering little more than output device spacing and installation advice. They appear to be based on optimal conditions of the most favourable possible system configuration and assumed daylight resource. Also different methods are used to describe system performance meaning that evaluation of alternatives is difficult. Although most HLS have their origins in academic research, a generic research effort based on accumulated experience of their use has not had time to materialise. A similar exercise for TDGS produced design guidance and norms, and it is to be hoped that this process will be repeated for HLS.

4 CONCLUSION

Daylight guidance has been one of the major areas of innovation in interior lighting in recent years and HLS is the latest expression of the technology. The innovative nature of HLS means that there are currently only two commercially available systems. As a result there is little accumulated experience of their use. It is likely that the lessons learned from feedback from TDGS installations in respect of design criteria, integration with other lighting systems and the building fabric and economics may be relevant to HLS.

The advocates of daylight guidance advance two main arguments for its use – firstly that they deliver daylight deep into interiors and, secondly, that in doing so energy may be saved by electric light substitution. The evidence to date is that some HLS can under favourable circumstances deliver large quantities of daylight, possibly sufficient to create a ‘well day-lit space’ as defined by ADF criteria. The light is delivered via luminaires. The evidence from studies of TDGS suggests that under some circumstances light coming out of a guide via a luminaire-like device will not be perceived as ‘daylight’, particularly in the absence of the other components of daylight notably contact with the exterior. In other respects HLS can potentially deliver better quality lighting than TDGS since the luminaires used have better light control and the possibility exists of colour matching of the dual sources.

HLS represents an advance over TDGS on a number of fronts. They offer the opportunity to transport light deeper into buildings and pose less practical problems, notably in terms of fire precautions. The use of a single output device offers seamless integration of electric and daylight. However this process requires sub-optimal solutions. For example the optics necessary for electric sources may need modification to accommodate the daylight emitters and vice versa. It is arguable that an integrated lighting system with separate output devices may perform better. Most of the HLS have been developed for sunlight sources but are now being marketed in locations where other sky types predominate. The same sequence of events occurred with TDGS and the full implications, in terms of requirements in other locations, have yet to be appreciated. The economics of HLS have yet to be explored. On the limited published evidence they represent substantially greater capital cost than TDGS. The latter have been shown to economic over the long term only if favourable assumptions are made regarding energy costs and the same must apply to HLS.

HLS offers an exciting possibility for lighting practitioners but much work is required to realise this. This includes – study of human response to HLS and development of suitable design criteria; development of design methods; feasibility of use of the various types of daylight guidance in different geographic areas; and the long term economics of such systems.

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The author is grateful to Mr M S Mahoub for his help with this paper.

POINT OF VIEW: QUALITY IN LIGHTING EDUCATION

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ABSTRACT

The professional certification in lighting is a recent action of CNRI (Romanian National Lighting Committee), based on the fact that a general curricula don’t generate automatically an acceptable qualification. This research relies on the methodology of development of the national superior education qualification (a project of the national agency –ACPART). According to the EC, this activity has already reached the frontiers of knowledge. The presented approach is even more ambitious, as it anticipates some of the demands of the national qualification background for superior education (in progress). The originality of this paper resides in the fact that it is in search of an instrument of objective evaluation of lighting specialists. The elaboration of the National Register of the Superior Education Qualifications (CNCIS) requires a long-term effort, which is ACPART’s mission. What is required is a methodology of competences assessment at the end of each of the education stages: licence and master. This is the area where the assessment will reach a new level, by looking for an approach, which makes the difference between the classic evaluation, and the pragmatic evaluation of the employer, on the other. Until then, this is the CNRI mission, in connection with professional association of electrical engineers (SIEAR). To demonstrate the tradition in lighting education at Technical University “Gh.Asachi” of Iaşi, a short history is presented, until these days.

1 INTRODUCTION

Starting from the premise that continuous studying and formation has become a necessity in Europe, that the barriers among countries not only prevent the access to educational and vocational formation, but also restrict the efficient use of knowledge and competences already possessed by individuals, the boards from the field of European educational policies asked for the elaboration and implementation of a **European Qualifications Background** [1], seen as some sort of meta-frame, the main goal of which is to consolidate the links between the staffs on a national and sector level, to facilitate and promote the transparency, the transfer and the acknowledgement of qualifications and competences on an European level. One of the directions of the European Commission’s policies is the re-formation of superior education institutions, so that they become more flexible, more coherent and more open-minded to the needs of the society, and thus capable to answer to the challenge of globalisation and to the needs of formation and re-formation of the European workforce. The reforms on this level should prepare universities to assume their role in a Europe of knowledge and to bring a more firm contribution to the attaining of the goals established by the European Commission through the Lisbon Strategy.

2 COMPETENCE ASSESSMENT IN LIGHTING

By taking into account the peculiarities found on an European level, the Commission suggests that the following transformations would represent the way to the success [2]:

- the breaking of the geographical and intersectorial borders that separate the European universities;
- the guarantee of the real autonomy and responsibility of each university;
- the development of partnership among universities, the business community, financial and local communities spokesmen;
- the guarantee of the demanded competences on the work market;
- the reduction of financial deficits and the finding of a way to make more efficient the activities in
- the fields of education and research;
- the augmentation of the number of programs of inter-disciplinary and trans-disciplinary studies;
- the reward of the highest level of excellence;
- the increase of transparency and attractiveness of the European Superior Education field.

The development of the Frame for Qualification in the Field of Superior Education (CNCIS) provides answers for a European need of access and progress in a university career, but regarding also the mobility of students and graduates. At the same time, it expresses a new perspective, more concentrated on the students, in agreement with the present international context. As a conclusion, in order to become a reliable mechanism of internal and external regulation in the field of superior education, this complex system, the CNCIS, should be intelligible for all the interested groups. To the external arguments, stated on an European level, one can also add those which can be identified on a national level, like: the absence of a coherent structure of organising and classifying the qualifications, a system of university formation that is rather narrow-minded as reported to the financial and social environment, as well as a weak balance between the demand and offer of education and formation.

All the stated arguments show the necessity of developing of the CNCIS and of assuming of responsibilities by the institutions involved in making decisions in the field of Educational Policy, these institutions being directly interested by the principles and mechanisms of development and implementation of CNCIS, and also by the effects that the CNCIS generates on a national and European level. A common point of view on the initial approach and further development of the CNCIS is essential. One of the expected results of the process of realisation of the CNCIS is the use of qualifications, expressed in terms of results of studying. Two fundamental elements for the attaining of this objective are the active participation of all the relevant and interested categories, as well as their desire to take active part in the subsequent process of the curricular re-formation. The qualifications description is realised by the competences, because these are the main criteria for the employer. But CNCIS is to general and no details about lighting competences are indicated, until now. This is the perspective that assessment must be reconsidered.

3 THE STRATEGIC ACTOR: ACPART

As a national authority in the field, The National Agency for the Qualifications in the Field of Superior Education and Partnership with the Financial and Social Environment (ACPART) organises the frame of qualifications in partnership with the educational institutions and with the financial and social partners [3], by:

- the elaboration, implementation, updating and monitoring of the CNCIS, which will permit a broader acknowledgement of the results of the study, expressed in terms of *knowledge, abilities and competences*;
- the guarantee of the transparency of the CNCIS on a national and international level;

We can go even further, as we anticipate certain needs that will only arise after the creation of the National Board for Qualifications in the field of Superior Knowledge. This is the bench-mark that defines this exploratory research, the goal of which is to solve complex problems that can only be looked at from an inter-disciplinary point of view (the field of engineering and the educational sciences). The originality resides in the fact that we are in **search of an instrument of objective assessment**. This demand may seem rather far from realisation, mostly because the establishing of the National Register of Qualifications in the field of Superior Education in Lighting requires a long-term and sustained effort. But the procedure of university qualification validation (ACPART, annex 5, sheet 7: The Qualification Referential) already mentions that, besides the qualification curriculum and the inter-disciplinary sheet, the methodology of evaluation of competences and knowledge are also imperative to be specified at the end of the studies.

4 The APPLIED UNITS OF COMPETENCE

This is the area where we intend to revolutionize the assessment, by looking for an approach which makes the difference between the classic evaluation, influenced by all *the tolerated deviances* [4], on one hand, and the pragmatic assessment of the employer, on the other. This new vision, which comes in contradiction to the traditional point of view that “teachers know how to evaluate the best”, will draw the universities nearer to the business area and to the employers, a priority that can be this way fulfilled. The regulation of such an evaluation instrument is extremely difficult to realise, mostly because of the negative reactions of both teachers and students. One of the assessment instruments of **applied units of competence** will allow a more thorough knowledge of the truth regarding the results of learning [5]. This aspect is important on an individual level (*How competent have I become?*), but also from the point of view of the organisations whom are either preparing, or looking for specialists. As for the European opening of this instrument, it will allow us to have a broader view on the competence phenomenon on a European scale. What can be more motivating for a graduate than to be able to compare him with specialists all over the world?

If the role of the traditional subjective evaluation decreases, man will become a competitor willing to self-surpass himself. This is how this paper intends to bring a qualitative chance, the student being thus able to place himself on a multi-annual, European even, scale of competences he has gained. This way, the educator’s value will increase too, because he will be seen as the main generator of plus-value for society. The traditional teacher-student relationship will become a real co-operation for every student to achieve competences in accord with his own professional development. As soon as the objective evaluation instrument will be regulated at a quota imposed by the employer, the relationship between the universities and the business climate will change considerably. The employers will give up the stereotypical phrase: *"Give me graduates so that I prepare them for the job I need"*. The universities will be able to enter periodical evaluation mechanisms of continuous learning, being thus able to certificate the progresses of the individuals engaged in formal or informal learning processes.

The main goal is the creation of such an evaluation instrument depart form the applied units of competence, on different types of jobs. A process of re-formation of the curriculum can already be noticed nowadays. The goal of this research is to create for each applied unit of competence a set of procedures to test the attained level. Of course, this means a different assessment, more detailed, of the knowledge obtained so far [6]. What is more important is that this instrument needs time to become credible, because it is necessary not only to create and validate the evaluation instrument (which will function on the basis of problems and situations simulation in a specific evaluation software), but also to organise a system of description of the competences not from the teachers' point of view, but from the point of view of the business specialists, who prove their competences on a daily basis. This is the most difficult approach, but at the same time it is the only one able to make this assessment instrument credible. By testing specialists already occupying different functions, the actual degree of the acquired competences will become clear.

5 THE ASSESMENT OF A FUZZY PROCESS

Both educators and students will be able to evaluate their performance in a detailed way and to give answers to questions like: *"Which is the degree of qualification of a specialist who wants to work in a certain field of activity, after graduating a university stage?"*

We want to measure something fuzzy. Competence is something witch belongs to the experienced specialists? No, it must be fixt this believes. Now, the professors but also the students will be able to measure the level of the competence after licence or master study, for a specific occupation and role.

The pioneer's work consists in the intervention in the purpose to improve the quality of the educational process in engineering. We have good information about different evaluation procedure at universities. We well know some procedures that impose a normal distribution (Gauss) for the results. But even there, the results are not good, because the financing system (based on number of students) impose the ignorance like a standard. It is sufficiently to be not the last, and the graduation is guarantied. We have a superficial evaluation system, time consuming, and with no resolution at all. In this point the proposed work will make the differences. The assessment will function based on PC network, and with special software. Based on this laboratory, each student will solve specialised problems to reveal the level of the competence (not only knowledge!).

It is important to emphasise this: it is a difference to evaluate knowledge and it is more difficult to describe and to evaluate competence!

After the hardware support, a huge database is necessary to be realised. This database will contain problems, learning objectives, algorithms and all that is necessary to generate in random way and off course with no human intervention, the specific tests.

6 THE METHODOLOGY

The assessment has to provide firstly an obligatory answer: *What measure unit shall we use?* The elitist approach of teachers would be depressive for every specialist, because it reflects the educators' bent towards perfection. In employers' world, the perspective is different and more pragmatic.

After the elaboration of specific methods of testing, evidently based on computer technique (simulation, modelling, problems analysis, evaluation tests), will follow the interpretation of the results that will be correlated with the perception of the business environment towards the meanings of competences. The key element will be time, the surveillance of the graduates after their free evolution in the profession.

It is through repeated testing that statistical and personal evolution will be revealed. The efficiency of reduced preparation cycles will be revealed through demonstration, while the personal development of certain individuals will be demonstrated as a measure of the competences acquired throughout one's life.

7 BRIEF HISTORY OF THE ELECTRIC LIGHTING IN THE UNIVERSITY OF ELECTRICAL ENGINEERING OF IAŞI

Through the efforts of the Professor Dragomir Hurmuzescu, the Industrial Electricity School was born in 1910 as part of the University of Iaşi, than transformed in Electrical Engineering Institute, being the first academic school in the electrical field from Romania Studying the Annual of the University of Iaşi [7] it can be seen that between 1913 – 1916, through the foreseen disciplines was „Industrial physics and accumulators. Electric traction and Lighting" who's titular was Lecturer eng. N. Patriciu.

Undertaking a soviet model, the Electrical Engineering University had in 1951-1955 a single specialization called "The electrification of the industry, agriculture and transportation". The curriculum foresaw in the forth year of study a course of "Electrical Lighting" that was doubled by a project with the theme "Interior electrical lighting of houses and institutions". From 1948, another course kept in the university was the one entitled "Electrical lamps and luminaries". For these both mentioned courses, the titular was Professor Vasile Prisăcaru, which was in that time a personality of the electrical engineering in general and of the electrical lighting in particular and that worth some words of evocation.

Professor Vasile Prisăcaru was born in 1913 and starting with his last year of academic studies he was appointed, at 1st January 1942, as a trustee in the polytechnic school. He received his Ph.D. in 1965, and starting with 1967 he was appointed full professor with the Department of Electrical Energy Utilizations and Automation. He thought in a wide and a various fan of courses, not only the ones of lighting that were the most beloved. He received the Education Ministry Award in 1962 for the paper entitled „Experimental considerations on the dynamic auto modulation phenomena in the modulator-type magnetic amplifiers". The article „Lamps power determination for the lighting panels with circular-disk shapes" published in the Romanian review Electrotehnica nr. 12/1959 was quoted in the Italian review L'Ellectrotecnica in February 1965 and in the volume „New achievements in the electric lighting" Technical Documentation Institute of Bucureşti in 1961. In 1966 he was appointed scientific doctoral coordinator in the discipline „Utilizations of Electrical Energy", fact that allowed to several former young Ph.D. students in the decades '70s and '80s to sustain their thesis having the guidance of Professor Vasile Prisăcaru and to become at their turn professors in the Gheorghe Asachi Technical University of Iaşi. The Ph.D. thesis on the lighting field coordinated by Professor Vasile Prisăcaru are:

1. Contributions to lighting calculation using the electronic computers, eng. O. Stavrescu, 1974
2. Considerations regarding the photometric calculation of the lighting installations using models, eng. Claudia Botez, 1979
3. Contributions regarding the architectural lighting of the historical monuments, author eng. Iosif Gulacsi, 1985 – with application to Sf. Nicolae Church from Brasov.

The professor's love for lighting have been manifested in various series of popularization lectures, but also in the several research contracts from that we mention: „DC supply of the emergency lighting in the electrical power stations" beneficiary ICEMENERG Bucureşti - 1969, „Public lighting optimization" beneficiary ICEMENERG Bucureşti – 1972, or „Lighting of the Bucureşti metro" ICSPM Bucureşti – 1976.

One of the followers of Professor Vasile Prisăcaru in the Faculty of Electrical Engineering of Iaşi was Professor Lorin Cantemir. He became in 1960 Vasile Prisăcaru assistant. The moment's priority was to assure a proper material support for the applications. After some consultations with expert colleagues from Cluj (Dan Comşa) and Timişoara (V. Vazdăuțeanu), a number of 12 works laboratory were conceived and realized. We can mention the followings:

- Demonstrative panels with different fluorescent tubes;
- Automatic installation for the emergency lighting connection;
- Determination of the potential gradient along with the positive column to the fluorescent lamps;
- The study of the materials for the electric lighting sources;
- Operating - diagram tracing for the fluorescent lamps in different montages;
- Curve-plotting of the lighting intensity distribution for different luminaries;

After years, Professor Lorin Cantemir led two theses in the electrical lighting field as Ph.D. mentor:

A. Study of electrical and photometrical parameters of fluorescent lamps by optimising power supply. author eng. Dan Ioachim, 1998

This thesis offered the possibility to apply and gain two Romanian patents, as follows: RO 77070/1981 entitled „Device for the power supply of the low-pressure fluorescent lamps", authors D. Ioachim, M. Diaconescu and D. Jemna, respectively RO 89843/1977 entitled „Starter for the ignition of the low-pressure fluorescent lamps", author D. Ioachim.

B. Contributions regarding the architectural lighting, author eng. Paul Chirilă, 2005

In that thesis, a new concept called „dynamic architectural lighting” was introduced and also was obtained the Romanian patent RO 120864/2007 entitled „Method and installation for dynamic architectural lighting”, authors: L.Cantemir and P.Chirilă.

After Professor Vasile Prisăcaru retired, the ones who teaches in 1975–1997 Electrical Lighting, were Professors Mircea Oprişor and Dan Ioachim. They edited the following manuals:

- Ioachim, M. Oprişor – Electric lighting and industrial electric installations, Iaşi – 1987 Rotaprint
- Ioachim – Design of the industrial electrical installations, Iaşi - 1991 Rotaprint
- Ioachim - Design of the industrial electrical installations – Design reference book, vol. I şi II, Iaşi – 1991 Rotaprint

The ”Electrical Lighting and Electrical Installations” Laboratory has a room of 72 m^2 (Figure 1). The main laboratory works in the electrical lighting filed:

Figure 1 Electrical Lighting Laboratory

I. Stand of the low-pressure fluorescent lamps montages;
II. Panoply of light sources: usual (normal) incandescent and halogens lamps, fluorescent lamps (both usual and economic), supplied by electromagnetic or electronic ballasts, high intensity discharge lamps (sodium vapours, metallic halides, mercury vapours);
III. Photometric curves-plotting device for the light sources;
IV. Photometric characteristics' study and analysis of the lighting sources;
V. Stand for operating characteristic determination of the lighting sources (usual and halogen incandescent lamps, fluorescent lamps with inductive or capacitive ballast montage);
VI. Microprocessor-driven electronic ballast – Metrolight – of 250 W for HID lamps, with dimming possibility

Through the laboratory equipments we can mention: Analogical luxmeter Metro Blansko PU150; Digital luxmeter Mavoluxe 5032CIB USB – Gossen; Infrared thermometer with laser indication point ; Thermometer VT200 warm wired Kimo Constructer ; Three phase energy analyzer CA 8334 Chauvin Annoux.

In this effort we had a good model in The Lighting Engineering Center – LEC, established at Technical University of Cluj by Professor Florin Pop and his colleagues [8].

8 CONCLUSION

The preparing of the National Registry of the Qualifications in Superior Education is thus in work, necessitating a concentrated and long-time effort. Or, in the frame of the validation procedures of one university qualification (ACPART, annexe 5), is signalling (index 7: Qualification referential), that beside to qualification curricula and disciplines slips, must be specified the assessment methods of the competences at the finalization of the studies. This foresight guarantees that some of principles discussed in this paper will be quickly implemented in many universities, as long as the proposed instrument will be operational proved.

Some resistance to the change is possible. The depth which assessment takes gives the change. The final assessment, after one studies cycle, is changed from one simple ceremony without meaning (is not the place to demonstrate this affirmations, but the author assumes it) to a real measurement process. The measure means knowledge, and the knowledge is only the decrease of the incertitude degree. Unfortunately, the performances observed by educators are so weak in the last years, which the reaction of the educators may be one of to reject of this real evaluation necessity. But, in a perspective of five years, the things will change because the interaction of the educated – educator has the chance to orientate toward the formation of the real competences, and not auto-suggested. In present, the education is reported to a relative level (which is in continuous decrease), when we propose a referential objective for what should mean the competence. For the lighting education, we demonstrate that the problems are more difficult, because we need to find and to defend a place witch is indefinite, but also is assumed arbitrarily.

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LIGHTING EFFICIENCY AND LED LIGHTING APPLICATIONS IN INDUSTRIALIZED AND DEVELOPING COUNTRIES

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ABSTRACT

With the increase in the price of energy and with the public becoming more conscious of energy and environmental issues, more attention is being given for energy-efficient lighting. The design of energy-efficient lighting includes the use of efficient light sources, luminaires, control systems and also interior design with proper surface materials and placement of work places in relation to windows and luminaires. LEDs (Light Emitting Diodes) are new alternative light sources, which are foreseen to revolutionise the lighting technology in the near future.

Electrical networks in most of the developing countries are limited mainly to the urban areas and therefore more than one-quarter of world's population uses liquid fuel to provide lighting. Increasing luminous efficacy, long life-time, and low power requirements make LEDs suitable to be used for lighting applications in industrialized and developing countries. Cost analysis of LED based lighting systems driven with renewable energy sources in different parts of developing countries have shown them to be cost effective in comparison with the existing options.

1 INTRODUCTION

An energy strategy for Europe is aiming to balance sustainable development, competitiveness and security of supply. The proposed EU Energy Policy Targets and Objectives are: to reduce greenhouse gas emissions of developed countries by 30% by 2020; the EU has already committed to cutting its own emissions by at least 20% and would increase this reduction under a satisfactory global agreement, to improve energy efficiency by 20% by 2020, to raise the share of renewable energy to 20% by 2020 and, to increase the level of biofuels in transport fuel to 10%.

Lighting is a large and rapidly growing source of energy demand and greenhouse gas emissions. In 2005 grid-based electric lighting consumtion was 2 650 TWh worldwide, about 19% of the total global electricity consumption. That means 133 petalumen-hours (Plmh) of electric light was used, an average of 21 megalumenhours/person. In addition, each year 55 billion litres of gasoline and diesel are used to operate vehicle lights. More than one-quarter of world's population uses liquid fuel (kerosene) to provide lighting. [1] Global lighting electricity use is distributed approximately 28 % to the residential sector, 48% to the service sector, 16% to the industrial sector, and 8% to street and other lighting applications. For the industrialized countries national lighting electricity use ranges from 5% to 15%, while in developing countries the value can be as high as 86% of the total electricity use. [2]

More efficient use of lighting energy would limit the rate of increase of electric power consumption, reduce the economic and social costs resulting from constructing new generating capacity, and reduce the emissions of greenhouse gases and other pollutants. At the moment fluorescent lamps dominate in office lighting. In domestic lighting the dominant light source is still the more than a century old, inefficient incandescent lamp. Important factors for lighting today are energy savings, daylight use, individual control of light, quality of light, emissions during life cycle and total costs.

2 LIGHTING ENERGY AND EFFICIENCY

The building sector in the EU consumes over 40% of energy use in EU and is responsible for over 40% of its carbon dioxide emissions. Lighting is a substantial energy consumer, and a major component of the service costs in many buildings. The percentage of the electricity used for lighting in European buildings is 50% in offices, 20-30% in hospitals, 15% in factories, 10-15% in schools and 10% in residential buildings [3]. To promote the improvement of the energy performance of buildings within the community, the European Parliament has adopted the Directive 2002/91/EC on the energy performance of buildings. [4]

The average lighting system efficacy by region is estimated to be 50 lm/W in North America, 54 lm/W in Europe, 65 lm/W in Japan, 49 lm/W in Australia and New Zealand, 58 lm/W in China, 43 lm/W in Former Soviet Union and 43 lm/W in the rest of the world. 35,5% and 39,5% of the light is still provided by the inefficient T12 and T8 fluorescent lamps, respectively. [1]

LEDs (Light Emitting Diodes) are new alternative light sources, which are foreseen to revolutionise the lighting technology in the near future. According to Agilent Technologies the lumens/package value of red LEDs has been increasing 30 times per decade whereas the price is decreasing 10 times per decade [5]. The use of LED based lighting could decrease the lighting energy consumption by 50% by 2025 [6]. The future entrance of LEDs in the lighting market is dependent on improvements in conversion efficiency and optical power per package. Although most of the high-power LEDs (HP-LEDs) nowadays convert between 15 to 20% of the input power into light, their efficiency potential is far better.

3 IEA ECBCS ANNEX 45 ENERGY EFFICIENT ELECTRIC LIGHTING FOR BUILDINGS

International Energy Agency (IEA) is an intergovernmental body committed to advancing security of energy supply, economic growth and environmental sustainability through energy policy co-operation. IEA has Implementing Agreements (IA) to organize research. One of these IAs is Energy Conservtion in Buildings and Community Systems (ECBCS). The function of ECBCS is to undertake research and provide an international focus for building energy efficiency. Tasks are undertaken through a series of Annexes that are directed at energy saving technologies and activities that support their application in practice. The findings are also used in the formulation of energy conservation policies and standards.

One of the Annexes of ECBCS is Annex 45 Energy Efficient Electric Lighting for Buildings. The goal of the Annex 45 is to identify and to accelerate the widespread use of appropriate energy efficient high-quality lighting technologies and their integration with other building systems, making them the preferred choice of lighting designers, owners and users.

The aim of the Annex 45 is to assess and document the technical performance of the existing promising, but largely underutilized, innovative lighting technologies, as well as future lighting technologies and their impact on other building equipment and systems (ie: daylighting, HVAC). These novel lighting system concepts have to meet the functional, aesthetic, and comfort requirements of building occupants. The aim is to assess and document the barriers preventing the adoption of these promising existing and future technologies (ie: technical, economic, risk factors, resistance to change, legislative, etc.) and propose means to resolve these barriers.

The main deliverable of the Annex 45 will be the guidebook on energy-efficient lighting. The guidebook is targeted for lighting designers, electrical building services and system integrators in buildings and the end-users/owners. It will include lighting electricity statistics in buildings, lighting quality criteria, energy codes and description of lighting technologies and control systems. It will also present commissioning process for lighting (control) systems and case studies. Also, technical potential for energy efficient lighting and savings are considered and proposals to upgrade recommendations and codes are given.

4 LIGHTING IN DEVELOPING COUNTRIES

After Edison's futuristic statement over 100 years ago –"We will make electricity so cheap that only the rich will burn candles"[7] – the wishful dream of cheap, abundant electricity has not come true for more than 1.6 billion people around the globe, more people than the entire world's population in Edison's time. Only about 24% of the people living in sub-Saharan Africa had access to electricity in 2000 [8]. Electrical networks in most of the developing countries are limited mainly to the urban areas. In the rural areas of sub-Saharan countries, only 2% - 5% of the population is supplied with electrical networks. The grid connectivity is somewhat higher in countries such as Brazil, Bangladesh, India, Morocco, and South Africa, with 20% - 30% of rural population having access to electrical networks [9]. Rest of the people, who do not have access to the electric supply, use biomass and petroleum fuels for lighting. Fuel based lighting is not only inefficient and expensive compared to electric lighting, but is also a severe cause of respiratory and cardiac health problems. IEA [1] estimates that the annual energy consumed in fuel based lighting is equivalent to 65.6 Mtoe (Million Tons of Oil Equivalent) of final energy use. The estimated amount of global primary energy used for lighting is 650 Mtoe. The fuel based light sources include candles, oil lamps, ordinary kerosene lamps, pressurized kerosene lamps, biogas lamps, propane lamps, and resin soaked twigs as used in remote Nepali villages [10]. The ordinary wick-based kerosene lamps are the most widely used sources as fuel-based lighting in developing countries. For example, nearly 80 million people in India alone light their houses using kerosene as the primary lighting media [11].

The electrification rate in the developing countries has been continuously increasing during the past few decades. The urban electrification rate is higher than the rural one. The world urban electrification rate was estimated to be 91.2%, while the rural was 56.9% in 2000. Although the electrification rate is increasing, the number of households without electricity is also growing due to the population growth. Between 1970 and 1990, 18 million people in sub-Saharan Africa were newly supplied with electricity, but the total population growth at the same time was 118 million [12]. Similarly in South Asia, due to high population growth, the number of people without electricity grew by more than 100 million during the same period. Extending the electricity networks to rural areas of developing countries is very expensive due to the geographical remoteness, lack of basic infrastructures, and low population density. Hence, the remote and rural parts of the many developing countries are not expected to be accessed by electric networks in near future.

The use of renewable energy systems to produce electricity is becoming a viable option in fulfilling the basic energy needs of rural villages. There are a range of innovative and sustainable technology solutions which can meet the energy needs in developing countries [13]-[15]. The technologies involving wind power, solar power, and small-scale hydropower exploit the local resources, operate on small scale and have an advantage of meeting the needs of widely dispersed rural communities. The efficient use of electrical energy is very important issue in these situations because of the low level of power production capacity from these technologies and also due to the associated costs.

Light Emitting Diodes (LEDs) are rapidly evolving light sources. Increasing luminous efficacy, long life-time, and low power requirements make them suitable to be used for lighting in the rural villages. Cost analysis of LED based lighting systems driven with renewable energy sources in different parts of developing countries have shown them to be cost effective in comparison with the existing options [10]. The Light Up the World (LUTW) organization is one of the pioneer to apply LEDs for lighting in rural villages, and it has already lit up more than 14000 homes around the world [16].

ENLIGHTEN (Europe Nepal LIGHTing and Energy Network) was a co-operation project between universities from Finland, Lithuania and Nepal. TKK Lighting Unit coordinated this project where one activity was to combine LEDs with solar energy and to promote their use in rural Nepali villages in co-operation with Light Up the World Foundation (LUTW). LUTW was born in Nepal and it was the first humanitarian organization to utilize white LEDs in order to replace fuel based lighting in developing countries. Nepalese example of lighting an entire village of up to 30 homes with less energy than used by a single conventional 100 W incandescent lamp explains why LED technology is continuing to be popular in the rural areas without electrical networks.

Unlike the other technologies, LEDs started showing their applicability in lighting in the developing countries before coming to the developed country market. The low energy required by LEDs is the key point to make them suitable for sustainable lighting solutions to the most part of the developing countries which are still out of reach of electrical networks. Nepal is one of these developing countries, where people in remote rural areas depend on fuel based lighting (kerosene lamps, oil based lamps, and resin soaked pine sticks) to bring minimum lighting services at their homes. Fuel based lighting is not only inefficient and expensive but also a cause of many health problems due to the generated smoke.

5 LED applications

One interesting LED lighting application is their use in plant growth. Electric lighting in greenhouses is conventionally provided by discharge lamps (HPS), but with the use of LEDs totally new concepts of lighting are possible and also the quality of lighting can be optimised for different plants.

Greenhouse is a structure, usually made of glass, where the inside environmental conditions can be controlled for cultivation and protection of plants. This gives the possibility of cultivate crops in conditions close to optimal year-round. Greenhouses provide also protection against the sometimes harsh and each-day more unpredictable exterior climate conditions. Although optimal growth conditions are desirable, the fact is that in practice they are not always achievable due to technical or economical reasons.

At higher latitudes daylight availability during winter is a limiting factor. Therefore artificial light is commonly used to supplement or totally replace daylight in order to maintain or increase the plant productivity. Conversely, production costs should be kept low or reduced, if possible. This last factor is where efficiency plays an important role, and consequently also lighting.

In order to improve efficiency in greenhouses located at northern latitudes, several aspects should be optimized in the future, namely the isolation, ventilation, heating, cooling and lighting. Lighting is perhaps one of the factors with important energy-saving potential. The most common light source used nowadays in year-round horticultural industry is the HPS lamp, mainly due to the high efficiency and long lifetime. However its spectral quality is more appropriated for human vision than for plant growth applications. Additional limitations of HPS lamps are the mercury content, fragile, omnidirectional light emission, limited spectrum and light intensity control possibilities. For all these reasons LED-based luminaires are good candidates to replace HPS luminaires in greenhouses.

Today the main advantage of HPS lamps in relation to LEDs still is the electrical efficiency and light emission per lamp. However the potential efficiency of LEDs is increasing constantly. Future greenhouses will have to reformulate their automation systems in order to include spectral and intensity controls of the light sources. This will bring possibilities to growers and researchers as well as new challenges. The operation of the lamps will not be anymore limited to on or off but instead it will be possible to continuously dim according to daylight and weather conditions. Multi-spectral wavelength LED luminaires will allow to control and optimize the plant development at all different stages. Considering the large combinations allowed for control, computer-based control units will become more commonly used. This will facilitate the integration of the necessary systems required for optimization of the abiotic parameters inside the greenhouse. Future greenhouses may also benefit from the utilization of alternative energy systems, such as geothermal or wind energy.

A recent research showed the potentialities of LEDs as photosynthetic light source for plant growth in greenhouse and in phytotron [17]. The results obtained in greenhouse tests confirmed that utilization of red and blue LEDs as supplemental lighting was at least equally effective in accumulation of biomass as with HPS lamps. The addition of a third wavelength component in yellow to red and blue, gave the indication that further optimization for lettuce growth is still possible.

Additional experiments were carried out in phytotron conditions where plants were growth without the influence of daylight. The results have shown that under certain LED lighting quality it was possible to reduce the nitrate contents of lettuce plants significantly in relation to control plants grown under special fluorescent lamps.

In both studies the plants grown under LEDs had improved morphology than plants grown under conventional lighting. Also the carbonhydrates balance was better in plants grown under LED lighting.

6 CONCLUSIONS

Lighting is a large and rapidly growing source of energy demand and greenhouse gas emissions. At the same time the savings potential of lighting energy is high even with the current technology and there are new energy efficient technologies coming on the market.

To realise the savings potential of lighting we need international co-operation to find out the various aspects and possibilities of energy-efficient lighting. A new guidebook on energy-efficient lighting will be published by IEA Annex 45 at the end of this year. The guidebook is a result of co-operation between 21 countries worldwide. The guidebook is targeted for lighting designers, electrical building services and system integrators in buildings and the end-users/owners. It will include energy-efficient technical solutions for lighting and also possibilities for energy savings.

LEDs are seen as a future light source both for industrialized and developed countries. The low energy required by LEDs is the key point to make them suitable for sustainable lighting solutions to the most part of the developing countries which are still out of reach of electrical networks.

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FLICKER DOSE IN THE ROAD LIGHTING

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ABSTRACT

The flaring produced by the visual perception variation, owing to the subject and vehicles traveling on the roads, has to be assessed in order to prevent the tiredness state felt by the drivers. If the glare evaluation corresponds to the visual perception at a given moment, the flaring evaluation corresponds to the variation in time of the visual perception of the subject participating to the traffic. The term flicker is used for the flaring phenomenon [5]. Experimental determinations and computer aided design, previously realized by the authors, have emphasized important variations of the luminance perceived by a driver from a vehicle circulating on a road with nocturnal lighting. The evaluations made for the luminance fluctuations amplitudes have pointed out that these ones may exceed several times, in certain situations; the maximum admitted values of this flicker indicator [4]. Because for the flicker phenomenon exist standardized values even for the flicker dose indicator, which estimate the consequences in time of the visual perception variations, the aim of this paper is to assess this variable as well, for the conditions when the luminance fluctuations amplitudes have been determined. In this way, the evaluation of the tiredness state induced by the luminance variations is more correctly estimated.

1 INTRODUCTION

For the road traffic, the visual task perception is considered for a subject situated in a certain point having the coordinates specified in the frame of the lighting system and at a given moment. Because the subject changes his position in time regarding the lighting system and it has a relative variable position versus the vehicles taking part at the traffic, a variation of the subject visual perception has to be considered. This fact leads to the flicker phenomenon.

The following types of the luminance fluctuations have been emphasized in [4] for an observer traveling along a road:

- the longitudinal non-uniformity of the luminance due to the lighting system;
- the luminance variation due to the traffic from the same sense;
- the luminance variation due to the same sense traffic.

The frequencies of the luminance fluctuations determined for the observer standard position, for normal distances between vehicles and admitted speeds are in the range defined by the norms. Regarding the luminance fluctuations amplitudes, the values determined according the measurements [4] exceed several times the admitted values [5].

The flicker dose assesses more correctly the tiredness state induced by the luminance variations than the pair amplitude – frequency of the fluctuations, because it considers the product between the amplitude square and the fluctuations duration [2]. In this paper the evaluation of the flicker dose is realized using the same experimental and theoretical data as in the determination case of the amplitudes and fluctuations frequencies of the luminance [4].

2 THEORETICAL BASIS

2.1 Flicker phenomenon

As adopted even in standards, the flicker is defined by the impression of instability of the visual sensation, produced by a luminous stimulus whose luminance or spectral distribution fluctuates with time.

The instability or the visual sensations variability causes may be more than those included in the definition from the mentioned standard, as follows:

- luminous fluxes fluctuations emitted by the lighting systems;
- the fluctuation in time of the spectral composition of the received light;

- the human subject movement in a visual field, variable from the photometric variables point of view, but which is repeating it self in the space;
- shift of some successive lighting sources versus the human observer.

The luminance fluctuations amplitude is

$$\delta L_{vj} = \frac{|L_{vj} - L_{vj+1}|}{L_{vj}} \cdot 100 \text{ , \%,} \quad (1)$$

where L_{vj} represents the luminance for which the eye is accommodated in the moment t_i and L_{vj+1} is the luminance which is to accommodate the eye in the moment t_{j+1}. Unlike the relationship from the standard [5] referring to the voltage fluctuations understood as luminance fluctuations, the reference does not represent a rated value which is non-existent in the visual perception chain.

As a consequence of the definition (1) and of the fact that the eye adapting luminance varies between a minimum and a maximum value, the fluctuations amplitudes from maximum to minimum respectively from minimum to maximum will be not identical. Thus, the luminance fluctuation amplitude when the observer passes from the maximum luminance point L_M to the minimum luminance one L_m is

$$\delta L_{Mm} = \frac{|L_M - L_m|}{L_M} \cdot 100 \text{ , \%,} \quad (2)$$

while in the second case, when the observer passes from the minimum luminance point to the maximum luminance one, the luminance fluctuation amplitude value will be greater because in this case the variation amplitude is determined according to the relationship

$$\delta L_{mM} = \frac{|L_m - L_M|}{L_m} \cdot 100 \text{ , \%,} \quad (3)$$

where the denominator has a smaller value than the one from the relation (2).

The flicker phenomenon refers to the discomfort produced at the human brain level by the periodical variation of the visual perception. If in the indoor lighting installations the main cause is the variation of the voltage rms value, in the road nocturnal lighting the flicker generating cause may also be the drivers traveling through a non-uniform area of luminance or even the relative movement of other vehicles versus a considered observer.

2.2 Flicker dose

The luminance fluctuations effect in time over a human subject is more correctly assessed with the flicker dose [2] than using the fluctuations amplitude.

It has been experimentally established that the influence of the voltage fluctuations over the sight is dependant not only on the frequency and amplitude, but also on the shape of the modulating signal, in accordance with the determinations results presented in figure 1.

As it can be observed, the **minimum** of the **sensitiveness threshold** is for a sinusoidal signal for the voltage modulating, having a frequency of about 10 Hz and a relative amplitude of approximately 0,3%.

The evaluation of the voltage fluctuations influence is made in accordance with the **cumulative principle,** based on the recording of the tiredness accumulated by the eye up to the dose when work becomes impossible. The judgement is based on the equivalence of a fluctuation of f_i frequency and δU_{fi} amplitude with a fluctuation having 10 Hz as reference frequency and the equivalent percentage amplitude as

$$(\delta U_{10})_i = g_{fi} \; \delta U_{fi} \text{ , \%,} \quad (4)$$

in order to induce an identical discomfort sensation; the fluctuations equalization coefficients g_{fi} are experimentally determined in accordance with the source type and the fluctuations frequency.

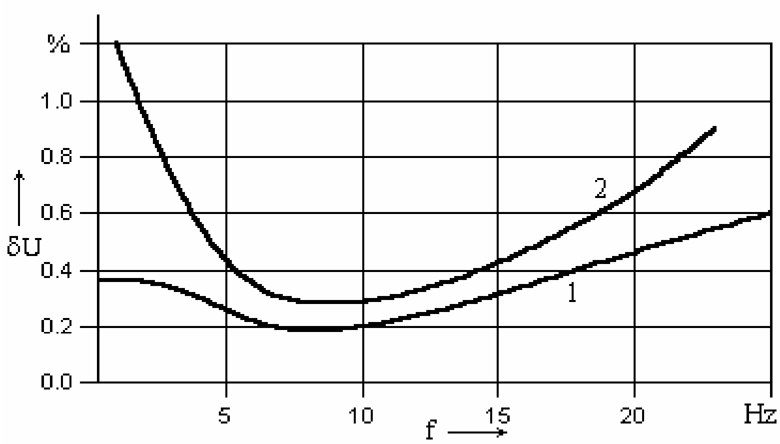

Figure 1 Variation of the sensibility threshold of the human sight with the modulator signal amplitude and frequency for: 1 - rectangular modulation; 2 - sinusoidal modulation.

The superposition of the effects of different frequencies fluctuations is realized with the relationship

$$\delta U_{10} = \sqrt{\sum_i \left(g_{fi}\ \delta U_{fi}\right)^2}\ , \%, \tag{5}$$

and the flicker dose is actually defined by the relationship

$$\varepsilon_F = \int_0^{T_0} \left(\delta U_{10}\right)^2 \cdot dt\ ,\ (\%)^2 \cdot \text{min}, \tag{6}$$

where T_0 represents the perturbation assessment (observation) period. The flicker dose expresses the total uneasiness that an eye feels during T_0. The dependence of the disturbing periodical flicker dose (0,3 %, la 10 Hz) versus its duration is presented in the Figure 2 (curve a). The curve corresponding to the imperceptible flicker is also reproduced in the Figure 2 (curve c). It can be emphasized that the admitted flicker dose (Figure 2, curve b) corresponds to a broken line situated between the curves for the imperceptible and disturbing doses.

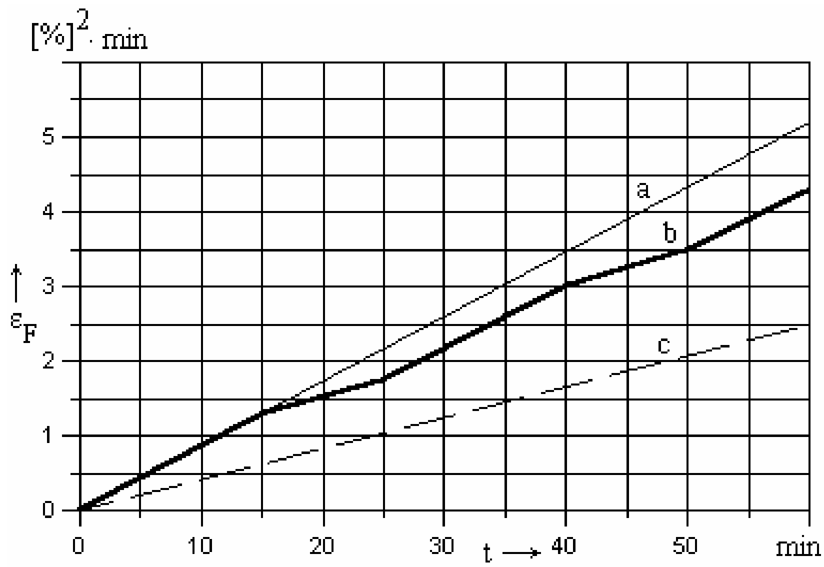

Figure 2 The periodical flicker dose dependence versus the flicker duration:
a - disturbing flicker; b - admitted flicker dose; c - imperceptible flicker.

2.3 Luminance fluctuations on the roads with nocturnal lighting

2.3.1 Luminance fluctuations owed to the lighting system

The road lighting systems are dependant on the emplacement modalities of the luminaires, the luminaires types and the characteristic variables of their emplacement. The luminaires emplacement modalities can be: axial; on a single side (left or right); bilateral –opposite; bilateral – alternative. The lighting system geometry, the distribution body of the luminous intensities for the luminaires, the lamps technical characteristics and the photometrical properties of the road surface represent the variables ensemble that conditions the values and the distribution of the luminance at the road level [1, 3].

The distance *d* between two poles from the same side of the road being the same, the following relationship is proposed in [4] for the frequency of the luminance fluctuations caused by the observer shift in comparison with the bilateral – opposite lighting system:

$$f_s = \frac{v_s}{d}\text{, Hz,} \tag{7}$$

where v_s is the vehicle (observer) speed related to the lighting system.

A nomogram for the frequency determination of the luminance fluctuations caused by the observer movement related to the lighting system in accordance with the relation (7) is presented in the Figure 3. It has been found that for the ranges of the considered calculus variables, the luminance fluctuations frequencies result in the interval (0,1÷1,8) Hz.

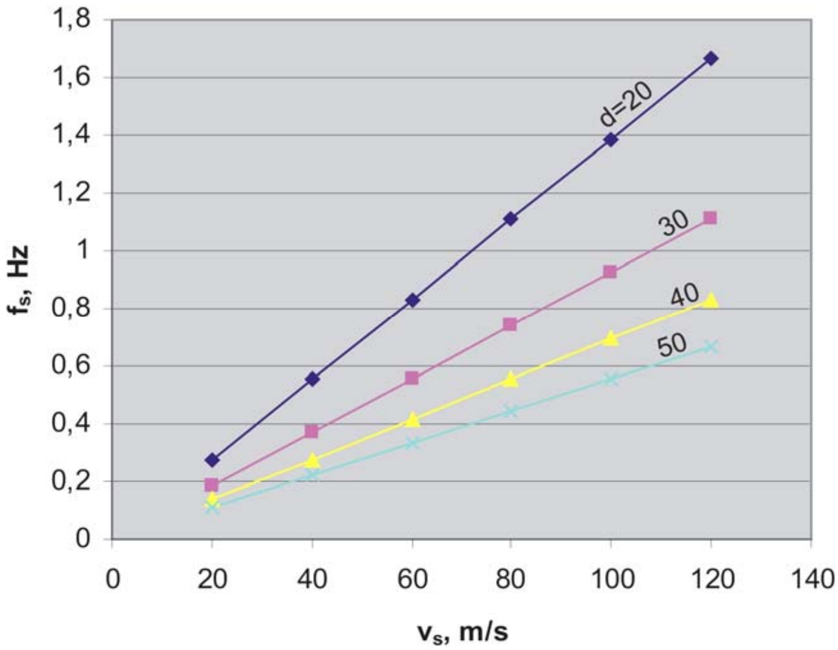

Figure 3 Frequency of the luminance fluctuations caused by the observer movement in comparison with the lighting system (*d* in m).

Regarding the luminance fluctuations amplitude the data were experimentally determined in [4] for a bilateral – opposite lighting system (road width - l_0 =14 m, distance between the poles - *d* = 33,3 m; luminaires mounting height - *h* = 9,4 m; luminaires type - Onyx 2N, equipped with lamps as SON T 250 W).

The luminance measurements results, effectuated along the longitudinal axis of the first lane are presented in the figure 4 (the height of the luminance-meter objective was adopted at 1,1 m above the road surface and the focusing ring of the apparatus was oriented to the point situated at 60 m forward, on the road surface). According to the measurements, the following values of the luminance fluctuations amplitudes owed to the lighting system have resulted:

$$\delta L_{mMs} = 30{,}2\ \%;\ \delta L_{Mms} = 23{,}2\ \%.$$

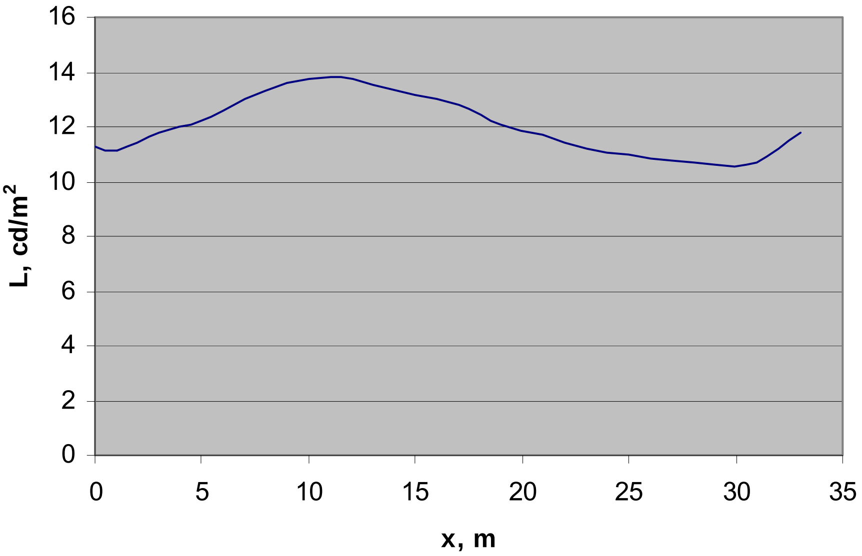

Figure 4 Profile of the luminance on the longitudinal axis of the first lane.

2.3.2 Luminance fluctuations due to the traffic from the opposite sense

For the vehicles traveling from the opposite sense, these ones impress the observer eye, when a vegetation veil doesn't exist, through maximum or minimum luminance, which vary in comparison with the distance between vehicles and the vehicles and observer speeds.

The frequency f_c of the luminance fluctuations owed to the traffic of the opposite sense vehicles is

$$f_c = \frac{v_s + v_c}{d_c}\text{, Hz,} \tag{8}$$

where v_c is the speed of the opposite sense vehicles, d_c - the distance between two successive vehicles which come from the opposite sense and v_s - the observer speed.

The nomogram from the Figure 5 allows the determination of the fluctuations frequency f_c for the usual values of the distances and the speeds.

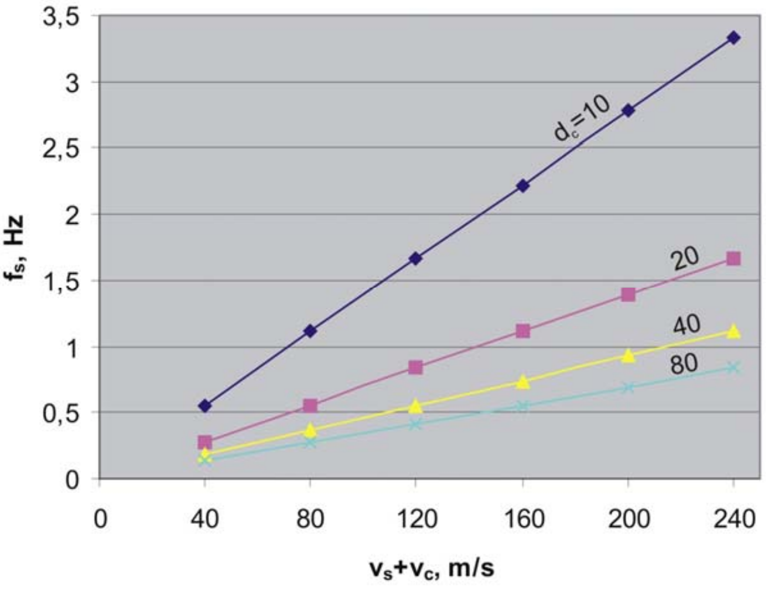

Figure 5 Frequencies of the luminance fluctuations owed to the opposite sense traffic (d_c in m).

As it can be noticed, the frequencies of the luminance fluctuations owed to the opposite sense traffic result in the interval (0,1÷3,5) Hz for the ranges of the considered calculus variables (d_c=10÷80 m).

Regarding the luminance fluctuations amplitudes owed to the vehicles coming from the opposite sense, the values determined in [4] are as follows:

$$\delta L_{mMc} = 6{,}12\ \%;\ \delta L_{Mms} = 5{,}77\ \%.$$

2.3.3 Luminance fluctuations owed to the vehicles that travel in the same sense

The frequency f_a of the luminance fluctuations owed to the same sense vehicles may be determined with the relationship

$$f_a = \frac{v_a - v_s}{d_a}\text{, Hz,} \tag{9}$$

where v_a represents the absolute speed of the same sense vehicles, d - the distance between two successive vehicles and v_s keeps the previously signification. For the ranges of the considered calculus variables, d_a =(10÷100) m and the speeds of (20÷120) m/s, the luminance fluctuations frequencies owed to the same sense traffic result in the interval (0,1÷2,5) Hz so in the defined interval of the flicker frequencies as well as in the previous case.

The luminance fluctuations amplitudes owed to the vehicles which overtake the observer vehicle on the adjacent left lane have the next values:

$$\delta L_{mMa} = 10{,}6\ \%;\ \delta L_{Mma} = 9{,}55\ \%,$$

in accordance with [4].

5 FLICKER DOSE IN CASE OF ROADS WITH NOCTURNAL LIGHTING

5.1 Flicker dose due to the lighting system

In order to calculate the flicker dose in case of roads with nocturnal lighting, having a certain amount of non-uniformity of lighting, three values of the traveling speed have been taken into account: $v_s \in \{50, 60, 70\}$ km/h and an equivalent number of traveling distances : $d_s \in \{3, 9, 18\}$ km. The choice of those values was made taking into account possible lengths of the access roads to large cities, as well as the range of legal speed limits allowed on these roads. As far as the distance between the poles that support the luminaires is concerned, we established this to be d=33, 3 m, in order to be able to use the experimental data in paper no. [4].

The variables and the values that lead to the determination of flicker dose are shown in table 1. The first variable calculated is the period of time t_p needed to travel the distances that were taken into consideration, according to the relationship:

$$t_p = \frac{d_s}{v_s}\text{, min;} \tag{10}$$

this variable needs to be calculated in minutes, as this unit of measurement is used to calculate the flicker dose.

Further on, the frequencies of the luminance fluctuations are calculated, using relationship (7) or the nomogram in figure 3; for the three values of speed taken into account, the following respective values of the fluctuations of frequencies are calculated: $f_s \in \{0{,}42;\ 0{,}50;\ 0{,}58\}$ Hz. The equalization coefficients $g_f \in \{0{,}08;\ 0{,}09;\ 0{,}10\}$ correspond to those values of the fluctuations of frequencies.

As it has been mentioned before (par. 2.3.1), there are two superimposed fluctuations, having the amplitudes δL_{Mms}= 23,2 % şi δL_{mMs}= 30,2 %, according to experimental measurements in [4]. The column „Calculated flicker dose” (Tab. 1) contains the results of calculations using relationships (5) şi (6), and as it can be noticed, those values are approximately (100÷160) times greater than the maximum admitted flicker dose values (according to the values in Fig. 2). This outcome was to be expected, given the fact that the amplitudes of the fluctuations calculated experimentally are approximately (8÷40) greater than admitted values.

Table 1 Calculation of the flicker dose for a lighting system

Speed of traveling, km/h	Traveled distance, km	Time, min	Frequency of fluctuations, Hz	Equalization coefficients, g_f	δL, %		Flicker dose, $(\%)^2$ min	
					δL_{Mm}	δL_{mM}	calculated	admitted
50	3	3,6	0,42	0,08	23,2	30,2	33,4	0,32
	9	10,8					100,2	0,97
	18	21,6					200,5	1,60
60	3	3	0,50	0,09	23,2	30,2	35,2	0,27
	9	9					105,7	0,81
	18	18					211,4	1,50
70	3	2.6	0,58	0,10	23,2	30,2	37,7	0,23
	9	7,7					111,7	0,70
	18	15,4					223,3	1,39

5.2 Flicker dose owed to the traffic from the opposite sense

In order to calculate the flicker dose owed to the traffic from the opposite sense the speed of the observer vehicle is considered to be one of the following three values: $v_s \in \{50; 70; 100\}$ km/h, and the vehicles coming on the opposite lane travel at v_c=70 km/h. As for the distance between the vehicles traveling on the opposite lane, this was considered to be d_c=60 m. The frequencies of the fluctuations were determined using relationship (8), and their amplitude values are consistent with the measurements (par. 2.3.2). The above mentioned data, the main intermediate variables and also the calculated flicker doses, are shown in Table 2. Of the intermediate variables, the time for traveling along the considered distances is important not only to the calculations of the flicker dose but also to the determination of the admissible dose, according to regulations.

The last column of Table 2 refers to the admissible flicker dose, determined in Figure 2, for the exposed periods of time of the observer, corresponding to the time needed to travel the given distances. It can be noticed that the calculated values are approximately (8,9...11,7) times greater than the admitted ones, which must be a warning signal, especially since the distances taken into account are relatively short.

5.3 Flicker dose due to vehicles traveling in the same sense

Calculation of the flicker dose due to vehicles traveling in the same sense was made taking into consideration the following aspects:

- the values of the speed of the observer vehicle (the subject): $v_s \in \{40; 50; 60\}$ km/h;
- the speed of the vehicles overtaking on the next lane was considered to be the same for all cases: v_a=90 km/h:
- the distance between two consecutive vehicles, traveling in the same direction as the observer vehicle is d_a= 70 m.

The calculation data, some of the intermediate results and also the respective flicker doses, are shown in Table 3

Table 2 Calculation of the flicker dose owed to traffic from the opposite sense, for a speed of the vehicles travelling on the opposite lane v_c=70 km/h

Traveling speed v_s, km/h	Traveling distance, km	Time, min	Fluctuations frequency, Hz	Equalization coefficients, g_f	δL, %		Flicker dose, $(\%)^2$min	
					δL_{Mm}	δL_{mM}	calculated	admitted
50	20	24	0,56	0,095	5,77	6,12	15,31	1,70
	35	42					27,80	3,10
	50	60					38,28	4,30
70	20	17,1	0,65	0,105			13,34	1,40
	35	30,0					23,40	2,20
	50	42,9					33,46	3,20
100	20	12	0,79	0,110			10,27	1,10
	35	21					17,98	1,60
	50	30					25,68	2,20

The maximum traveling distance (40 km) was set so that traveling at the minimum speed the observer vehicle should take one hour, this interval corresponding to the maximum period of time for which the admissible flicker dose is indicated (Fig. 2). Under those circumstances, all the time intervals for which the flicker doses are determined are within the limits of the maximum regulated interval of 60 minutes.

The frequencies of the fluctuations were calculated using relationship (9), and related to these, the equalization coefficients for the amplitude of the fluctuations were identified [2, 4].

Because, as shown from the beginning, (rel. 2 and 3, sub-heading 2.1), there are two fluctuations with the amplitude values of δL_{Mm} şi δL_{mM}, it was considered that the subject receives both these fluctuations, one over the other.

As in all the other cases, in the last column of the table the admitted flicker doses are shown, corresponding to the time intervals the subject was exposed, equivalent as values to traveling time. By comparing the calculated flicker doses and the admissible ones, it can be seen that the former are (18…32) times greater than the regulated ones, a fact which should also be a serious warning.

Table 3 Flicker dose due to vehicles traveling in the same sense for the situation v_a=90 km/h and d_a= 70 m

Traveling speed v_s, km/h	Traveling distance, km	Traveling time, min	fluctuations frequency, Hz	Equalization coefficients, g_f	δL, %		Flicker dose, $(\%)^2$min	
					δL_{Mm}	δL_{mM}	calculated	admitted
40	20	30	0,71	0,107	9,55	10,6	69,9	2,20
	30	45					104,9	3,30
	40	60					139,9	4,30
50	20	24	0,57	0,097			46,0	1,70
	30	36					69,0	2,70
	40	48					92,0	3,45
60	20	20	0,43	0,082			27,4	1,55
	30	30					41,1	2,20
	40	40					54,8	3,00

6 CONCLUSIONS

The flicker refers to the feeling of discomfort or tiredness of a human subject and which is caused by the variation of the visual perception of the flicker, with frequencies in the interval cu (0,01÷50) Hz. The discomfort caused by the flicker is felt at the level of the human brain, based on the variation of the visual perception received by the human eye and transmitted to the brain through the optic nerve. Following the reception of a larger flicker dose, the visual perception becomes unstable and, as a consequence, inconsistent with reality, a fact which may favor accidents both at the working place and on roads.

The definition of the luminance fluctuations amplitudes, given in paper [4], takes into consideration the essence of the flicker phenomenon. Three causes of the flicker on roads have been indicated, and as a consequence three types of flicker one due to the lighting system, one due to the vehicles traveling in the opposite sense and one due to vehicles traveling in the same sense. The value intervals of the fluctuations frequency were calculated for the practical values of the variables involved and for the fluctuations amplitudes were used experimentally determined values, for concrete situations.

The results obtained based on experimental data indicated high values of the luminance fluctuations amplitudes [4], a few times higher than the admissible values, as they were set in standards.

As a consequence, it was only expected that the flicker dose calculated for the three situations be out of admitted limits set in regulations. The results that were obtained for the doses of the three types of flicker show that, under normal circumstances, the values are a few times greater than the standards. The warning signals contained in the results of this research must mobilize the responsible authorities in order to take appropriate measures in order to lower significantly the flicker on roads, as at current levels this can represent an important factor of accidents that happen during nighttime.

And even more, we must add that, under certain circumstances, two or even all three types of flicker on the road can happen at the same time, intensifying even more the exposure of drivers and thus increasing the risk of accidents.

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PHOTOMETRY OF SOLID STATE LIGHTING IN THEORY AND PRACTICE

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ABSTRACT

Solid state light sources get used in a number of applications, both as signal lights (e.g. traffic lights and displays) and in in- and outdoor general lighting. As the spectral power distribution of the LEDs differs from that of traditional light sources, the uncertainty of their photometric measurements is larger than we were accustomed up to now.

Traditional photometry and lighting design does not take into consideration that not all human observers have the same spectral luminous efficiency function. In the present paper we analyze the differences practical photometric observers produce compared with receivers that simulate one of the typical human observers (e.g. 2° and 10° standard observer, observer with $V_M(\lambda)$ sensitivity, cone-fundamental derived sensitivity, or standard deviate observer).

It can be shown that for practical white light applications the average photometers intended for field use (i.e. with an f_1' of < 3%) are adequate, the readings of these photometers will not deviate more from the reading of an instrument that conforms to the standard observer by more than what the deviation for most of the population will be.

Key words: Photometry, spectral responsivity, spectral luminous efficiency function, spectral mismatch error index.

1 INTRODUCTION

Photometry uses the 1924 standard photometric observer's spectral responsivity curve[1], restated recently with higher precision in a CIE/ISO standard[2]. Since more than fifty years it is known that the $V(\lambda)$ function (the spectral luminous efficiency function) is too low in the blue part of the spectrum[3] and CIE published a corrected spectrum in the form of the $V_M(\lambda)$ function[4]. Interestingly this function is still not in practical use, based mainly on the fact that for traditional white light sources the difference of calculated luminous flux is small if instead of the $V(\lambda)$ function the $V_M(\lambda)$ function is used. A further problem with the $V(\lambda)$ function is that it relates to small field (2°) foveal vision, but it is used also in peripheral and large filed of view situations, where the 10° observer should be used for luminance evaluation[5] and for brightness evaluation some more complicated functions should be used[6]. A further complication is the fact that for a considerable part of the human population the $V(\lambda)$ function is not representative for vision. Here we do not want to refer to deutans, only to those who have slightly deviating spectral sensitivity, described by the CIE deviate observer[78]. (Although there are reports that question the validity of the CIE deviate observer[9], we used it in our evaluation, as it is the only internationally accepted function.)

A CIE Technical Committee is working on cone fundamental based colour matching functions[10]. In this respect they evaluate the use of a physiologically-relevant 2 degree (and 10 degree) $V(\lambda)$ luminous efficiency function, based on the work of Stockman and co-workers[11,12]. These functions might replace at one time the aged 1924 function, and one should investigate the significance of a change using these functions.

With the invention of light emitting diodes (LEDs) light sources came onto the market who's relative spectral power distribution (SPD) differs considerably from those of traditional light sources. In case of white light sources constructed from red-, green- and blue emitting LEDs the SPD consists of three narrow spectral bands, one of which lies in the region where the $V(\lambda)$ function is in error, producing well visible discrepancy between visual appraisal and instrumental match.

2 SOURCES, DETECTORS AND TEST SAMPLES

2.1 Source spectra

Two groups of spectra have been collected: Warm White colour temperature light source spectra and daylight spectra. In both cases a CIE standard Illuminant (Ill. A and D65) was used as reference spectrum. To show the differences to traditional light sources in both groups fluorescent lamp spectra were also included. For both studies LEDs built from blue chips and yellow phosphors (p-LEDs) as well as clusters of red, green and blue emitting LEDs (RGB-LEDs) were used. Spectral power distribution of the test sources is seen in Figure 1 for the 2856 K group and in Figure 2 for the Daylight group. Colorimetric characteristics are seen in Table 1.

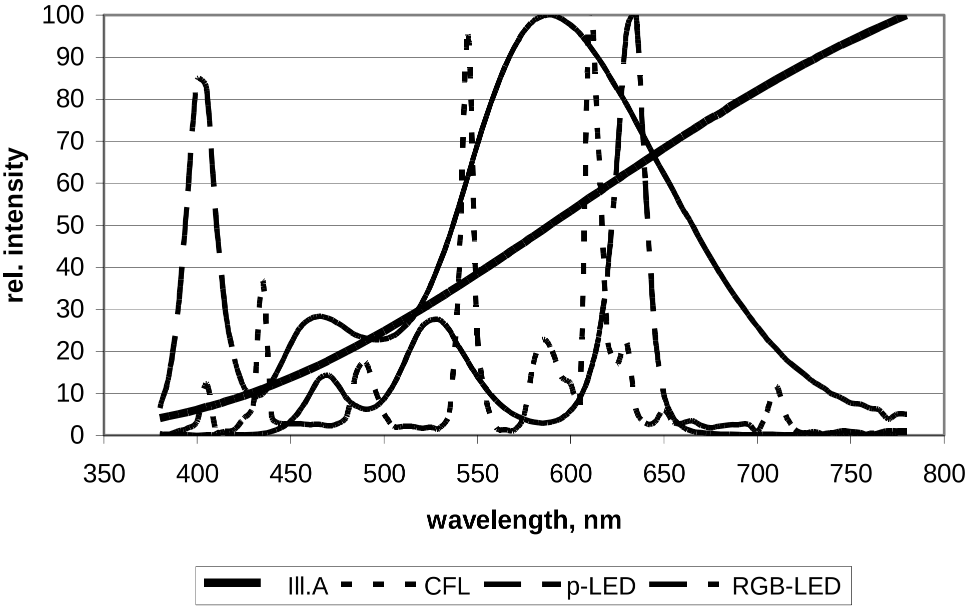

Figure 1 SPDs of the 2856 K group of sources

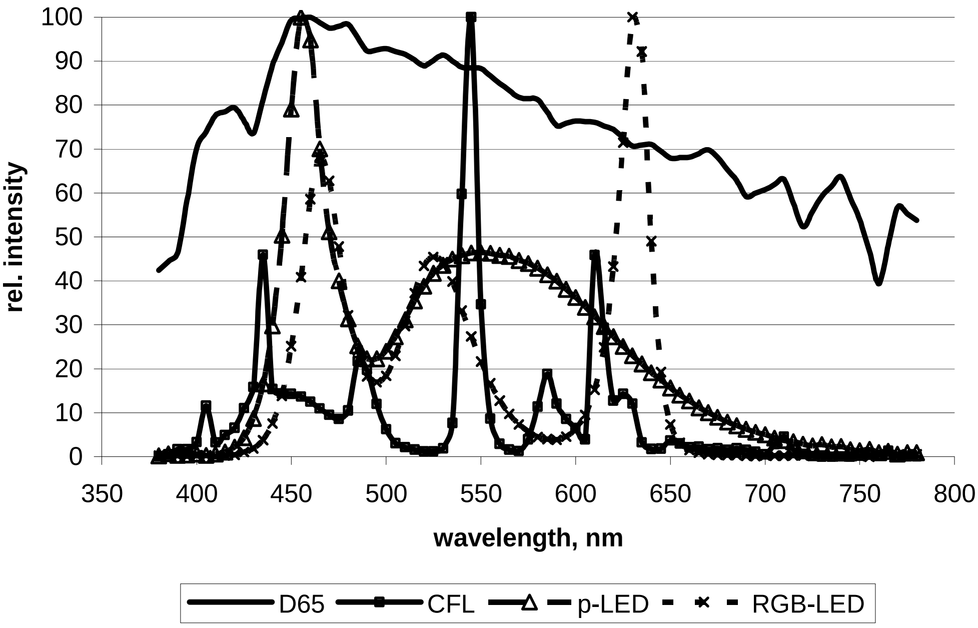

Figure 2 SPDs of the D65, CFL and two LED sources

Table 1 Colorimetric characteristics of the sources used in the present experiment

2856 K group				
Lamp designation	Correlated colour temperature, K	General colour rendering index, Ra	x	y
Illuminant A	2856	100	0,4476	0,4420
Compact fluorescent lamp	2895	85,7	0,4420	0,4016
p-LED	2879	72,5	0,4508	0,4165
RGB-LED	2885	31,5	0,4466	0,4091
6500 K group				
D65 illuminant	6503	100	0,3127	0,3290
CFL	6081	73,6	0,3189	0,3514
p-LED	7153	79,6	0,3023	0,3240
RGB-LED	6782	46,5	0,3091	0,3212

2.2 Detector spectra

As reference the CIE 1924 spectral luminous efficiency function ($V(\lambda)$) was used to evaluate photometric characteristics. As test spectra the $V_M(\lambda)$-[4], the $V_{10}(\lambda)$-[5], the cone fundamental based V*(λ)-function[12], the first CIE 10° deviate observer spectral responsivity function ($y_{10,d}(\lambda)$)[7], and several real photometer responsivity functions have been selected. Figure 3 shows the spectral responsivity curves of the theoretical eye-responsivity functions. Figure 4 shows the spectral responsivity of the real detectors, here the detectors are characterized by their spectral mismatch error indices, f_1', based on the CIE recommendation to use for the $V(\lambda)$ function the standard Illuminant A as reference source[13].

Table *2* shows the tabulated f_1' values for the theoretical and practical receivers.

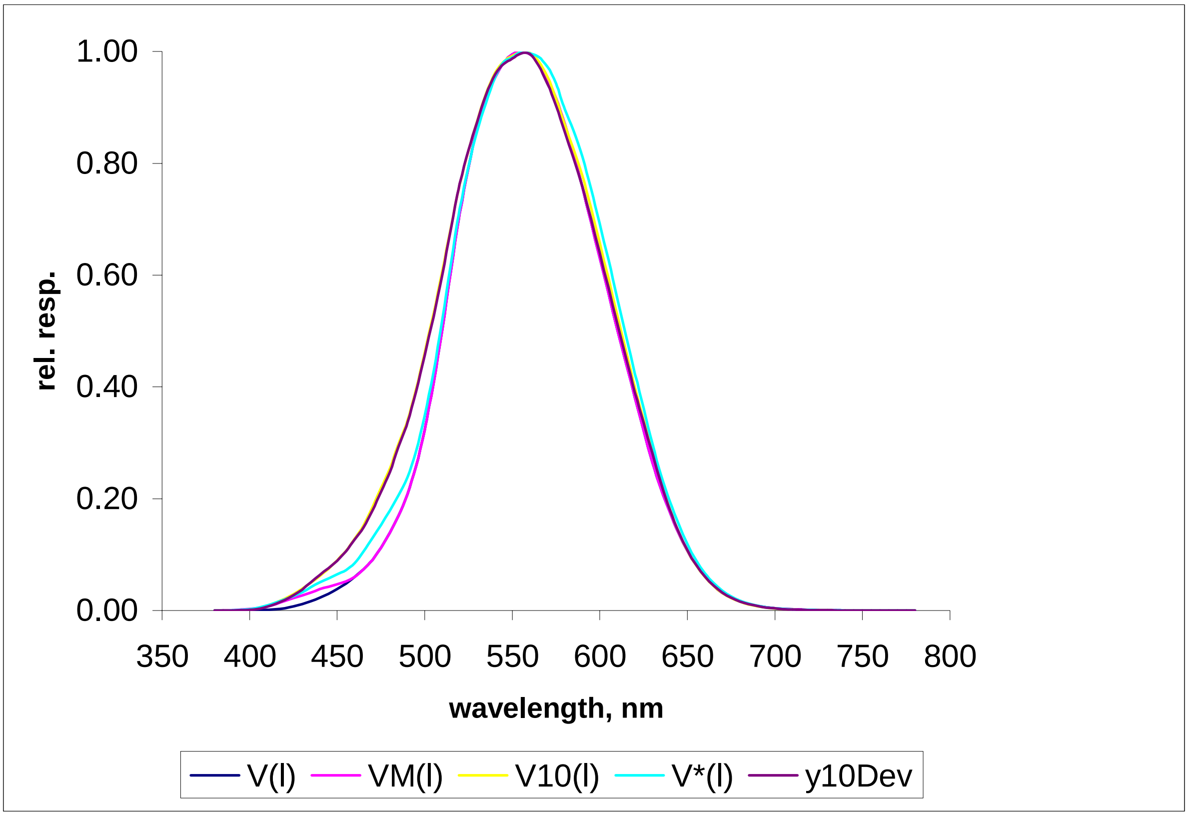

Figure 3 Spectral responsivity curves of the $V(\lambda)$, $V_M(\lambda)$, $V_{10}(\lambda)$, $V^*(\lambda)$ and $y_{10,d}(\lambda)$ functions

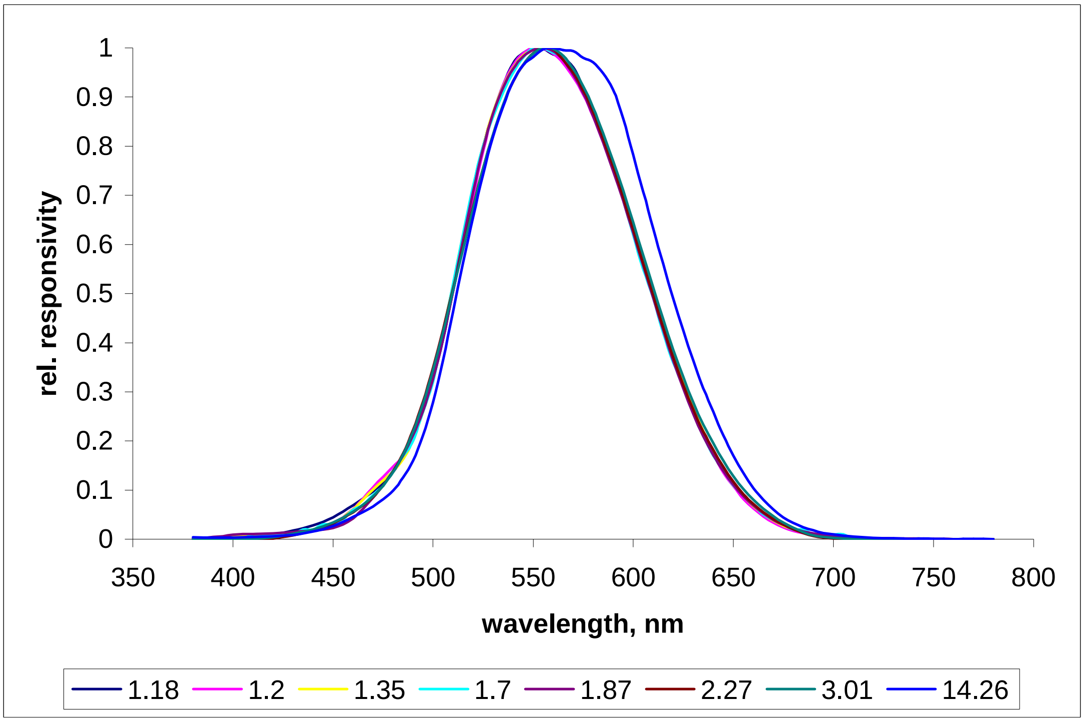

Figure 4 Spectral responsivity of a number of Si-photoelements and CCD arrays adjusted to the $V(\lambda)$ function, detectors are qualified by their f_1' values

Table *2* f_1' values of photometric functions and detectors used in the present investigation

	$f_1^{'}(V(\lambda))$
$V(\lambda)$	0
$V_M(\lambda)$ function	0,73
$V^*(\lambda)$function	5,65
$y_{10,d}(\lambda)$ function	9,47
$V_{10}(\lambda)$ function	9,51
CCD luminance meter-1	1,18
Photometer-l	1,2
y-channel of a tristimulus colorimeter	1,35
Photometer-2	1,7
Photometer-3r	1,87
Photometer-4	2,27
Photometer-5	3,01
CCD luminance meter -2	14,26

3 EXPERIMENTS AND DISCUSSION

3.1 Spectral mismatch error index evaluation

The simple comparison of the f_1' values of the different theoretical and practical detectors permit already some interesting conclusions: The $V_M(\lambda)$ function corresponds to an extremely good detector, usually not realizable in practice. But the tentative $V^*(\lambda)$ function deviates considerably from the standard $V(\lambda)$ function, it would not been accepted in most practical applications. Interesting is also that the f_1' values of the $V_{10}(\lambda)$ function and its deviate observer function are practically the same. There was only one CCD luminance meter that had a bigger f_1' value than the theoretical functions. This shows that for many applications one requests "better" instruments then the human eye, or one uses instruments that do not measure the quantity one is interested in (e.g. large filed illumination measured with 2°observer illuminance meter).

3.2 Photometric evaluation

Present standards prescribe the use of the CIE 1924 standard photometric observer to evaluate light source performance, irrespective of the viewing situation, and instrument manufacturers are forced to mimic the $V(\lambda)$ function, although in many situations the use of an other function would be more appropriate. Our endeavour was to compare the photometric values of detectors with different goodness of fit (f_1' values) of the $V(\lambda)$ function with those values one would obtain by using other spectral visibility functions. In this respect we calculated the spectral integrals of the following form:

$$\int_{380\,\mathrm{nm}}^{780\,\mathrm{nm}} S_\lambda s(\lambda)\mathrm{d}\lambda \qquad 1.)$$

where S_λ is the SPD of one of the light sources shown in Table 1 and $s(\lambda)$ the spectral responsivity of the photometric functions and detectors (see Table 2). Data were normalized to data obtained with the CIE 1924 standard observer function.

Figure 5 shows the differences detectors and photometric functions with different f_1' values will produced if calibrated with CIE standard Illuminant A and used for measuring light produced by different light sources. The errors of the measured values using all functions and detectors with f_1' < 3% will show the correct value within a ± 2% range. Even detectors and photometric functions with f_1' < 6% can be used safely with the tested white light sources. The situation is quite different if we use a photometer designed for the 2° observation in a situation where a large filed observer would be more appropriate. For the daylight sources (both real daylight and produced by p-LED or RGB-LED) the differences become 2 – 3 times higher. This should be kept in mind if one compares the effect of different light sources in different applications.

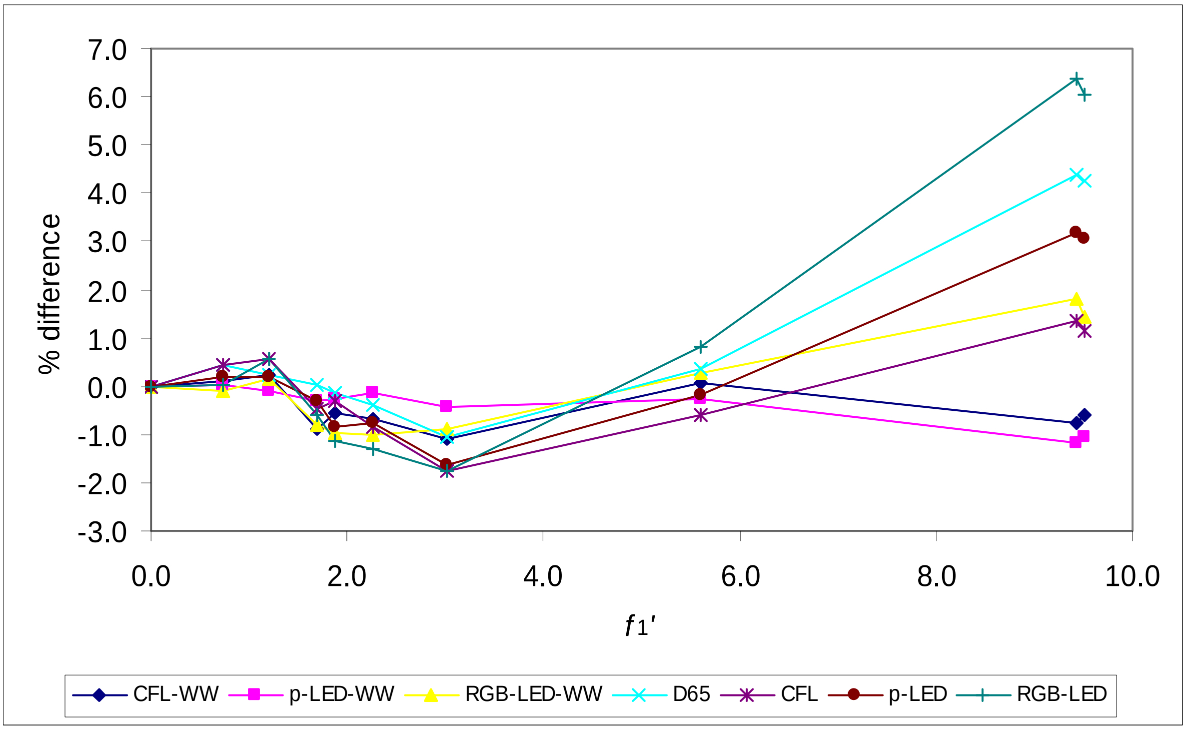

Figure 5 Per Cent difference of measured photometric values for the different light sources in case of the detectors and photometric functions relative to $V(\lambda)$ and CIE St. Illuminant A

4 CONCLUSIONS

In this paper we analyzed the effect of spectral responsivity on measuring accuracy if samples are irradiated with different light sources. As could be shown the visual mechanisms (foveal and para-foveal vision) and errors in the standardized spectral sensitivity curves show larger deviations as differences produced by general purpose instruments.

From our investigations we can conclude that illuminance and luminance measuring instruments with spectral mismatch error indices smaller than 3° will provide measurement results that show smaller scatter than produced by using a non-appropriate spectral luminous efficiency function. In this respect it is of particular importance that a change from the 1924 spectral luminous efficiency function to the $V^*(\lambda)$ function will not produce – at least for the tested light sources producing white light – a difference bigger than ±1%. The question might be different if colorimetric effects, either produced by coloured lights, or by shining white light on coloured surfaces are considered, but this is beyond the scope of the present paper, some aspects of this will be analyzed in a subsequent publication[14].

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WHAT THE ARCHITECTS ARE EXPECTING FROM THE ARTIFICIAL LIGHT?

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ABSTRACT

Working with light is not easy. Should it begin with architects and end with light engineers, or vice versa? Shall we find other ways to improve visions and predictions about our projects? It certainly evolves and we think that some thoughts of the architects may put some light upon an overview. How can we help intuition, use experience and references, success stories, as well?

The discussion about sustainability risks to be sometimes a kind of subject which everyone understands, but each person tumbles in a different way. It happens so with every comprehensive notion, quite old or new, with dynamic, whom perception cannot be but holistic, as architecture, for example.

INTRODUCTION

We tried to separate from the concept coverage “sustainable lighting” a few ideas resulting from a dialogue between the architects (authors), who have tried to systematize the wishes and the expectances from the lighting domain. We added some utopian and speculative ingredients too, but we know that the border between the science fiction and design is not defined clearly anymore. Starting from big to small, from general to detail, we should talk firstly of the light culture.

Figure 1 Liberty Center, Bucharest, 2008, Ostick & Williams and Dico si Tiganas, architects.
Space as a giant screen for light projections

1 LIGHT CULTURE

This should rejoin the interference principles of the specialists in the light production with those who implicate them in the project, designers, but also the critical opinions and the final users challenges as well.

The light culture should be remarked distinctly, unifying the efforts which are starting from the industry and sale with those from research and creation. The light is selling, like any other product or service, the concurrence generating performance, more and more also from the energetic and financial crisis which puts the accent on the efficiency. We are talking much more about the intelligent light or we should talk about the advanced light. The light culture needs what is motivating the issue and disposes the principles in any cultural, critical and theory domain. A critique of light should be interesting distinctly of the architectural space critique or of the design.

At the end of the year 2008, after the city hall of Cluj has decorated the public spaces with festal ornamental lights, the press has reacted quite strongly, interrogating the public and the specialists, trying to discern about the "operation" quality. The City Hall representatives have told that they succeeded to supply quite a lot of light to very low prices and with consumptions remarkable low. For the first time, the public has commented discontent of the colors and telling that he does not recognize the elegance seen in Vienna. Being interrogated, we answered that also this Christmas will go and perhaps that next year will be different, counting much more the current lighting and the gestures hardly reversible than this ephemeral actions, which can be seen through an objective critique as experiments.

Figure 2 CFR 1907 Cluj, Stadium, 2008, Dico si Tiganas, architects. Different light interplays.

2 LIGHT THEORY

After the critical accumulation it should be interesting a theory of light with history, evolutions, styles, currents, courses and avant-garde. The validated principles should be organized and structured , rejoining the perception elements, the composition, technology, norms and study of case about the masters works. theory has always the role of guidelines, we need.
Hereinafter, we grouped some ideas of the discussion about what the architects are expecting for, from the light under the titles: architectural design, energy, object design and art.

3 WHAT DO THE ARCHITECTS EXPECT FROM LIGHT?

3.1 Architectural Design:

The architects need operative instruments in order to help them to integrate the light in the projects and to work with it, as being a true construction material.

They need of the capacity to operate with the light in the concept phase, sketchily, approximately insightful and quite easy.

One of our displeasures is that almost always we intervene with the study of light and of installations necessary tardily after the space was been configured, trying only adaptation, corrections and scenography on an imposed stage. Thereby, the light does not contribute as generator to the space configuration but only to the final exploitation. How can be surmounted this failure?

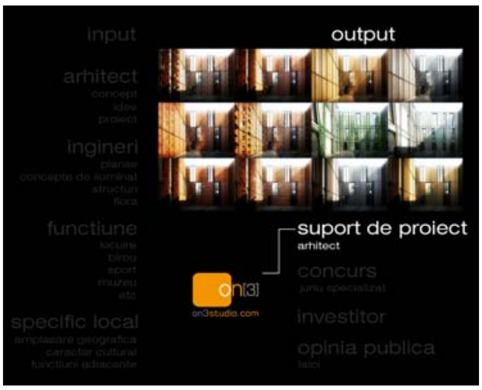

Figure 3 on (3) studio, Hamburg, image making concept. From the exhibition in Cluj Napoca, 2008.

We need simulation instruments to a conception level, but also of the theoretic guide support with references and examples. It is necessary a quick software, friendly, unsophisticated, which should captivate the unprofessional of light to the conceptual work with it. Hereinafter we need other instruments which should permit comparisons, options and decisions for the concepts adopting and not to send later, after the projects development to the habitual exit from the budget and the cancellation of ingredients which should make the concept being possible. We need indicators of generic costs, of classes for the lighting concepts or levels, e.g.: basic, normal, minimal, innovative, advanced, ultra performing. The intimate cultural component has his place in these levels. We need to be able to propose general budgets, in function of the theme expectance. All these should be synthesized in INDICATORS for the lighting conception.

3.2 Energy

The LCC concept, Life Cycle Costs must be extended to the lightening systems. As architects, we are interested how much costs the initial investment, the unitary energetic consumptions costs and along the construction functioning , the maintenance costs, sustenance and repairing. Without indicators and relevant methods of calculation, of CAD and BIM instruments, everything remains between intuition and personal experience. If we look towards the car industry we can see how clear are clarified the problems there: initial price, class, performances, consumption, safety, insurances, fees, buy-back values and subjective indicators of quality perception. We should believe that things are simple. They became simple due to a car culture well organized, global which get into the profoundly acknowledgment of the public. Even the children admit from tender ages the car brands, their performances and they have clear options. Why we should not have something similar for architecture and our actual subject, such as the sustainable light?

Figure 4 Light advertising for no light

3.3 Object Design

The light is source and effect. It is always dual, corpuscle and wave, necessity and decoration. The light signifies also the lamps design or the lightening devices which should signify anything in objects domain. The unconventional and the innovative have invaded the domain. We are talking about systems, accessories, command, interactivity, meaning about the high-tech zone but also about tradition, style, correspondences. We need lamps. We need good products delivered by the industrial design, unique one or products with signature and lamps which can be created or adapted for certain brands. We need adequacy possibilities of the lamps to the character of an architectural work. The lamps shall be applicable with the time spirit, with the lifestyle, apparel, perfumes, watches, vehicles and music. We would like to visit a museum of lamps of always and from everywhere, but to participate also to show-room exhibitions or even on the catwalk.

3.4 Light as Art

The light is an artistic domain. Public, private, of collection, static or in movement, the light is spectacle when it is thought. The meeting between the light and the public remembers of the speleologist incursions in the underground world dipt generically in obscurity. The acknowledgement, the physical and metaphorical discovery were present through the carbide lamps from the explorers headpieces and the magnesium flashes of the cameras. The universe of the fluid sculptures formation realized to the geological speed of the planet has became biotic in the light. Look a complex experience with an important emotional component. If exists a photographical art, a cinema art based on the light, called strongly “the seventh art”, why should not be exist even the eighteenth art, the dance, all the performing arts, trying sometimes to be a subject itself. We think that this state must be consolidated.

Figure 4 Bosh Rexroth Factory, Blaj, 2007, Dico si Tiganas architects. Involuntary light effects

4 CRAZY IDEAS

Finally, some ideas: speleologist, ballerina, anniversary cake and the barometer.
The “speleologist” is a frontal lamp which wares on head, on the coiffure, hat, cap or elastic support, being able to create a vague hallow, ambient but also being able to lighten continuously or when requested, like the far beam of vehicles, guided, if the person likes to read or to look for something.
Carrying a torch, a handlamp, a candlestick is something known.

The speleologist lamp should be agitated, put on the desk, used as static, when it is undressed. The lamp is attached directly to the person. In our absence the light is not necessary. It is an idea for the personal lightening, adaptable.

The “ballerina” is in the middle of the lightening circle of the stage projector: “In the spot light”. This follows her movements, evolution, emphasizing her into individuality and importance. We understand again that the light has no sense in our absence and the seeing, in this case of the sight, of the concentrated attention. As the video cameras can follow us in space, the technology of the sensors combined with the computation had generated automatic technologies of orientation.

Let’s imagine that on the road we should be guided by the guided light of spotlights , on the sidewalk. Their intensity should vary depending on the cram and hour. It is an idea for the interactive.
“The anniversary cake” wares a lot of figures and it is accompanied with candles. It is full of symbol, centripetal, being as an ephemeral jewelry which marks a moment. The anniversary torte is an hour which we devour after the candles were been damped down , getting down the moment, digesting it. How should appear a ritual lamp, anniversary, inedible but compensating this with interactivity and adaptability? How should it be to have each of us the anniversary lamp which we receive in a certain moment and we take it with us, by adding glowing components with the time march? It is an idea for an object possible traditionally, based on light.

The “barometer” is that incomprehensible device which tells us precisely based on millimeters mercury what happens with the weather by using anterior references. We always felt that it needs a translation in order to be understood by everyone. How should appear a “barometer” lamp which shall indicate us the weather tendencies and to be emplaced in the public area, littering cold or hot light, announcing the storm, the orange code or the heat summer? It is an idea for the informational public lightning , expressly coded.

Are you expecting to find out something unknown from the unpronounced secrets of architects? We don’t think so. The way between ideas, extravagances, projects, consecrations and traditions is long and discontinuous but fascinating. It is astonishing how we are progressing due to the war, disasters or wishes of new adventures and pleasures.

5 DON’T FORGET TO…

Our final invitations: procure the Encyclopedia of light, unwritten yet, visit the global Museum of light culture, in course of invention and don’t refuse yourselves , sometimes, an evening to a restaurant with glowing specialties, where the senses interfuse in a sophisticated manner into glasses and plates, which for the moment are seeking for a chef.

Figure 5 Tiago Mall, Oradea, 2008 …, Ostck & Williams and Dico si Tiganas, architects

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TEN YEARS OF SUSTAINABLE LIGHTING IN TRANSYLVANIA

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1 INTRODUCTION

The last decade has seen many improvements in curricula and teaching methods in Romanian universities. The building sector, particularly that of civil buildings, shows promising prospects of future development. In the last years, many projects were and are financed by the World Bank, BERD (European Bank for Reconstruction and Development) PHARE and ISPA programs to improve or refurbish the water supply network in many Romanian cities, the buildings thermal insulation of the buildings, to enhance the thermal energy savings, to improve the quality of the environment. There is a great demand for up-to-date technology and know-how for a resource-conscious building, renovation and energy planning.

Lighting represents an important part of building energy consumption in the EU – around 10% of the total electricity consumption, ranging from 5% (Belgium, Luxemburg) to 15% (Denmark, Netherlands, and also Japan). The global electric lighting energy use may be split in four sectors: services 48%, residential 28%, industrial 16% and street lighting and other 8%. Lighting systems design trends are dynamics both in time and between countries. The recommended illuminance level represents only one of the design parameters, but it is determinant for a lighting system and its energy consumption.

Lighting electricity consumption accounts for about 20 to 30% of the total energy required by an office building. On average, the investment cost of lighting facilities for an office building works out at around 1 to 2% of total investment. The power density for standard fluorescent lighting installations varies from 13 to 20 W/m^2. Recent progress in equipment and design demonstrates the possibility to reduce these values in the range of 7 to 10 W/m^2

Savings will vary by country, depending on existing baseline conditions. Energy saving measures in lighting must be accepted by the users and must be associated with an improvement of their standards working condition, having in mind even the fact that the annual lighting consumption of an office worker is of the order of one hour of the his/her salary cost.

2 THE LIGHTING ENGINEERING CENTRE LEC

The Lighting Engineering Centre **LEC** was founded in April 2000 at the Technical University of Cluj-Napoca, following the accomplishment of the CME-03551-97 Tempus-Phare project *Lighting Engineering Centre – LEC – an excellence centre for consultancy and continuing education in the lighting field in direct link with the needs of the labour market".* This project, developed between December 15, 1998 – March 14, 2000, concentrated the efforts of university professors from Cluj-Napoca, Barcelona, Helsinki and Naples.

Figure 1 Professors Ramon San Martin Paramo and Florin POP

The main objective of LEC was and is to create a regional pole of interest in lighting in the North-Western region of Romania, linked with the needs of the labour market and the improvement of the educational curricula. Here continuous formation in the lighting field is being provided by seminaries and workshops, short postgraduate courses dealing with the Management of Electric Installations and Lighting, research studies on modern, energy efficient lighting systems, bi-annual **International Conference ILUMINAT** (starting with 2001), editing lighting journal **Ingineria Iluminatului** (Lighting Engineering) journal – the Romanian scientific journal in lighting field, half-yearly edition, summer courses. The Lighting Engineering Centre concludes the work developed at the Technical University of Cluj-Napoca in the area of lighting education and research.

Figure 2 ILUMINAT 2001, Opening Lecture of Prof. Ir. Wout van BOMMEL, CIE President

Figure 3 In 2001, together with BEST (Board of European Students of Technology) office of the Technical University was developed a European Summer Course “Light & Lighting, Ambience, Management and System” with the participation of 21 students from Europe. The course presentation and the written support were performed in English.

Dr. Florin POP was invited to participate at the International Seminar **Advanced Daylighting and Electric Lighting Systems in Architecture, 9–22 October 2003**. The Seminar was organized by the Light & Architectural Environment Laboratory – LAEL, Kyung Hee University, Seoul, Korea, director Prof. dr. Jeong Tai KIM. Professor Florin POP presented the conferences "Recent Research Trends on Advanced Daylighting System", for the Master students in Arhitecture and "Lighting in Eastern Europe: A Romanian Case Study", for LAEL members. Two agreements for university cooperation were signed: The Memorandum of Understanding between the College of Architecture and Civil Engineering, Kyung Hee University, Korea, and the Universitatea Tehnică din Cluj-Napoca, Romania (signed by Prof. Florin POP on behalf of the Rector of U.T.C.-N.) and The Memorandum of Understanding between Light & Architectural Environment Laboratory, Kyung Hee University and Lighting Engineering Center, Universitatea Tehnică din Cluj-Napoca.

Figure 4 Professors Inhan KIM (chairman, major in Architecture), Jeong Tai KIM (director of LAEL), Florin POP, Byung Ik SOH, Dean, Hee-Cheul KIM, Sun Kuk KIM (chairman, major in Architecture)

3 LIGHTING PROJECTS

LEC was involved in several interior and public lighting projects, and the red line was to propose high quality and energy efficient solutions, and also to sustain the activity of the center. LEC have worked only for City Councils and Cluj Universities.

3.1 Rehabilitation of pedestrian lighting in residential districts of Cluj-Napoca and Dej

The public lighting for pedestrian pathways or for mixed traffic pedestrians/vehicles between blocks of flats was made in the same time with the urban structure. For this reason the lighting system was designed and installed between 1960-1990. The existing system presents many deficiencies and cases of destruction, determined by vandalisms, physical and technical use, inadequate protection, and low quality of lighting equipment.

The City Council Of Cluj-Napoca initiated, in May 2004, a study conducted by the Lighting Engineering Center of the Technical University of Cluj-Napoca for the rehabilitation of pedestrian lighting in two residential areas of our city: Grigorescu and Gheorghieni districts. The other areas were studied by the Romproiect Electro Company. A similar project was conducted for the Dej district Dealul Florilor.

The aims of these studies were: a) to survey the existing situation; b) to present the new European and national regulations concerning this matter; c) to propose a modern energy efficient system, and d) to generate specific GIS maps of the whole lighting system and electric network.

The survey have involved our students in order to determine: a) position and type of luminaries; b) Columns types, lamps, electrical boxes, c) areas with special maters.

Proposals for a modern lighting system were targeted to obtain a high quality photometric environment and energy efficiency. The design was based on the quality requirements stipulated on the Romanian norms NP 062-02 and SR EN 60598 and European or CIE guidance. For instance, the proposed systems on the Grigorescu district will use an installed power 20,493 W instead of the used power 3,062 W of existing old lamps.

The LEC has proposed a GIS system, based on the maps received from Map Office of the City Council, using AutoCAD software from AutoDESK. The following attributes have been allocated to each light point: district, column identification number, column type and height, lamp type, luminaire type, functional status, date of luminaire mounting, date of last lamp replacement, electrical box characteristics. The GIS map and technical audit of the lighting installation offer to the Cluj-Napoca municipality a very useful database for a well-preservation of the facilities of this public utility and for the further development of the necessary maintenance service.

An important aspect was related to avoiding the light pollution. The luminaries are mounted on the top of the columns, four meters tall. The distribution of the light is rigorously directed to the pedestrian area, to illuminate only the pathway in their immediate surround.

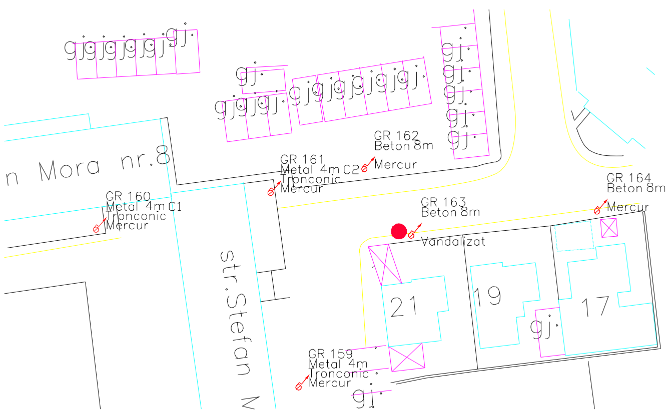

Figure 5 GIS maps for district lighting

3.2 Interior lighting

LEC was involved in the projects for “Nicolae Balcescu” High-School and for UBB *Academic College and* Swimming pool. For all three community buildings, we have choose efficient and state-of-the-art solutions in order to create models for other local projects.

The “Balcescu” high-school, built in 1879, changed during time from gas lighting to electric lighting but without lighting quality (illuminance under 100 lx, low colour rendering and flicker). A brand new lighting solution was created on 2005, with T16 lamps, electronic ballast and asymetric blackboard lighting and direct/indirect general lighting, in respect to CIE regulations.

Figure 6 “Balcescu” High-school before (left) and after (right) rehabilitation

The Academic College building was erected in the “Art Deco” style, in 1935. The initial solution for cove lighting from 1935 is unknown. Starting from the lamp base found in coves we suppose that it was some kind of linear incandescent lamps (which means that the maintenance of the coves at 12 m height was extremely difficult). Some reparations were made in the ’70s and on the central coves bare battens luminaires with T12 2x40 W lamps were installed. The owner requested for a very flexible of the main hall to adapt easily for different events: concerts – static lighting, conferences, meetings, PhD presentations – dynamic lighting. For this reasons it was necessary to adopt a lighting control system, efficient and economic. As the concert hall use an indirect lighting system, with very long coves, it was compulsory to use T16 lamps (class "A" of energy efficiency) with dimmable electronic ballasts.

The Academic College Hall lighting system did not alter the building spirit. The newest solutions were used there, some of them for the first time in Romania.

Figure 7 The Main Hall lighting system

3.3. LEDs issues

From many different points of view, the LEDs issues are similar to those of early CFLs. There were great expectations and high prices with quality problems. As well, it took more than 10 years to have a stable CFLs market.

Since 2007, several projects have been started in Cluj-Napoca based on LEDs’ long-life, small dimensions and alleged energy efficiency. These projects have been mostly targeted on exterior architectural lighting, rather than on interior lighting. Few LED databases were originally available, so the lighting systems design has been based on software imagery or *in-situ* trials.

A few conclusions may be drawn after the development and installation of lighting systems for two squares and several buildings in the city of Cluj:

- excellent solution on color lighting, even if limited to new buildings;
- this solution has raised problems for historical buildings (color rendering, LED floodlight too close to buildings and all building imperfections revealed by light);

- a higher number of luminaries have to be used for a building, compared with metal-halide solutions;
- higher investment costs as compared to traditional lighting systems;
- exterior cabling on historical building is problematic;
- luminaire orientation is essential.

Based on our own projects and experiments, we may conclude that formation of LED-trained lighting designers is necessary for the success of future high quality lighting projects. Strong cooperation with architects is compulsory.

4 PROGRAMS PROMOTING LIGHTING ENERGY EFFICIENCY AND ENERGY SAVING MEASURES IN RESIDENTIAL BUILDINGS

The Lighting Engineering Center of the Technical University of Cluj-Napoca, Romania was recently involved in two programs for promoting lighting energy efficiency and energy saving measures in residential buildings: EnERLIn – European Efficient Residential Lighting Initiative, an EIE-SAVE program to promote Compact Fluorescent Lamps in the residential sector, and CREFEN – Integrated software system for energy efficiency and saving in the residential sector, a Romanian CEEX (Excellency in Research) program.

The Questionnaire and Promotional campaign to promote the CFLs use in residential area was developed on four levels, by the UTC-N - Lighting Engineering Center - with the support of three partners of the programme: ELECTRICA Distribution Local branch, on a volunteer cooperation, and EnergoBit and PRAGMATIC Comprest electric dealers, on the sub-contractual basis. The whole average number of the CFLs is **2.86 units** per people (family, house), received from 8 questionnaire campaigns (7 EnERLIn, 1 CREFEN), 892 people/ houses, 2551 used CFLs, November 2005 – May 2008. The CFLs distribution power in Western Romania is presented in the Figure 8, as a result of UTC-N EnERLIn Questionnaire Campaigns, during the period of November 2005 – May 2008. Favorite powers for CFLs are 13 W and 20 W.

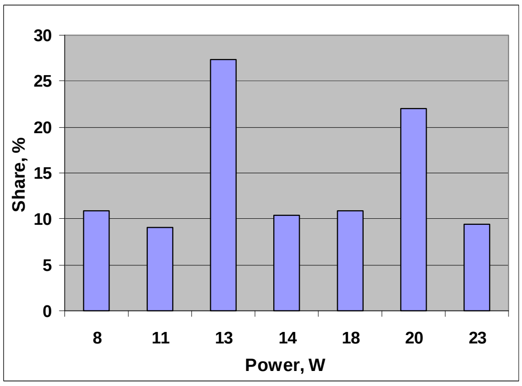

Figure 8 CFL distribution power in Romania
597 households, 1988 CFLs, 2005-2008

The luminaires equipped with CFLs with increased energy efficiency currently have a large development. In the frame of the EIE-EnERLIn program, a selection of the most representative luminaires dedicated to CFL use has been realized – see Figure 9.

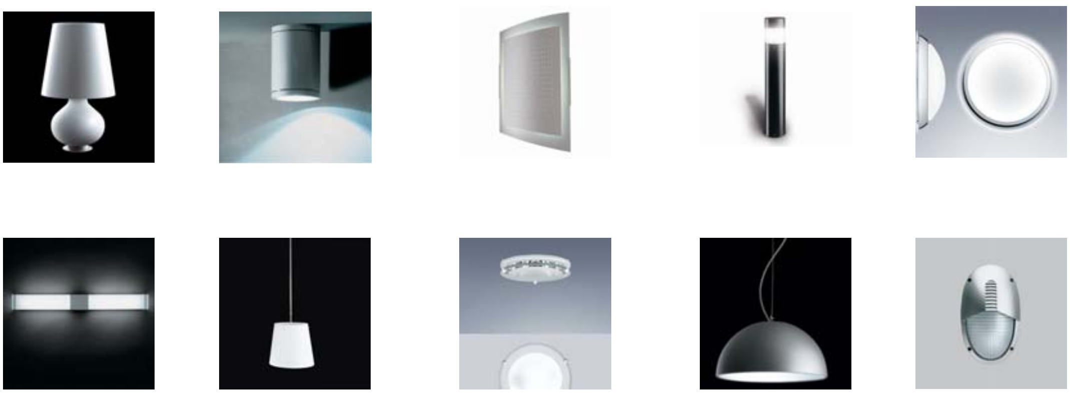

Figure 9 10 most representatives luminaires dedicated to CFL use

Most residential users are less knowledgeable of technical (qualitative and quantitative) and economical aspects concerning (a) real contribution of lighting for energy consumption; (b) energy efficiency of lamps; (c) quality of the obtained lighting. The general conditions of illumination inside a room are the result of combining the quality of the desired lighting with the photometrical characteristics of the furnished room (for example, the sizes and shape of room, the reflectance of the room surfaces). Among the factors characterizing room lighting we mention the photometrical characteristics of luminaires and their setup. The study realized by the Lighting Engineering of the Technical University in Cluj-Napoca in the frame of the CREFEN research program presents the selection parameters of a luminaire to be considered for the residential sector, the thresholds for the increase of use of energy efficient lighting in newly built households, the requirements concerning the integration of compact fluorescent lamps (CFL) in the design of residential luminaires. In the case of the design of interior lighting installations we have to consider a series of principles and methods relevant to energetic efficiency. A simple software application allows any user with minimal knowledge of information technology to design the lighting installation in his/her own household based on energy efficiency criteria.

A relatively recent study establishes that lighting for kitchen, living room, bathroom and exterior areas consumes approximately 50% of the total lighting consumption. 25% of the lamps installed in households consume 75% of the total lighting energy. Approximately 20% of energy is consumed by portable luminaires, powered through wall outlets.

The analysis of CREFEN program reply sheets (November 2005) on a total of 290 households has shown that the installed power for lighting in the analyzed households has an average value of 853 W - Figure 10. With an average surface per home of 37.39 m2, (CREFEN - phase report 2005) we obtain an average specific installed power of 22.81 W/m2, with a preponderant incandescent lighting.

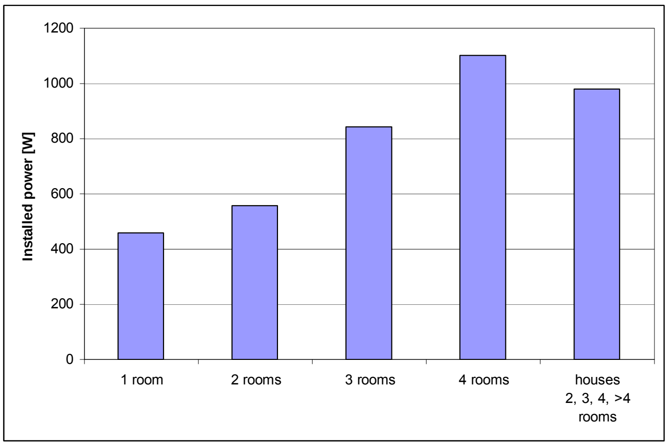

Figure 10 Average installed power for residential lighting - source CREFEN

5 LIGHTING EDUCATION

Our basic activity is to teach one semester of lighting for 3rd year in Building Services Faculty. This involves more the basic of lighting technology and design and a small lighting project using Dialux. Lighting education was the first step in preparing new generations of lighting specialists. From 1998, LEC launched the six weeks postgraduate courses in Lighting Installations Management which include beside lighting, architectural and management chapters. Till 2000 we manage to prepare 30 professionals in lighting. In 2001 we supported a European summer course on lighting with BEST (Board of European Students of Technology) organisation.

We also should mentioned the organization of ILUMINAT Conferences, started in 2001. These conferences gave the chance to the people to listen to excellent presentations from speakers from all over the world and rise debates on various subjects. Speakers like (alphabetical order) Wout van BOMMEL, David CARTER (today), Luciano di FRAIA, Liisa HALONEN, Koichi IKEDA, Jeong Tai KIM, Janos SCHANDA, Axel STOCKMAR (which attended all conferences) and so many others enhanced the level of interest on events and, together with Romanian participants, managed to make an excellent place to exchange ideas and strength the lighting community.

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POWER QUALITY ANALYSIS OF BUILDINGS LIGHTING INSTALLATIONS

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ABSTRACT

Many of the devices designed to reduce the energy consumption can have a very detrimental effect on the power quality of the system they are fed from and it is thus short-sighted to heavily promote such devices without considering these effects. Prevention is far more cost effective than finding a cure for the problem after the fact. Therefore electricity utilities and customers must become familiar with these products and their possible impact on the power system investigated. One example of such a product is the compact fluorescent lamp with electronic ballast which is is being promoted as an alternative to the incandescent lamp. It consumes much less energy with comparable luminous output and lasts longer, however if used in large numbers have a very detrimental effect.on power supply quality. Therefore while these products are designed to reduce energy consumption, care must be taken to evaluate the possible impact they may have on the system.

1 INTRODUCTION

As defined by ISO, the power quality represents all the characteristics and the particularities of a product or service, which materialize the ability to respond to the potential or expressed needs of the user.

According to IEEE, the power quality is the concept of the supply and of the tying down of sensitive equipment in a manner that allows proper operation of them.

In literature, the term of power quality is used, but in a wider sense, referring to both the problem of harmonic pollution generated by non linear loads, and other types of electromagnetic disturbances occurred in power systems.

Lighting is an important consumer of electricity and an important component of cost of use in many buildings. At European level, the use of electricity for buildings lighting is 50% for offices, 20-30% for hospitals, 15% for factories, 10-15% for schools, and 10% in the residential sector [1].

2 DISTURBANCES IN LIGHTING

The characteristics of power voltage in network provider (frequency, amplitude, wave shape, voltage three-phase symmetry) are subject to change during normal operation of the power network due to loads variation, disturbances generated by certain equipment, or of damages that have external cause.

Sudden interruption of voltage supply followed by a restoration of voltage after a short period of time is a voltage gap supply and cause interruption of the functioning of the lighting appliances.

The connecting of lighting systems in electric power supply installations where the voltage has relatively frequent variations - fluctuations - cause the flicker effect (the impression of instability of visual sensation induced by a light stimulus, whose luminance or spectral distribution fluctuates over time (EN 50160), with significant effects on the quality achieved lighting. Sustainability fluorescent lamps or discharge lamps depend mainly on the number of coupling cycles. The effect of power fluctuation is small.

On the other hand, the lighting installations may place in lighting network supply significant electromagnetic disturbance: - *the harmonic voltage supply*, caused by non-linear characteristic of the electrical discharge; - *unbalanced*, because electric lamps are connected in phase; - *disturbance of high frequency* in the case of electronic ballasts; - *voltage gaps* due to the need of reactive power (the presence of inductive ballast in discharge lamps).

Disturbances caused by electric lighting must be reduced below acceptable limits, and in this sense, the electricity provider can monitor these disturbances and adopt, together with the consumer, the measures necessary to limit their levels [2].

Harmonics are a consequence of nonlinear loads which "consumes" the deformed shapes of the voltage, and as a consequence of movement of such currents will occurre deformed voltages [3].

The unbalanced caused by lighting systems can be solved in general case, by a judicious connecting of the light source on the three phases when the consumer is connected to a three-phase network. In the case of single connections, the provider has the obligation of solving the problems [2].

3 THE HARMONIC POLLUTION

The harmonics are signals whose frequency is a multiple of the fundamental frequency. Depending on rank of the harmonic, defined as the ratio between harmonic frequency and the fundamental frequency, the curves of voltage or current produced by polluting sources may be: - harmonic if their rank is an integer; - subharmonic if their rank is subunitar; - interharmonic if their rank is different from an integer multiple of the fundamental frequency.

Harmonic analysis is based on Fourier Postulate, that any continuous periodic function of period T can be represented by a sum of fundamental sinusoidal component and a series of sinusoidal harmonic components of higher order, which are whole multiples of the fundamental frequency. Harmonic analysis is the process of calculating the amplitude and phase of the fundamental signal and of the higher order harmonics.

The deformation of the voltage/current wave is characterized by the following indicators:
a) the distorting residue, which represent the wave which is obtained from a regular given wave after suppression of the fundamental harmonic;
b) the harmonic level, γ is the ratio, expressed as a percentage of the actual amount of the considered harmonic (An) and the actual amount of fundamental component (A1): - for the voltage curve $\gamma_u = U_n/U_1 * 100$ (%); - for the current curve $\gamma_i = I_n/I_1 * 100$ (%).
c) the distortion coefficient δ is the ratio, expressed as a percentage, of the actual amount of distorting residue and the actual amount of the fundamental component.

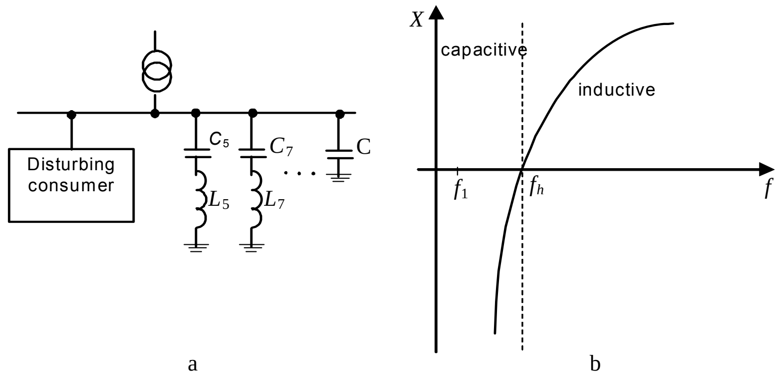

Figure 1 Harmonic filter on the bars of a disturbing consumer (a) and frequency variation of reactants of a resonant circuit of a passive filter (b) [4].

There are known several effects on the harmonic waves on the power network. These effects depend on the shape and location (position) of the higher harmonics source, and the configuration and characteristics of the network where these harmonics are propagated:

- emergence of the resonance phenomenon on the higher harmonic frequencies, which can produce currents and voltages over the normalized limits;
- overpowering and possible damages to the capacitors batteries;
- the break of the insulation of cables and wires when overvoltages apair;
- influence on the accuracy and veracity indications standardized measuring devices;
- increased loss and heat of the transmission cables, transformers and rotating machines;
- mechanical oscillation of synchronous and asynchronous machines;
- the interference phenomenon with the microprocessor and relays protection management.

Limiting harmful emissions in the form of harmonics is achieved by mounting the passive filters, active filters and mixed filters. Passive filters contain a number of resonant series circuits LC (Figure 1) for harmonics taken into account, giving a zero reactance for harmonics of rank h to be filtered (Figure 1 b).

Note that for the fundamental harmonic f1 each of the resonance circuits of the filter has a capacitive character, and the equivalent capacity must be taken in regard in analyzing the issues of power factor compensation. Where the capacitive input of the harmonics filter to compensate reactive power is not enough, on the power supply bars it may be connected the capacitors battery C.

In most practical cases, the fitting of a passive filter for harmonics of rank 5, 7, 11 and 13 ensure that the disturbance levels are in the allocated disturbance levels.

Active filters provide monitoring of the electrical quantities (voltage or power) waves form on the consumer terminals (by CPU (Central Processing Unit)) and ensure the development of a sinusoidal wave determined by correcting the operation of the disturbing consumer. Active filters are used to correct the power wave (FAC) - Figure 2 a, and to correct the voltage wave on the power bars (FAT) - Figure 2 c.

In the case of the current active filter (FAC) the power curve of the consumer circuit (through power translator TC) it is monitored and the filter determines a signal (Figure 2 b) which provides the wave correction so that the power network to be absorbed a sinusoidal electric current, with the same amount of the actual power absorbed by the disturbing consumer.

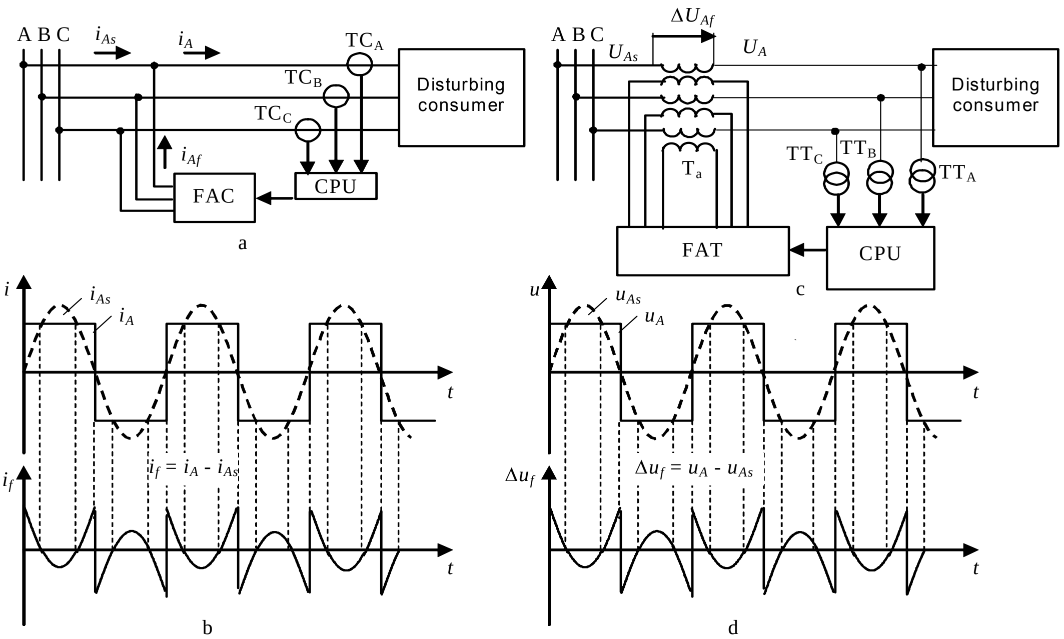

Figure 2 Active power filter (a), the shape of the currents of the circuit for phase A (b), active filter voltage (c) the shape of the voltage circuits for phase A (d) [4].

In the case of the voltage active filter (FAT) the voltage wave at the disturbed consumer terminals (through voltage translators TT) it is the monitored (by CPU), and the filter results a voltage Δu_f which connects in series with the consumer load using an auxiliary transformer Ta, so that the voltage on the power bars to become sinusoidal, with the same value with the actual voltage at the terminals consumer (Figure 2 d).

Mixed filters are used in particular to limit the nominal power of the active filters and comprise a passive filter for the main harmonics (usually 5, 7, 11 and 13) and an active filter for the other harmonics.

The choice of the type of filter is made by the consumer, the solution adopted being dependent on actual harmonic spectrum emitted by the consumer, the allocated level of disturbance, and economic aspects [4].

In many office buildings and commercial facilities, the fluorescent lighting, the ventilation-air conditioning equipment and information/communication (computers, printers, faxes, copying devices) contribute significantly to the apparition of unsinusoidal currents in buildings electrical installations.One of the major sources of buildings harmonic pollution is the fluorescent lamps.

4 FLUORESCENT LAMPS

Fluorescent lamp or fluorescent tube is a mercury vapor discharge lamp at low pressure. The prime of the discharge is made at discharge lamps by overvoltage (shock voltage) decreased slowly, by ionization, of the resistance of the environmental discharge or by combining the two systems. To stabilize the discharge is used the ballast. It must meet the following conditions: to ensure the stabilization of discharge, to produce a high power factor, to have a low percentage of harmonics, to be fitted with systems to mitigate the radio or TV perturbances, to provide a quiet operation in a time living as long.

Compact Fluorescent Lamp – CFL - combine a high luminous efficacy and colorimetric characteristics of a good low power and high life expectancy (on average 8000 hours to 1000 hours for GSL). Currently manufactures make two types of CFL, one with a full construction (with magnetic or electronic ballast built-in socket) and the other one with a modular construction (with ballast independent). The first type is intended to directly replace the General Service Lamp - GSL existing lighting; the second requires an adjustment or specific lighting bodies. The fluorescent powder is the type of tri-phosphor with a light emission in three narrow bands of color.

The classical types of ballast may be replaced with the electronic ones with frequency converter (up to 20 kHz). Increasing the frequency leads to the elimination of flicker phenomenon. [5].

As a general rule is recommended to use CFL with color value greater than 80 and those with embedded electronic ballast. CFL magnetic ballast is more difficult and has the risk of unbalance the lighting devices. Moreover, major manufacturers no longer produce conventional CFL ballast (magnetic). It is not profitable GSL replacement of interior spaces where they operate a relatively small number of hours. [6].

5 THE ANALYSE OF DISTURBANCES

Electronic ballast offers a number of advantages which include: increasing efficiency, eliminating flicker and stroboscopic effect, instant ignition, increased life of the lamp, unity power factor, the possibility of regulating the flow of light.

On the other hand, the electronic ballast can create problems of harmonic pollution on the power network and electromagnetic interference with other electronic equipment. If you do not take precautions, the wave power absorbed by the rectifier and filter is highly distorted (Figure 3), with a high content of harmonics.

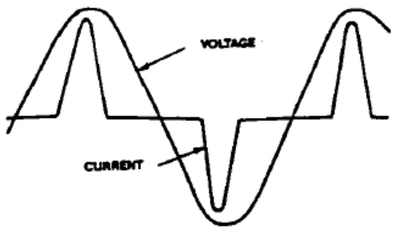

Figure 3 Wave power absorbed by the rectifier and capacitive filter [7].

Although the fundamental current wave is in phase with the voltage, the power factor can be decreased due to harmonics, the value 0.5-0.6. There are two ways to ameliorate this problem-correction using active or passive power factor.

In the passive scheme, a passive low-pass filter is used before the rectifier (Figure 4). This filter not only reduces the harmonic content to acceptable levels, but also has the role of a filter for electromagnetic interference that would propagate to the network. In addition, this filter protects electronic ballast from transient currents that may come from the network. Electronic ballasts using passive power factor correction raises the power factor to a value of 0.90-0.96 and a distortion factor of the value of 22-32%.

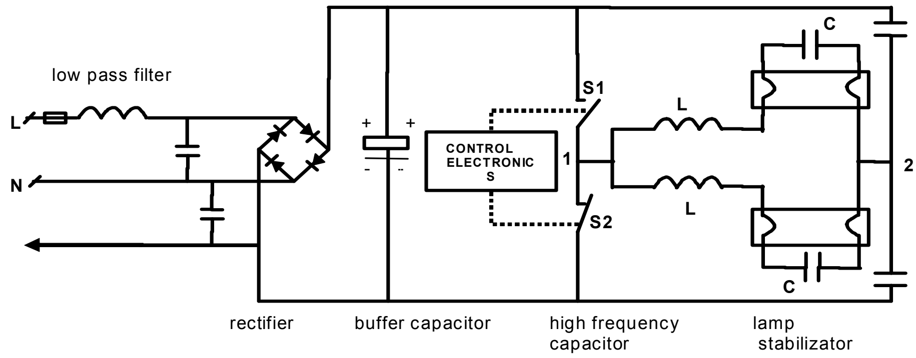

Figure 4 Circuit diagram of an electronic ballast with passive power factor compensation [7].

The active power factor correction is implemented by introducing a high-power regulator between rectifier and capacitive filter. With this type of circuit (Figure 5) it is conducted a almost sinusoidal current wave, the power factor having a value close to 1 (99.8%) and the distortion coefficient is below 5% [7].

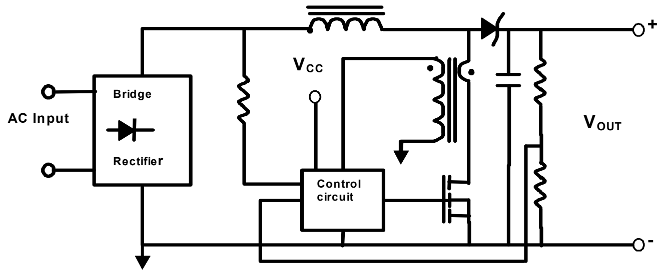

Figure 5 The circuit diagram of an electronic ballast with active power factor correction [7].

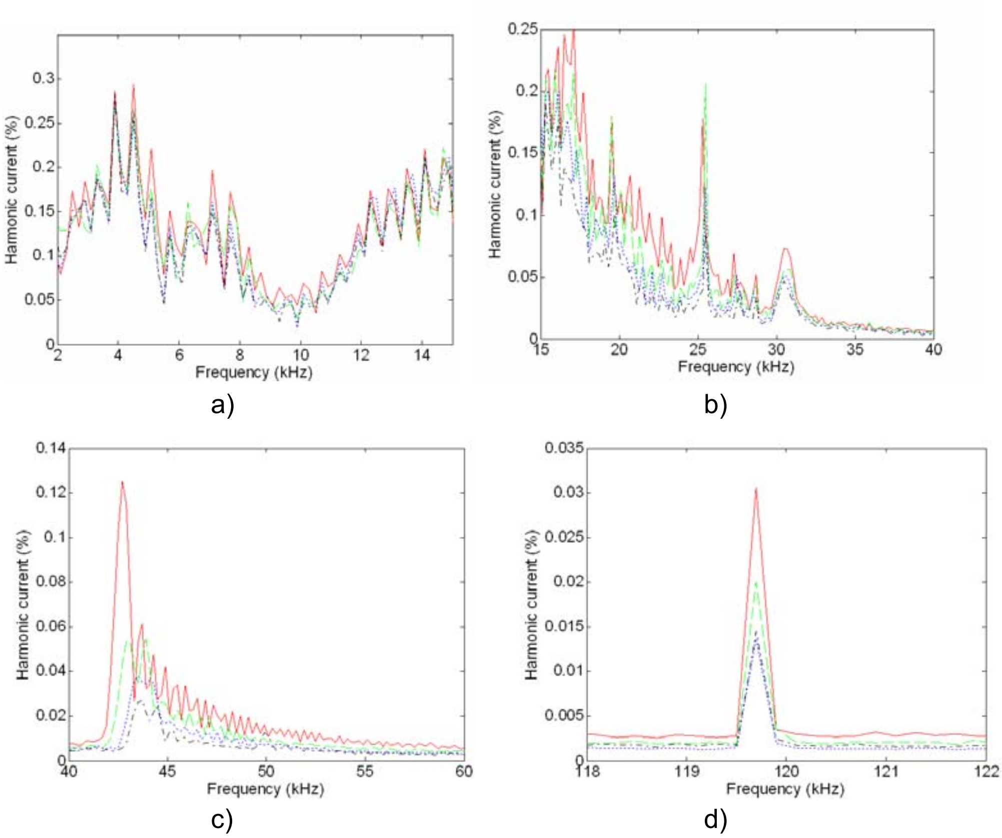

Figure 6 Spectrum current frequency band: a) 2-15 kHz, b) 15-40 kHz, c) 40-60 kHz; d0 120 kHz, for a lamp (red), two lamps (green), three lamps (blue), and four lamps (black) [8].

An interesting analysis of high frequency current disturbances (2-150 kHz) due to modern fluorescent lamps, made by comparing the measured frequency spectrum of up to four lamps in operation simultaneously, indicates the existence of some stationary component (eg 119.8 kHz) while other components show a variation in the frequency spectrum (Figure 6). Measurements were performed in an office building, each lamp containing two electronic ballast and three fluorescent tubes of 28 W each. Ballasts are designed for a rated voltage of 230 V and have a power factor equal to 0.98.

In Table 1 are shown values of the current harmonic disturbances, as a percentage of the fundamental, depending on the number of lamps. From the analysis, it appears that the spectrum of harmonics is independent of the number of lamps [8].

In Figure 7 experiments are presented for three groups of lamps, the first containing 12 lamps CFL, the second group 24 of lamps CFL, and the third with 36 lamps CFL. The lamps that were used have a power of 14 W. It is noted that current harmonics tend to gather, rather than cancel each other [9].

Table 1 The level of harmonic currents, depending on the number of lamps [8].

Harmonic level / Number of lamps	3	5	7	9	11	13	15
1	7.2	1.7	1.9	1.7	0.6	1.3	1.0
2	7.7	1.7	2.1	1.7	0.4	1.3	0.9
3	7.7	1.8	1.9	1.7	0.5	1.3	1.0
4	7.6	1.8	2.0	1.7	0.5	1.4	1.0

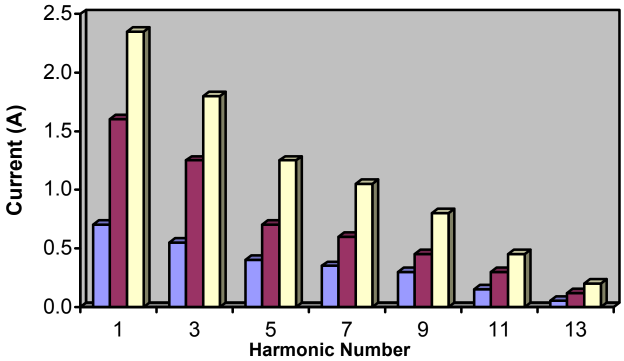

Figure 7 The level of current harmonics for the three groups: group 1 (blue), group 2 (cherry), group 3 (yellow) [9].

Making a comparison between two types of lamps, a fluorescent lamp (fluorescent tube) of 40 W and a compact fluorescent lamp of 11 W show the compact fluorescent lamp increased energy efficiency compared to incandescent lamps, but also that using electronic ballasts with enhanced quality together with harmonic filters will improve the quality of lighting, the light intensity, the power factor and it will reduce the disturbances than if it use a simply capacitor to increase the power factor. The results of different measurements are shown in the following tables [10].

Table 2 Performance of fluorescent lamp 40 W, equipped with various types of electromagnetic ballast [10]

Type of CFL	Voltage, V	Current, A	Power, W	Power factor	U_{ON}/U_{OFF}	Lux	THD, %
A	240	0.36	49.9	0.565	167/133	93	8
B	240	0.37	50.3	0.541	171/140	88	7

Table 3 Performance of fluorescent lamp 40 W,equipped with electromagnetic ballast, with or without capacitor [10].

	Voltage, V	Current, A	Power, W	Power factor	THD, %
Without capacitor	240	0.372	53	0.593	8
With 3μF capacitor	240	0.273	51.25	0.784	28

Table 4 Performance of fluorescent lamp 40 W, equipped with various types of electronic ballast [10].

Type of ballast	Voltage, V	Current, A	Power, W	Power factor	U_{ON}/U_{OFF}	THD, %
A	240	0.171	39.10	0.953	134/48	11
B	240	0.294	36.90	0.521	88/55	40
C	240	0.149	33.21	0.928	118/42	13
D	240	0.159	36.84	0.959	60/32	11

Table 5 The level of harmonic currents in fluorescent lamp 40 W, equipped with electronic ballast [10].

Component, n	3	5	7	9	11	THD%
Level of harmonics, γ_i	24.8	19.5	11.3	7.4	4.3	46

Table 6 Performance of CFL lamp 11 W, equipped with various types of electromagnetic ballast [10].

Type of CFL	Voltage, U_{ON}/U_{OFF}	Current, mAr	Power, W	Power factor	Lux	THD, %
A	180/144	146.3	18.1	0.511	14	8
B	186/138	149.9	18.5	0.519	18	7
C	187/140	151.3	18.8	0.514	17	8
D	188/120	154.4	18.1	0.488	14	7

Table 7 Performance of CFL lamp 11 W, equipped with various types of electronic ballast [10].

Type of CFL	Voltage, U_{ON}/U_{OFF}	Current, mA	Power, W	Power factor	Lux	THD, %
A	100/56	104	11.8	0.511	24	40
B	82/54	114	13.5	0.519	23	48
C	98/56	112	12.8	0.514	20	42
D	142/84	121	13.4	0.488	19	46

Table 8 Impact of CFL to use lamps for a building with active power required of 100 kVA [10].

% CFL load	1.5	4.1	9.4	26.3	50
Total power factor	0.84	0.82	0.78	0.65	0.54
Voltage distortion, %	0.3	0.7	1.5	4.4	5.4
THD, %	1.7	4.5	9.8	23.5	55

Four case studies were conducted with different CFL group loadings, to analyse their impact on a distribution system.
A. Case Study 1 (CS1): this is the worst case scenario in terms of lighting and other load demands. The total load is assumed to be at full load. Lighting loads installed is assumed to be the 60 Watt incandescent bulbs for both residential and commercial buildings. This can be during high lighting demand in the night when all lights are ON.
B. Case Study 2 (CS2): case study 1 is repeated, this time all the incandescent bulbs are replaced with 14 Watt CFL's and all are ON.
C. Case Study 3 (CS3): a diversity factor of 0.6 is widely used [1] therefore, for this case study all lighting and other loads for both residential and commercial are reduced to 60% of full load. This case was selected to represent realistic conditions. A reactor is added in series with the capacitor as a harmonic filter to reduce the %VTHD which is 14.00% to 5.74517%.
*D. Case Study 4 (CS4): f*or this case study it is assumed that only 60% residential CFL's and 10% of commercial CFL's are ON. Other loads are assumed to be at 10% of full load. This case study represents night time around 20h00. Harmonic penetration results were obtained at the point of common coupling [10].

Table 9 The penetration of harmonics in the PCC (point of common coupling) [10].

Index	CS1	CS2	CS3	CS4
V_1	6167.17	6175.42	6246'39	6319.7
$\%V_3$	0.99255	0.83815	2.96818	0.26067
$\%V_5$	0.97265	1.69527	4.14631	0.49566
$\%V_7$	0.95647	2.22744	0.9488	0.56234
$\%V_9$	0.93897	0.52756	1.89477	0.33273
$\%V_{11}$	0.91936	2.0427	1.06091	0.49496
$\%V_{13}$	0.89785	0.85566	1.17857	0.08985
$\%V_{THD}$	2.31928	3.70419	5.74517	0.99681
$\%V_{RMS}$	6168.83	6179.65	6275.29	6081.7

5 CONCLUSIONS

Compact fluorescent lamps with electronic ballast are used increasingly in the residential, commercial and industrial buildings. Although these lamps provide a greater efficiency and a life expectancy greater, compared to incandescent lamps and fluorescent tubes, they generate a large number of harmonics causing perturbatory effects in the power energy network. Analyzing the results presented it can be concluded that the level of distortion depends on the type of lamp used CFL, ballast type, the coefficient of distribution, the number of CFL lamps in use, the type of correction the power factor. Current distortion in case of CFL lamps is very high, and may result in a level of unacceptable distortion of the voltage in PCC.

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KNX AND DALI – CONTROLLING THE LIGHT

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ABSTRACT

The efficient use of energy is becoming increasingly important in a single-family house or in an office complex, whether the demand for comfort and versatility in the management of air-conditioning, lighting and access control systems is growing at the same time. More convenience and safety coupled with lower energy consumption can however only be achieved by intelligent control and monitoring of all products involved. This however implies more wiring, running from the sensors and actuators to the control and monitoring centers. Such a mass of wiring in turn means higher design and installation effort, increased fire risk and soaring costs.

1 INTRODUCTION

The load is always switched directly in the classic electrical installation. The switch and/or sensor is either linked directly to the load or linked via an installation relay. The wiring of the switch/sensor to the load determines the function.

In electrical installations with KNX technology, the load is switched indirectly. All the operating elements – called sensors – and the actual switching elements – called actuators – are linked via a common transmission medium (twin-core cable and/or radio and/or power network). If a push button is pressed or a sensor detects movement, it sends information via the transmission medium to the designated actuator which then switched the load.

KNX specifies many mechanisms and ingredients to bring the network into operation, while enabling manufacturers to choose the most adapted configuration for their market. The following Figure 1 shows an overview of the KNX model, bringing the emphasis on the various open choices. Rather than a formal protocol description the following details the components or bricks that may be chosen to implement in the devices and other components a full operational system.

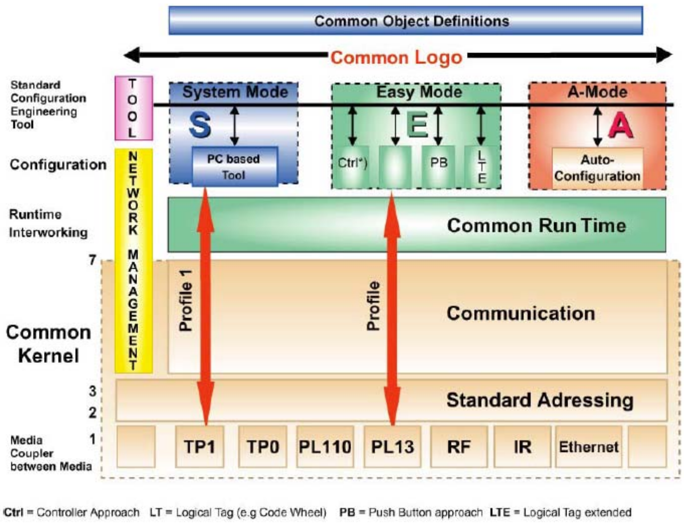

Figure 1 KNX model [3]

2 WHAT IS KNX?

The European Installation Bus (EIB) was developed at the beginning of the 1990s due to the higher demands placed on the security, flexibility and convenience of electrical installations. This is the hart of the current KNX system – the worldwide only open standard for Home and Building Control fulfilling an International Standard (ISO/IEC 14543-3) as well as an European Standard (CENELEC EN 50090 and CEN EN 13321-1) and Chinese Standard (GB/Z 20965).

By establishing the KNX trademark, a sign for quality and the problem-free combination of devices from different manufacturers was created. The KNX Association certifies the devices and ensures the conformity with the norms as well as interoperability.

Due to its versatility, the standard enables:

- Application in all types of buildings (residential, functional and industrial premises)
- Different communication media (TP, PL, RF)
  - TP-0, (Twisted pair, type 0). This communication medium, twisted pair, bitrate 4800 bits/s, has been taken over from BatiBUS. The KNX TP0 certified products designed for this medium, will operate on the same busline as the BatiBUS certified components but they will not exchange information amongst each other.
  - TP-1, (Twisted pair, type 1). This communication medium, twisted pair, bitrate 9600 bits/s, has been taken over from EIB. The EIB and KNX TP1 certified products will operate and communicate with each other on the same busline.
  - PL-110, (Power-line, 110 kHz). This communication medium, power line, bitrate 1200 bits/s, has also been taken over from EIB. The EIB and KNX PL110 certified products will operate and communicate with each other on the same electrical distribution network.
  - PL-132, (Power-line, 132 kHz). This communication medium, power line, bitrate 2400 bits/s, has been taken over from EHS. KNX PL132 certified components and EHS 1.3a certified products, will operate together but will not communicate with each other, without a dedicated protocol converter. The work-group “A-mode”, will define this converter in the A-mode specifications.
  - RF, (Radio frequency on 868 MHz). This communication medium, radio frequency with a bitrate of 38.4 kbits/s, has been developed directly within the framework of the KNX standard.
  - Ethernet, (KNX-over-IP). This widespread communication medium can be used in conjunction with the “KNX-over-IP” specifications, which allow tunneling of KNX frames encapsulated in IP frames.
- Various configuration options (System and Easy mode) – Figure 2

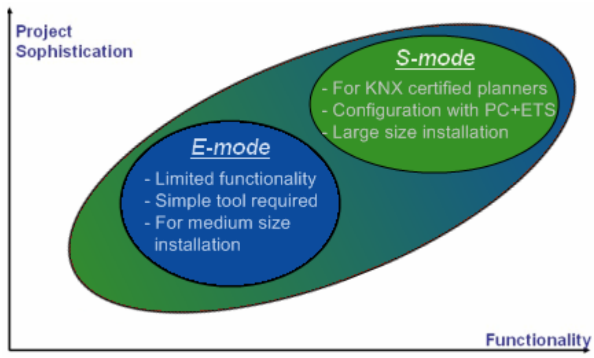

Figure 2 Configuration options [5]

The “S-mode” (System mode) is meant for well trained installers to realize sophisticated building control functions. All “S-mode” components in an installation will be addressed by the common software tool (ETS), based on the product database provided by the manufacturer, for their planning, configuration and linking. With ETS each component can exactly be programmed, according to the specified requirements. The “S-mode” configuration offers have the highest degree of flexibility in functionality and in communication links.

The “E-mode” (Easy mode) is meant for installers with a basic training providing a fast learning curve solution but with limited functions, compared to “S-mode”. The “E-mode” components are already pre-programmed and loaded with a default set of parameters. With a simple configurator, each component can partly be reconfigured, mainly parameter settings and communication links.

Konnex Association offers a manufacturer independent configurator called “ETS 3 Starter” to allow installers to plan, configure and link special selected KNX certified products in installations with standard functionalities.

As essential ingredients of KNX, we find in a rather top-down view:

• Interworking and (Distributed) Application Models for the various tasks of Home and Building Automation; this is after all the main purpose of the system.

• Schemes for Configuration and Management, to properly manage all resources on the network, and to permit the logical linking or binding of parts of a distributed application, which run in different nodes. KNX structures these in a comprehensive set of Configuration Modes.
• a Communication System, with a set of physical communication media, a message protocol and corresponding models for the communication stack in each node; this Communication System has to support all network communication requirements for the Configuration and Management of an installation, as well as to host Distributed Applications on it. This is typified by the KNX Common Kernel.
• Concrete Device Models, summarized in Profiles for the effective realization and combination of the elements above when developing actual products or devices, which will be mounted and linked in an installation.

3 WHAT IS DALI?

DALI stands for Digital Addressable Lighting Interface and is a protocol set out in the technical standard IEC 62386.

AG-DALI is a working group set up by leading manufacturers and institutions in the field of digital lamp/luminaire control to promote DALI technology and applications.

DALI is a dedicated protocol purely for lighting control. This means that DALI cannot be used to control other systems such as BMS.

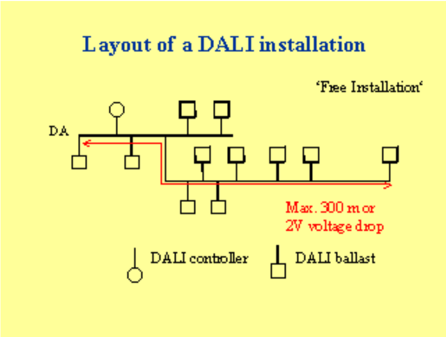

Figure 3 DALI layout topology [8]

However, DALI is effective for scene selection and for getting feedback regarding faulty light sources. This makes it very useful to use together with building automation systems where remote supervising and service reports are required.

System Description/Main DALI features and benefits compared to 1-10V analogue control systems.

- Individual control of fittings: each unit in the DALI network has it´s own individual address, therefore it is possible to communicate directly to the components in the fittings
- Multichannelling use: through only one pair of control cable it is possible with DALI to control several different groups of fittings
- No mains switching needed: the lights can be switched off by commands coming directly from the DALI control system making the mains switch unnecessary
- Backchannelling: the information flow is bidirectional with the DALI system. Instead of only giving commands about the light level to the fitting DALI system enables also information feedback on the condition of the fittings. the fitting can transmit information about
- whether the light is switched on or off,
- the preset light level
- the ballast condition
- simple DALI wiring: the cabling consists of a simple two wire cable, independent of any building topology between the units in the system
- Easy system re-configuration: once the system is installed and configured it is very easy to change the functioning of the system, changing of scenes and functions of lighting is only a matter of programming and needs no hardware changes anymore

- Easy to add new components: when the lighting system needs to be enlarged new components can be added anywhere in the DALI system, no wiring configuration rules apply on the DALI line in this aspect.

Main differences between DALI and building automation buses:

- DALI has a limited system size (64 addresses).
- DALI is meant only for communication in lighting systems as BMS includes other functionality as well (HVAC, alarm systems...)
- A BMS system commonly has unlimited expansion possibilities, which DALI does not have
- DALI is not competing against BMS systems, it is only complementing them through an interface

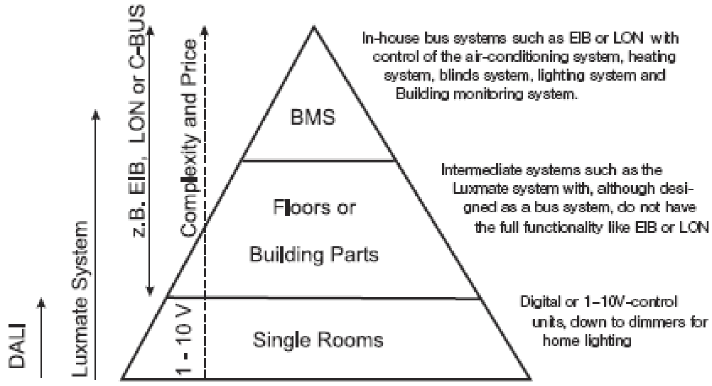

Figure 4 DALI and Building Management Systems [4]

3.1 DALI as a stand-alone system

This is the simplest option. In most cases, it will consist of a simplified control unit not using the full functionality of DALI. It is a real stand-alone lighting control system without connection to the building management. All functions (even start-up, maintenance etc.) are carried out locally. Control elements and sensors are connected to the control unit as usual, in analog or digital form.

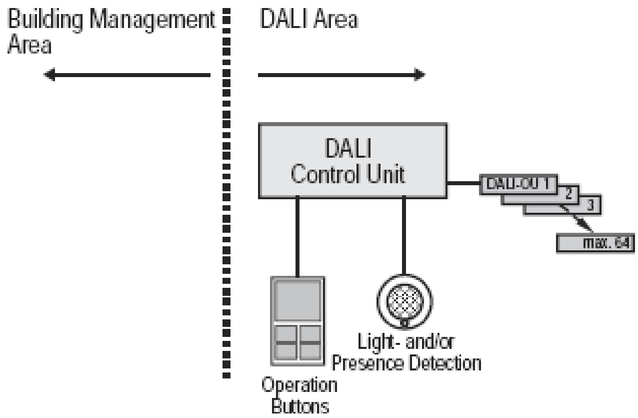

Figure 5 Stand alone system [4]

3.2 DALI as stand-alone subsystem

This option is a stand-alone subsystem within the building management. However, compared to option one it is connected to the building management system. Only the most important information (fault status, central switch functions) will be exchanged with the building management.

It can be in the simplest form a *yes* or *no* with regards to faults or failures. Sensors, control elements, programming unit and remote control can be integrated as usual (for example wireless). Initialization can be carried out via building management provided that this option will be offered by the software tools.

This system is also operational without Building Management.

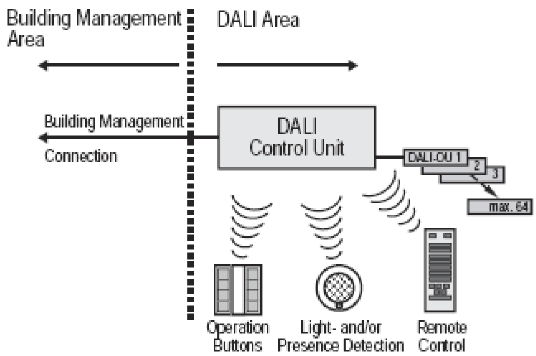

Figure 6 Stand alone subsystem [4]

3.3 DALI as pure subsystem within Building Management
A translator (gateway) is planned for this option. All components installed in a room or building part use the same technique of data transfer as the Building Management. The gateway translates from the Building Management to DALI and in reverse order to establish the communication between Building Management and DALI-units. A typical application for example is EIB that uses the appropriate control elements, switches, sensors etc.

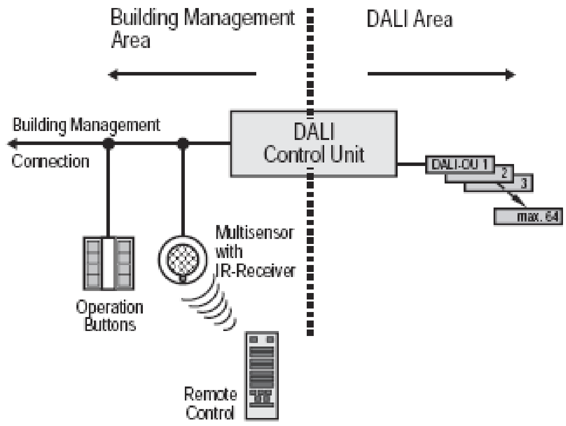

Figure 7 Pure subsystem [4]

The lighting system has not been designed as stand-alone solution for this kind of application. In this case, initialization of the lighting control system is part of the start-up process of the complete building management system.

4 APPLICATIONS AND BENEFITS OF THE KNX SYSTEM

The implementation of the electrical installation in KNX technology offers a range of benefits for planers, electrical installers and users:

a. For the planner: Increased reliability during the planning stage due to the possibility of defining the transmission medium at an early stage, selecting products independently of the manufacturer and planning of the installation, even if the final requirements have not yet been established
b. For the electrical installer: The installation is carried out as before in conventional sub-circuit distribution boards and boxes but the wiring is clearer and simpler. It is possible to access the KNX installation remotely via the internet using a gateway. The KNX system offers new areas of business such as security monitoring when the customer is absent, adapting the installation to the latest technology, optimizing the installation with regard to energy savings at a later date as well as the storage and care of documentation.
c. For the end user: The KNX system is modern, cost-effective, flexible in the event of changes and additions and the availability of the devices in the future is ensured due to the variety of manufacturers and the connection to EN 50090. Comfort functions and logic operations are possible which were either not feasible with the conventional system or

would have incurred high costs. In functional buildings, combined and extended load management as well as facade control enables a clear reduction in energy costs.

4.1 Control of lighting

The interior and exterior lights of a building can be switched or dimmed individually, in groups or from an unlimited number of locations. The operation is carried out manually via KNX push buttons, remote control via radio as well as automatically dependent on time, brightness, movement or via the automatic detection of people in the vicinity.

Luminaires in a room which are switched and/or dimmed can be combined together in a lightscene. The lightscene can be modified, stored and retrieved by the user at any time. The lighting is usually linked to sun protection and visual protection, security (alarm with switching on of interior and exterior lights), panic lighting.

Figure 8 KNX simple ensemble (Source+line coupler+load switch)

4.2 DALI KNX Interface

DALI is an addressable interface. The application primarily targets room-dependant lighting management. The integration in a higher-order KNX system is carried out via gateways. The complete project design and addressing of a DALI installation can be carried out via the ETS program. Devices which are fitted with a DALI interface are controlled centrally. This control unit takes over the tasks of a master which is responsible for the control and scanning of the individual components. One or several operating elements can be connected, depending on the design of the DALI control unit. Moreover, the integration of brightness sensors and installation of constant lighting control circuits is also possible. Depending on the capacity of the gateway, the functionality of a DALI installation can be fully integrated in the KNX system during commissioning, operation and diagnosis.

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REHABILITATION OF LIGHTING INSTALLATION OF CENTRAL UNIVERSITY LIBRARY - ENERGY EFFICIENCY CASE STUDY

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ABSTRACT

The paper presents the rehabilitation of the lighting installation for the two eight story book deposits that are parts of the Central University Library in Cluj-Napoca. The project consisted of several operations, the most important being the change of the old incandescent lamps with more efficient fluorescent lamps mounted on electronic ballast luminaires and the mounting of movement sensors based on KNX technology. A comparison before/after is also presented, based on the figures we gathered in the last year and a half since the installation is fully working. The project is a full success from the economical, technical and physical comfort point of view and can further serve as an application example for similar buildings. This project emphasises the use of the EIB-KNX protocol (the world's only open standard for home and building control) for energy efficiency applications.

1 INTRODUCTION

The library (Figure 1) was founded in 1872, at the same time as the University of Cluj (now Babeş-Bolyai University). Its initial stock, about 18.000 volumes, was made up by gathering the collections received from the Law Academy of Sibiu, the Medical School and Government Archives of Cluj, and those of Iosif Benigni's rich private collections. In 1873/74 the Transylvanian Museum was transferred to the Central University Library. Its library had been founded in 1859, as the Library of the Society of the Transylvanian Museum, on the basis of donations and grants from Metropolitan Bishops Andrei Şaguna and Alexandru Sterca-Şuluțiu and Count Imre Mikó. In 1860 the Library of the Transylvanian Museum had been declared "public" and open for the use of citizens, but in 1873/74 it was transferred to the university, being moved to a location near the Central University Library. Although housed in the same building, these two large libraries grew independently of each other for about half a century.

Figure 1 Main entrance BCU

Since its founding until 1909, the library functioned in the main University building. From 1906 to 1908, the current library building was erected following plans by architects Gergely Kálmán and Korb Floris Nándor; books were then moved there in 1908-09. Extensions to the building were added until 1934, and an annex with a capacity of over 2,000,000 volumes was added in 1961. In 2006 the total number of publications in the entire network (central building and the branch libraries) has reached approximately 3,600,000 volumes.

Being one of the most beautiful buildings in Cluj-Napoca, it is also one of the oldest ones. For that reason the electrical installation is almost entirely out-of-date. The entire electrical system needed to be upgraded to fulfil the actual safety standards. The situation was so critical that there was a notice from the authorities warning the institution on the shutting down of the library.

Only the rehabilitation of the two book deposits will be treated in this paper.

2 THE CONCEPT OF ENERGY EFFICIENCY

Energy Efficiency (EE) encompasses all changes that result in a reduction of energy used for a given energy service (heating, lighting...) or level of activity. This reduction in energy consumption is not necessarily associated to technical changes, since it can also result from a better organization and management or improved economic efficiency in the sector (e.g. overall gains of productivity). This definition of energy efficiency is provided by the World Energy Council (WEC) (Figure 2).

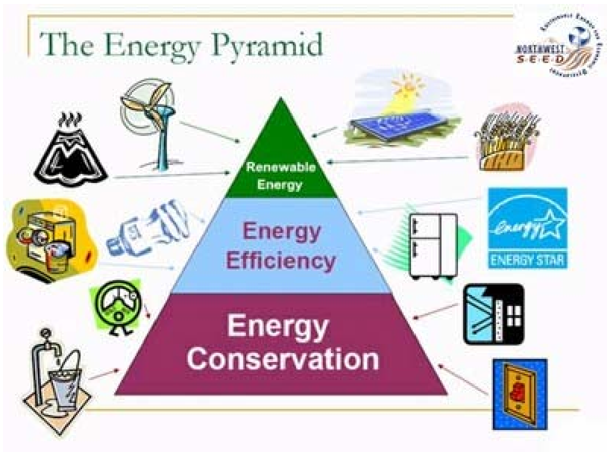

Figure 2 The energy pyramid [8]

In some cases, because of financial constraints imposed by high energy prices, consumers may decrease their energy consumption through a reduction in their energy services (e.g. reduction of comfort temperature; in car mileage; in lighting intensity). Such reductions do not necessarily result in increased overall energy efficiency of the economy, and are easily reversible. They should not be associated with energy efficiency.

To economists, energy efficiency has a broader meaning: it encompasses all changes that result in decreasing the amount of energy used to produce one unit of economic activity (e.g. the energy used per unit of GDP or value added). Energy efficiency is associated with economic efficiency and includes technological, behavioural and economic changes.

Energy efficiency is first of all a matter of individual behaviour and reflects the rationale of energy consumers. Avoiding unnecessary consumption of energy or choosing the most appropriate equipment to reduce the cost of the energy helps to decrease individual energy consumption without decreasing individual welfare.

Avoiding unnecessary consumption is certainly a matter of individual behaviour, but it is also, often, a matter of appropriate equipment: thermal regulation of room temperature or automatic de-activation of lights in unoccupied office rooms are good examples of how equipment can reduce the influence of individual behaviour.

3 INITIAL SITUATION

In 2006 the two - eight story book deposits had a lighting system composed of 2000 incandescent lamp luminaries, 60 W each. The Library's employees were complaining about the lack of visual comfort, limited ability to read, and unreliability of the system (around 70 incandescent lamps had to be replaced every week). Furthermore, almost all the luminaries remained lit from the beginning (8 am) of the program to the end (20 am), this leading to a useless energy consumption. Therefore we decided to start an investigation. Using a Luxmeter we measured the light level and we were astonished to find out that it was 25 Lx. The Romanian norms recommend a level of 150 Lx for the book shelves. Drastic measures had to be taken, in order to assure the normal level of comfort and energy efficiency. We decided to act as follows: to install more efficient luminaries and to integrate a management system that ensures the limitation of the lighting installation to a minimum period, by using movement sensors.

4 TAKING ACTION

We realized from the very beginning that the human factor has a very high importance in the energy consumption. We noticed that the personnel were never turning off the lights after leaving an area of the deposits. Only at closing time a responsible person was going throughout the building to close the lights. Obviously this had to stop. We had to install movement detectors on every access zone. The system we chose was KNX/EIB because of the flexibility and low maintenance costs. We had to install 2 sensors in each zone because the circulation sense was in two ways: one sensor at each zone entrance mounted in the main corridor. Each floor had three independent zones.

In order to achieve the necessary light intensity we realized complex lighting calculations using Dialux software package. We also did live simulations in different zones, meaning we took some luminaries and temporarily installed them to make the measurements. Finally the optimum solution was to use 1x36 W fluorescent lamps (electronic ballast). Roughly we replaced the 60W incandescent lamps with 36 W fluorescent lamps and the corresponding luminaires.

5 USED EQUIPMENT – GAMMA INSTABUS

GAMMA *instabus* based on KNX/*EIB* is a distributed, event-controlled bus system with serial data transmission for the controlling, monitoring and signalling of operational functions (Figure 3). All the connected bus devices can exchange data over a common transmission path, the bus. Data is transmitted in serial mode and in compliance with precisely defined rules (the bus protocol). The data to be transmitted is packed into a telegram and sent over the bus from a sensor (the command output) to one or more actuators (the command receiver). Each recipient acknowledges receipt of the telegram when the transmission is successful. If no acknowledgement is issued, transmission is repeated up to three times. If the telegram is still not acknowledged, the send operation is aborted and the error noted in the memory of the transmitter.

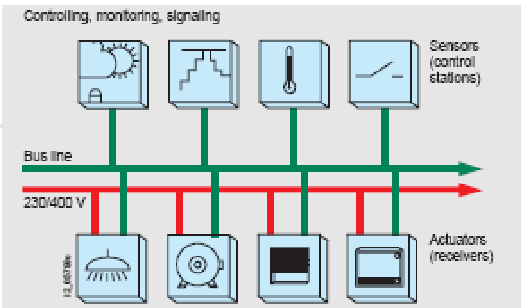

Figure 3 System overview

Transmission of data using KNX/*EIB* is not electrically isolated as the power supply for the bus devices (24 V DC) is transmitted at the same time. The telegrams are modulated on this direct voltage, whereby a logic zero is transmitted as a pulse. The omission of a pulse is interpreted as a logic one. The individual data of the telegrams are transmitted in asynchronous mode. However, transmission is synchronized by start and stop bits.

Here are the main components that are part of this system:

Figure 4 Taster 1 fold

The taster (Figure 4) was used for manual switching of the luminaires.

Figure 5 Bus coupling unit

The bus coupling unit (Figure 5) ensures the interface between the device and the KNX system.

Figure 6 Load switch 8 channels

The load switch (Figure 6) connects and disconnects the lighting loads (up to 16 A).

Figure 7 USB interface

The USB interface (Figure 7) ensures the interface between the commissioning software (ETS) and the KNX components.

Figure 8 Movement detector

The movement detector/sensor (Figure 8) has the ability to detect the slightest movements and send a telegram through the BUS.

Figure 9 Fluorescent lamp luminaire

Fluorescent lamps 1x36 W with electronic ballast (Figure 9) were used in the deposits. Close to 1700 luminaries have been mounted.

6 CONCLUSION

During the one and a half year period since the installation is fully running we have reduced the electrical energy consumption by 50%, from around 600kWh/day to 300kWh/day. The light intensity has increased from 25 Lx to 155 Lx. The physical comfort of the employees increased significantly according to their confessions (Figure 10). The maintenance costs have also decreased especially by reducing the number of bulb replacement.

Figure 10 Area deposit view after rehabilitation

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OPTIMUM TARIFF SELECTION FOR PUBLIC LIGHTING SYSTEMS

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ABSTRACT

This paper aims to highlight the optimum tariff used for public lighting systems in order to minimize the electricity bill. The freedom of choice between regulated tariffs and the negociated tariffs on the competitive market offers the consumer a diversified range of possibilities, depending on the electricity consumption. This paper presents the results of applying the regulated tariffs to the captive consumers, and two scenarios for the competitive pricing in relation to the specific energy consumption for the public lighting systems.

1 INTRODUCION

In the context of an acute economic crisis, assessing opportunities to reduce the invoice cost of electricity could lead to significant results and rapid depreciation of investments made. Public lighting necessary for security, safety and comfort at night, and for displaying nocturnal potential of a city, is an important consumer and a significant cost related to the local budget. Therefore, choosing a tariff related to optimal parameters of consumption is a very important step in minimizing costs.

Liberalization of the electricity market opened new possibilities for consumers, through the diversified supply tariffs, offered by the private energy retailers. Structurated in two categories, the regulated market and the competitive market, allowed consumers a choice between regulated tariffs and the possibility of negotiating a price on the competitive market. Until 1st of July 2007, the date of full opening of the electricity market in Romania, the consumers that have chosen regulated tariffs were named captive consumers and those with negotiated rates, eligible. After this time the name was passed to consumers, with a subcategory, consumers beneficiaries of the universal service. In this article are used the concepts of captive consumer and eligible consumer.

2 TYPES OF TARIFF

There are four types of regulated tariffs for captive consumers, depending on the sizes billed, power and energy, hourly areas for the week days or week – ends and months in the billing period: simple monomer (invoicing energy consumption); differentiated monomer (invoicing energy differentiated by hourly areas); simple binomial (invoicing energy and power); differentiated binomial (invoicing energy and power differentiated by hourly areas);

For captive consumers, non-household, the following tariff types are provided for active energy consumption:

- Tariff A33 is a binomial differentiated rate with duration of use for maximum power and it is the most complex form of billing for the active energy consumption. It provides the billing energy in peak, off-peak and normal hours, also for peak and rest load power, taking into account the duration of use, resulting in three versions of the tariff, for small, medium and large utilisation;
- Tariff A is a binomial differentiated rate and a complex form of billing for electricity consumption, which provides the quantities of energy and power in peak and rest hours, taken into account for the bill;
- Tariff C is a simple binomial tariff and is applied to consumers which require a certain power, that the supplier is forced to ensure it permanently. The consumers can also require a possible consumption (standby system) in a given period, that the supplier guarantees;
- Tariff B is a monomer differentiated rate, structured in peak and rest hours;
- Tariff E1 is a complex day - night tariff differentiated in day and night hours for the week days and week-ends;
- Tariff E2 - is a simplified day – night rate, which distinguishes only the day hours and night hours;
- Tariff D is the simplest form of energy billing, with one price component for the energy consumption [6].

The competitive market allows tariff negotiation with certain conditions stipulated in the supply contract. Most contracts are based on load forecasts, which must be provided to the supplier, at least 5 days before the start of billing period. The load power variations for the consumer's forecast can appear in a certain range specified in the contract. Violating this condition leads to quite severe penalties for the consumer. New pricing trends imply a greater involvement of consumer purchasing electricity directly from the market, trought the retailer, licensed as energy supplier and acting as a brokerage firm. One of the strategies determines the acquisition of energy for public lighting by a year contract purchased from the Centralized Bilteral Contracts Market (CBCM) and the adjustment of the electricity deficit and surplus on the Day Ahead Market (DAM) or on the Balancing Market (BM). A second strategy could be the acquisition of energy on the DAM, as any imbalance will be assessed on the BM [5]. Choosing the best tariff involves continuous tracking of changes that can occur on both the competitive and regulated market.

3 CASE STUDY

The optimum tariff selection for the public systems in urban areas requires monthly load curves presented in figure 1. The bills calculations were performed taking into account the week days and week – ends of the year 2009 (Table 1). Load curves classification was done for hours of day and night, in close correlation with the sensor that determines the start and stop of lighting.

The determination of the load curves on the basis of the daylight saving time can be visible for the months april and november. Although regulated tariffs approved by the competent authority by order ANRE 134/2008 sets their values as of 1st January 2009, they may change by the end of the current year.

Calculations were performed throughout the year for the regulated tariffs in force. Estimates of electricity consumption for this year are lower than those for last year, the first decline since year 2000. Spot electricity market (in Romania DAM) is expected price decrease in close correlation with declining consumption, this year's trend is an indicator in respect with this parameter. However, prices on spot markets in Western Europe are still high, and greater values for the allocation of cross-border capacity could increase the exports and along with that the price on the domestic spot market.

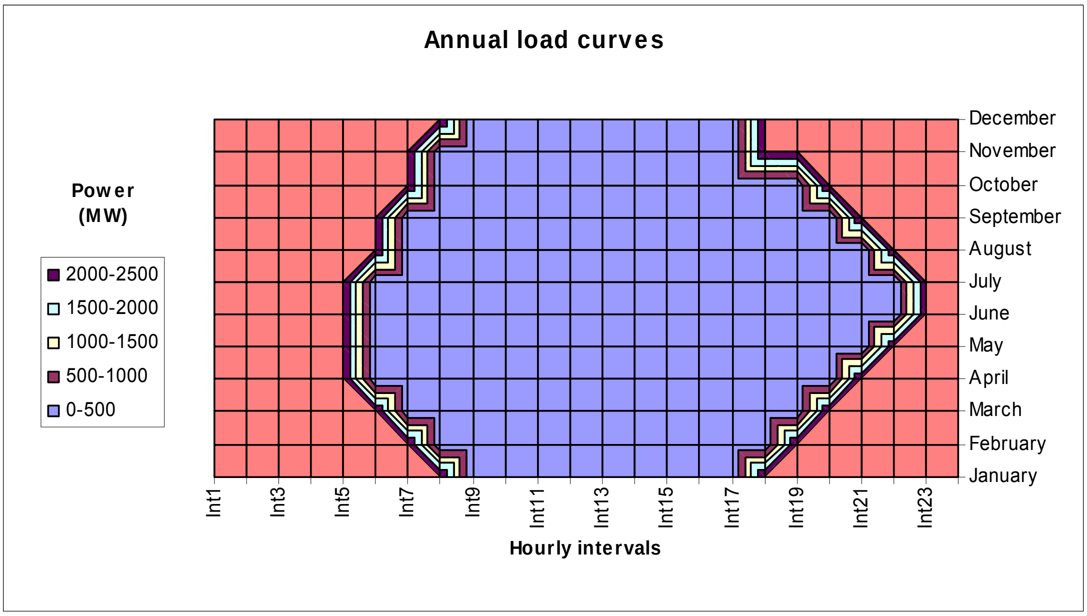

Figure 1 Load curves for a year relating to a public lighting systems in urban areas

Large variation in prices causes consumers to choose between regulated tariffs associated with captive consumers. In the example given was considered an average load for the time intervals of operation. This paper presents the calculated bills for the nine regulated tariffs to the Northern Transylvania distribution area and low voltage level [1]. The contracted active power and the maximum recorded active power specifically for each rate and each hourly area are presented in tables 2 and 3 [6]. Because they are equal no penalties or claims were calculated for consumers. The optimal tariff is determined by the minimum annual average price for the examined consumer, althought it can exist the possibility of applying for some months more advantageous tariffs than the optimal rate considered for the entire year.

Table 1 Week days and week – ends corresponding to each month of the year 2009

2009	Week days (Mon - Fri)	Week - Ends (Sat - Sun)	Total number of days
January	22	9	31
February	20	8	28
March	22	9	31
April	22	8	30
May	22	9	31
June	22	8	30
July	23	8	31
August	21	10	31
September	22	8	30
October	22	9	31
November	21	9	30
December	23	8	31

Table 2 Contracted power

Putere contractată (Kw) (Tarif binom)	A33		A		C
	Vârf	Rest	Vârf	Rest	
	2500	2500	2500	2500	2500

Table 3 Maximum recorded power

Putere maximă înregistrată (Kw) (Tarif binom)	A33		A		C
	Vârf	Rest	Vârf	Rest	
	2500	2500	2500	2500	2500

In Tables 4 and 5 is described the distribution of energy consumption for each of the regulated tariffs in every month of year 2009 and also the total annual load consumption. The length increasing of time day and night time decrease is associated with a greater weight of electricity consumption in off-peak hours or rest hours for tariffs A, B and A33, or day and night hours for E1 and E2 rates [6].

Table 4 Electricity consumption for tariffs A33, A, B, C şi D [6]

Electricity consumption (Kwh)	A33			A		B		C, D
	Peak	Rest	Off-peak	Peak	Rest	Peak	Rest	
January	330000	277500	555000	387500	775000	387500	775000	1162500
February	200000	230000	480000	280000	630000	280000	630000	910000
March	165000	177500	510000	232500	620000	232500	620000	852500
April	110000	150000	415000	150000	525000	150000	525000	675000
May	55000	132500	432500	77500	542500	77500	542500	620000
June	55000	55000	415000	0	525000	0	525000	525000
July	57500	57500	427500	0	542500	0	542500	542500
August	52500	130000	515000	77500	620000	77500	620000	697500
September	110000	150000	490000	150000	600000	150000	600000	750000
October	165000	232500	532500	232500	697500	232500	697500	930000
November	262500	270000	517500	375000	675000	375000	675000	1050000
December	345000	272500	545000	387500	775000	387500	775000	1162500
Annual	1907500	2135000	5835000	2350000	7527500	2350000	7527500	9877500

Total invoices and average prices are outlined in tables 6, 7, 8 and notice that the optimal tariff for the regulated market is E2 [1]. Because the average prices of the rates are similar and the load curves for public lighting systems differe from town to town, it would be advisable to evaluate them prior for determining the optimum tariff. The results have occurred following the calculations made on the basis of regulated tariffs, adding the fact that the total invoice was done due to the help of the operational procedure used for the pricing of electricity to captive consumers [1], [6].

For negotiating a price is necessary to obtain eligibility. Therefore the consumer is obliged to terminate the contract at least 5 days before the billing period with the current retailer, to pay all outstanding debts or to be taken by the future retailer who signs the supply contract and to set a smart meter capable to record the load curves.

Table 5 Electricity consumption for tariffs E1 şi E2 [6]

Electricity consumption (Kwh)	E1		E2		Electricity consumption (Kwh)	E1		E2	
	Day	Night	Day	Night		Day	Night	Day	Night
January	330000	832500	465000	697500	July	0	542500	0	542500
February	200000	710000	280000	630000	August	52500	645000	77500	620000
March	165000	687500	232500	620000	September	110000	640000	150000	600000
April	110000	565000	150000	525000	October	165000	765000	232500	697500
May	55000	565000	77500	542500	November	262500	787500	375000	675000
June	0	525000	0	525000	December	345000	817500	465000	697500
Annual E1	Day	1795000	Night	8082500	Annual E2	Day	2505000	Night	7372500

Table 6 Monthly and yearly electricity invoices for tariffs A33, A, B [1] [6]

Total Invoice (EUR)	A33			A	B
	d.u. Mi	d.u. Me	d.u. Ma	Total	Total
January	134,314.11	108,676.38	111,363.14	149,740.36	156,369.07
February	100,070.24	83,369.12	87,169.30	122,064.65	119,042.26
March	91,885.00	79,201.77	84,629.60	120,545.64	107,224.51
April	72,232.26	65,116.16	71,521.65	102,530.60	79,986.02
May	62,175.41	58,598.63	66,003.14	95,372.57	64,781.47
June	53,481.17	52,115.04	59,703.89	82,061.48	45,397.47
July	55,350.37	53,913.70	61,751.69	84,796.86	46,910.72
August	67,434.75	62,165.72	69,136.75	99,394.22	71,483.00
September	77,635.84	68,791.37	74,763.44	106,422.51	86,471.38
October	98,579.84	83,792.78	88,772.76	124,567.29	113,926.04
November	118,379.28	97,091.60	100,452.32	141,018.11	144,839.55
December	135,856.20	109,771.66	112,372.09	149,740.36	156,369.07
Annual	1,067,394.47	922,603.95	987,639.77	1,378,254.66	1,192,800.57

Table 7 Monthly and yearly electricity invoices for tariffs C, D, E1, E2 [1] [6]

Total Invoice (EUR)	C	D	E1	E2
	Total	Total	Total	Total
January	113,864.14	120,649.42	98,968.67	98,523.98
February	92,353.83	94,443.84	73,605.91	73,252.60
March	90,633.62	88,476.24	67,472.52	67,250.17
April	76,469.38	70,054.50	52,055.37	51,676.69
May	73,210.73	64,346.36	44,761.92	44,687.80
June	65,228.80	54,486.83	34,815.83	34,815.83
July	67,403.10	56,303.06	35,976.36	35,976.36
August	79,018.36	72,389.65	49,735.66	49,827.28
September	82,089.67	77,838.33	57,029.06	56,650.38
October	96,441.25	96,519.53	72,611.99	72,389.65
November	104,570.81	108,973.67	87,033.40	86,915.36
December	113,864.14	120,649.42	99,963.06	98,523.98
Annual	1,055,147.82	1,025,130.85	774,029.75	770,490.09

Eligible consumers will be forced to conclude contracts with transport and distribution operators, because the tariffs for electricity transport and distribution are regulated and different in each country area [4]. The final price payed by the consumer is determined taking into account:

- tariff ofered for electricity by the power plant;
- tariff for injection of electricity into the national network;
- tariff for system services;
- tariff for services provided cetralized market operator;
- tariff for distribution services associated with each voltage level;
- tariff for electricity extraction from the network;

Table 8 Average monthly prices and average yearly prices for the regulated tarrifs

Average price (EUR/Kwh)	A33			A	B	C	D	E1	E2
	d.u. Mi	d.u. Me	d.u. Ma	Total	Total	Total	Total	Total	Total
January	0.11553	0.09350	0.09580	0.12880	0.13451	0.09796	0.10378	0.08513	0.08476
February	0.10996	0.09162	0.09580	0.13414	0.13082	0.10148	0.10378	0.08088	0.08050
March	0.10778	0.09291	0.09927	0.14139	0.12577	0.10632	0.10378	0.07914	0.07888
April	0.10700	0.09648	0.10597	0.15189	0.11849	0.11330	0.10378	0.07712	0.07656
May	0.10028	0.09451	0.10646	0.15382	0.10449	0.11809	0.10378	0.07219	0.07207
June	0.10186	0.09927	0.11372	0.15631	0.08647	0.12425	0.10378	0.06632	0.06632
July	0.10202	0.09939	0.11384	0.15631	0.08647	0.12425	0.10378	0.06632	0.06632
August	0.09669	0.08913	0.09911	0.14250	0.10249	0.11330	0.10378	0.07130	0.07144
September	0.10353	0.09173	0.09967	0.14189	0.11530	0.10945	0.10378	0.07604	0.07552
October	0.10599	0.09009	0.09545	0.13395	0.12251	0.10369	0.10378	0.07808	0.07785
November	0.11273	0.09246	0.09568	0.13430	0.13794	0.09960	0.10378	0.08290	0.08278
December	0.11687	0.09443	0.09667	0.12880	0.13451	0.09796	0.10378	0.08598	0.08476
Annual	0.10806	0.09340	0.09998	0.13954	0.12077	0.10681	0.10378	0.07837	0.07801

The energy purchased from the market already has tariff for injection of electicity into the network included in the price, so to the total cost it will be add the rest of the remaining tariffs. For the Northern Transylvania distribution area all costs for the regulated tariffs are shown in Table 9 [2], [3].

Table 9 Regulated tariffs for network services that are added to the price of energy purchased on the competitive market [2], [3]

Tariff for the system service (EUR/MWh)	Tariff for services provided by the cetralized market operator (EUR/MWh)	Tariff for distribution services (EUR/MWh)			Tariff for energy extraction from the network (EUR/MWh)	Total regulated tariffs (EUR/MWh)
		LV (0,1 – 1 KV)	MV (1 – 110 KV)	HV (above 110 KV)		
4.71705	0.07047	19.70918	9.86633	4.30595	1.58566	40.25465

In addition occurs an extra-charge, the commission for power trading on the centralized markets collected by the electricity supplier, benefiaciary of the retail license. The cost of this fee is estimated at 1.18 EUR / MWh consumed. To calculate the electricity invoice for a tariff related to the competitive market it will be studied two different scenarios:
- first scenario - the purchase of energy from the CBCM in off-peak hours (ie, daily between 22:00 - 06:00) for a year and the deficit or surplus for the load curves presented in Figure 1 will adjust on the DAM. Such a contract implies charges of filing for the auction (2% of the total contract value) and staggered payment at the end of the billing period;
- second scenario - the acquisition of the energy from the DAM according to the load curves, given the fact that energy at night is cheaper then during the day. Guarantees are charged seven days before the time of purchasing electrcity from this market (the estimated value of the energy to be purchased) [5].

Rates considered for the invoice are average month prices of year 2008 relating to each hourly interval [7]. The calculations were made based on history of price schedules, collected from the site operator's centralized market in Romania.

This estimate was made because of the context and the current trend of decreased electricity consumption, given that 2008 was the year with the highest average prices for the peak and of-peak day period, associated to the DAM from opening in 2005. Price of energy purchased in off-peak hours for 2009 on CBCM varies between 34.06 and 34.77 EUR / MWh. In this case we took as reference price for the current energy acquired in off-peak hours 35.24 EUR / MWh [7].

3.1 Scenario I

Given the assumptions and data were obtained the results shown in Table 10. The average price for 1 kWh of energy consumed is higher than the optimal rate achieved by the application of regulated tariffs to the load curves presented in Figure 1. A brief analysis of Table 10 shows that for this case, energy is more expensive for the end and beginning of the year and cheaper for the period of the middle. It is then directly proportional to energy consumption. Observed high costs of network services, approximately 50% of the total costs of the invoice, prevents the supplier to submit an attractive offer for the analysed consumer type.

3.2 Scenario 2

Average annual tariff for this scenario related to the energy sold to such a public lighting system is still inferior to the optimal regulated rate (Table 10). The calculations show average annual price value approximately equal to that of the first scenario. It can be observed a decrease in the price for winter months, an increase in the summer and the start of the year. Electricity purchased only from the DAM is not approved due to the variable costs of the invoice, being possible large differences from one month to another. Although in some cases this acquisition strategy may lead to favorable results, the high risk of buying at a very high price in relation to regulated tariffs or annual average price obtained in the first scenario, and the fickleness price on the DAM, leads to abandone this option [7].

Table 10 Invoices and average prices to assess the possibilities of purchasing power on the competitive market (Scenario I and II) [7]

Estimates 2009	Monthly electricity consumption (MWh)	Total invoice of electricity consumption for eligible consumers (EUR) Scenario I	Total average price (EUR / kWh) Scenario I	Total invoice of electricity consumption for eligible consumers (EUR) Scenario II	Total average price (EUR / kWh) Scenario II
January	1,162.50	100,572.02	0.08652	100,327.21	0.08631
February	910	76,136.80	0.08368	76,090.75	0.08361
March	852.5	68,950.97	0.08088	63,107.59	0.07402
April	675	54,203.45	0.08029	49,307.10	0.07306
May	620	48,935.38	0.07893	46,245.82	0.07458
June	525	40,281.77	0.07672	42,993.42	0.08189
July	542.5	41,569.55	0.07663	45,731.09	0.08429
August	697.5	55,102.03	0.07900	59,076.53	0.08469
September	750	61,769.91	0.08236	69,028.30	0.09204
October	930	81,355.00	0.08748	88,338.63	0.09500
November	1,050.00	95,195.10	0.09065	95,155.77	0.09063
December	1,162.50	96,334.63	0.08288	85,333.24	0.07341
Annual	9,877.50	820,406.62	0.08307	820,735.44	0.08309

4 CONCLUSIONS

Results obtained from calculations made for each of the regulated tariffs and the prices practicated on the competitive market, have sought to highlight the optimal tariff for active energy consumption. The analysis in the previous chapter indicates that a consumer type like a public lighting, uses as optimum rate, in order to reduce the cost of electricity bill, the tariff E2 regulated for captive consumers [6]. Consequently, the reckonings confirm that this tariff related to the corresponding annual load curves in Figure 1, achieved the lowest cost per 1 KWh of active energy consumed. From the monthly average of prices obtained, is observed that for some months of the year, rates on the competitive market are superior those on the regulated market. An approach which combines the purchasing of electricity from the competitive market, with that of purchasing electricity from the regulated market is not possible. The current legislation limits the return to the regulated tariffs, allowed two times, after which the consumer loses the right to choose a regulated rate [4]. If for the regulated market the optimum tariff is prescribed without any possibility of negotiation, on the competitive market, there may be strategies correlated with an increased interest from the costumer that can lead to good results in terms of annual energy aquisition.

Such a strategy may include buying monthly energy from CBCM for months in which the price is high on the DAM. Given the large variation in prices and high risk in terms of bill cost, addressing such a strategy is not a viable solution.

In the current economic context the evaluation of the various offers for the electricity tarrifs leads to real possibilities of reducing the costs for energy consumption.

For a better understanding of the prices we have considered that 1 EUR = 4.2569 LEI, the exchange price valid for 10.02.2009.

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OPTIMIZATION OF RELIABILITY ELECTRIC SUPPLY OF EMERGENCY LIGHTING OF A HOSPITAL

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ABSTRACT

With new regulations and strategies electricity market, power quality issues is the one of the priorities of the electric energy sector in general, and safety in the supply of electricity to the lighting of safety in particular.

Theme paper in the fall issue of power quality in general, and safety in the supply of electricity to the lighting of safety in particular. Of the many issues and demonstrations quality electricity safety, quality in the supply of electricity, is the component with the highest degree and rapidly renewing. It is work of applied presenting the design should be adopted for ensure a reliable supply of safe lighting electricity to a hospital. Solving the problem consists in determining the optimal solution to supply electricity to a hospital n the assumption of optimizing the reliability of electricity supply in general and the installation of security lighting in particular.

1 INTRODUCTION

Sites for use in medical, it is necessary to ensure safety of patients who may be subjected to the use of medical electrical equipment.

According to IEC SR 60364 7 710:2005 defined three different groups of medical areas in a hospital:

Group 0: use medical establishment in which no party applied not intended to be used ;

Group 1: use the site where the medical applied are intended to be used as follows:

a) outside, or,

b) invasive of all body parts, except where applicable;

Group 2: medical site for the parts used are intended to be used in applications such as intracardiac acts, operators and fields where vital treatments discontinuity (stopping) power endangers life.

Medical establishments in group 1 and group 2, lighting should be connected to at least two circuits, one of which must be connected to a safety standard under IEC SR 60364 7 710:2005.

In locations medical electrical distribution system must be designed and conducted so as to provide automatic switching to mains power source backup (safety) circuits fueling essential life according to IEC SR 60364 7 710:2005 standard, as in Figure 1.

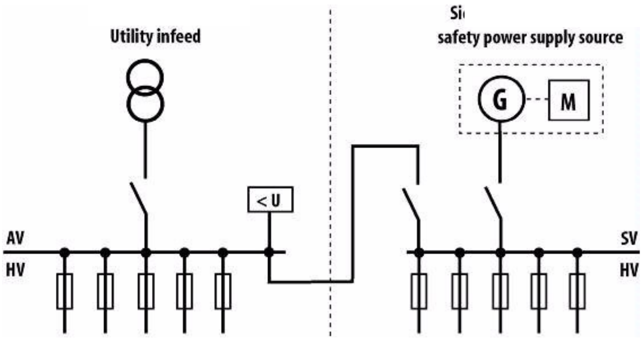

Figure 1 Automatic switching from power mains at the safety source

Special conditions for supply of safety:

a) the supply of safe switching time less than or equal to 0.5

In the event of a lack of voltage on one or more conductive painting of distribution, a power source within the security must maintain scialitic power lamps and other lamps essential, for example, endoscopy, for 3h and in addition must to provide automatic switching in less then 0.5 s.

b) the supply of safe switching time less than or equal to 15 s

According IEC SR 710.556.7.5 and 710.556.8, the equipment must be connected in less than 15 s to a source of supply security for a minimum of 24 h, when the voltage on one or more conductors to power distribution panel for the main safety has fallen by more than 10 % of the nominal supply voltage and this for more than 3 s.

c) supply services safety for switching higher 15 s

Other than those in paragraphs a and b that are required to a maintain hospital services may be manually or automatically connected to a power source for safety, operating for a period of least 24 h.

2 CASE STUDY
HYPOTHESIS: REQUIRED LEVEL OF RELIABILITY OF THE SAFETY LIGHTING OF A HOSPITAL

The electric supply of emergency lighting of a hospital is achieved through the scheme shown in Figure 2.

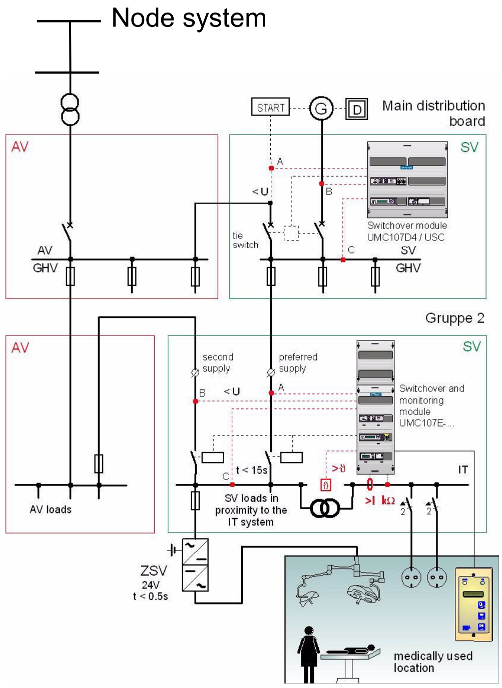

Figure 2 The electric supply of emergency lighting of a hospital

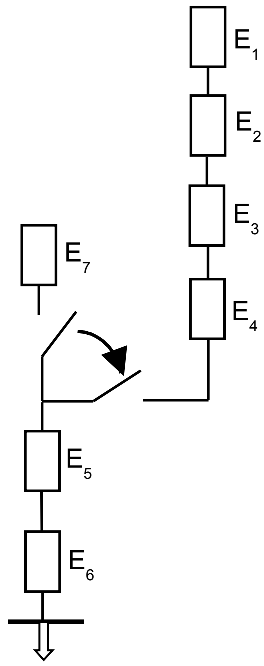

Figure 3 Block diagram of the electric supply of emergency lighting of a hospital

The electrical parameters of consumer are:
- average power required of consumer are Pc = 3 [MW];
- amount of damages caused to consumers by non delivery of a quantity of electricity by 1 [MW];
- operating planned during ten years, id Tp = 87600 hours;
- intensity of damages and intensity repair of system elements.

Let establish the optimal redundancy of the radial elements in the two variants of electric supply processed in Figure 3 with a level of reliability required at the electric supply of emergency lighting of a hospital (the safety rate of electric supply).

3 STRUCTURE

Mathematical model to optimize the redundancy elements of the scheme illustrated in Figure 3 variant I off base to include security lighting:

Optimized variables are the number of identical items in the reserve for each element of the scheme, or:

E_1 - Node system = x_1; E_2 - Medium voltage bar = x_2; E_3 - Transformer = x_3;
E_4 - Electric line in cable LEC1 = x_4; E_5 - Electric line in cable LEC2 = x_5; E_6- UPS = x_6.

- for E_i we will dipose of x_i identical elements in parallel with the element E_i $i = 1,6$

Vector of variables to be optimized:

$$\mathbf{X} = \left[\mathbf{x}_1\ \mathbf{x}_2\ \mathbf{x}_3\ \mathbf{x}_4\ \mathbf{x}_5\ \mathbf{x}_6\right]^T \tag{1}$$

Criterion function to optimize the model, is determined by minimizing the cost elements (equipment E_i)
In the study:

$$min\{C(\boldsymbol{X})\} \tag{2}$$

$$C(X) = \sum_{i=1,6} c_i \cdot X_i \tag{3}$$

Where: c_i is specific costs [m.u./ea] and they have hypothetical values because the cost of equipments and electric lines varies depending on the manufacturer (performer), to admit their expression [m.u.] (currency units). L_1 = 0,3 [km]; L_2 = 0.090 [km]

c_1 = 120 [m.u./ea]; c_3 = 110 [m.u./ea]; c_5 = 27,8*L_2 [m.u./km];
c_2 = 5 [m.u./ea]; c_4 = 51,8*L_1 [m.u./km]; c_6 = 70 [m.u./ea].

Model restrictions are imposed two conditions:

a. The construction, under which the number of items in the reserve for each equipment E_i will be:

$$1 \leq X_i \leq 3 \quad i = 1,6 \tag{4}$$

b. technical requirements provided for safety operation of power Gsig. amount required by the consumer, or:

$$P(X) \geq Gsig \tag{5}$$

where: $P(\boldsymbol{X})$ is system reliability.

The model thus formulated was solved using the MATLAB programming environment.

4 Results

In table 1, initial values were calculated for variant non optimized of system.

Optimal values were calculated for variants optimized of redundancy elements presented in table 2, through running the optimization for different degrees of safety Gsig in the electric supply of emergency lighthing to the hospital, or obtained in table 2 the optimal number of elements E_i and optimal parameters of reliability $P(X)$, hours of interruption $M_\beta(\boldsymbol{X})$ and number of interruption $M_\upsilon(\boldsymbol{X})$

Table 1 Initial values

X_1	X_2	X_3	X_4	X_5	X_6	$P(\boldsymbol{X})$	$M_\beta(\boldsymbol{X})$	$M_\upsilon(\boldsymbol{X})$	COST
1	1	1	1	1	1	0.9843	1371.2	6.7614	323.042

Table 2 Optimum values

Gsig. imposed %	X_1	X_2	X_3	X_4	X_5	X_6	$P(\boldsymbol{X})$	$M_\beta(\boldsymbol{X})$	$M_\upsilon(\boldsymbol{X})$	COST
98	1	1	1	1	1	1	0.9843	1378.9	6.8075	323.042
99	1	1.0695	1.0918	1.1293	1.2151	1	0.99	876	4.1998	336.036
99.9	1.0503	1.4134	1.7105	1.5622	1.5785	1	0.999	87.6	0.9668	419.483
99.99	1.4645	1.3481	2.4262	1.6519	1.9978	1.1221	0.9999	8.76	0.3717	558.572
99.999	1.9067	1.3442	3.0024	1.6593	2.3536	1.5380	0.99999	4.9261	0.2505	705.130

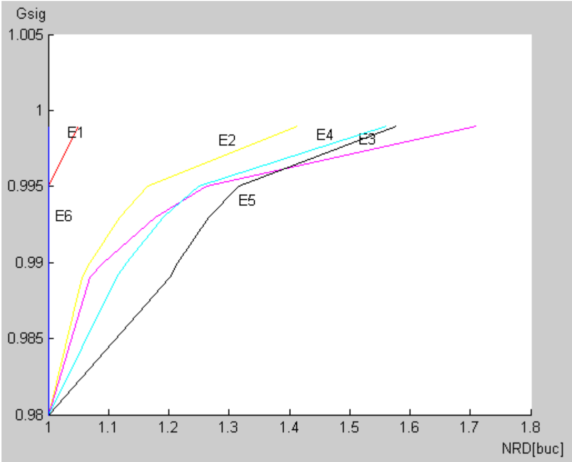

Figure 4 Increase safety supply system based on the number of redundant element for a reliability of 99.9

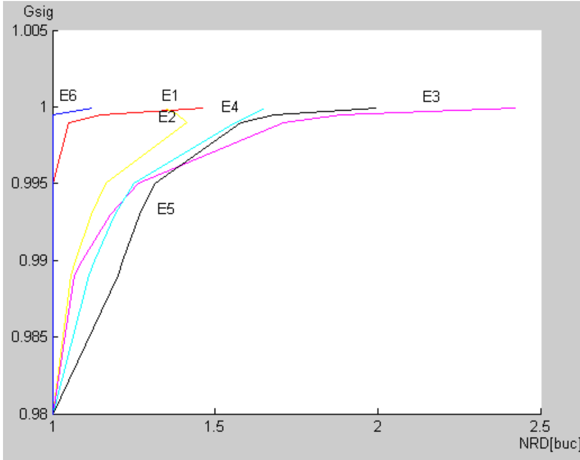

Figure 5 Increase safety supply system based on the number of redundant element for a reliability of 99.99

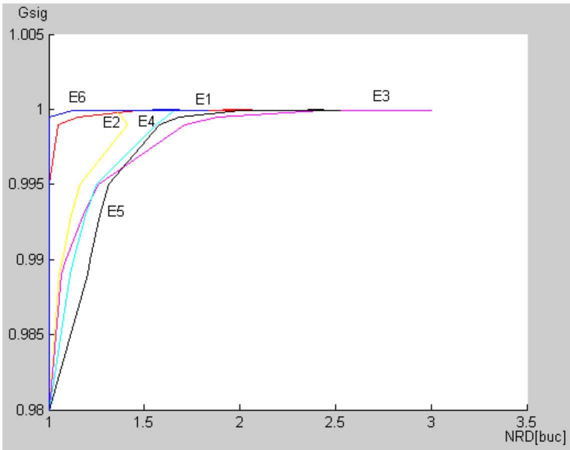

Figure 6 Increase safety supply system based on the number of redundant element for a reliability of 99.99

5 CONCLUSIONS

It is noted from Figures 4,5 and 6 a different increase in the number of elements optimal redundancy (NRD) for each equipment E_i, with the degree of safety Gsig.
This growth is based on:
- parameters of reliability of equipment $E_i(\lambda_i ; \mu_i)$;
- cost per unit of equipment;
- position equipment in the system.

Improving the safety and reliability of electric power supply to lighting is obtained subtracting hours of interruption $M_\beta(X)$ and number of interruption $M_\upsilon(X)$, once with the bigger number of elements of the system and implicit costs.

Note from the graphs 4,5,6 and the table 2 that can be achieve through a degree of safety very big 0.9999 by introducing an element of reserve for X_3, X_4, X_5, id by introducing an element of reserve for transformer, electric line in cable LEC1 and electric line in cable LEC2.

In variant II of study, the lighting power safety is achieved through two identical transformers in parallel on the same diagram in Figure 3

Results of this study case are presented in table 3 for the non optimized variant and in table 4 for the optimized variant.

Table 3 Initial values

X_1	X_2	X_3	X_4	X_5	X_6	$P(X)$	$M_\beta(X)$	$M_\upsilon(X)$	COST
1	1	1	1	1	1	0.9965	1325.33	5.8831	433.042

Table 4 Optimum values

Gsig. imposed %	X_1	X_2	X_3	X_4	X_5	X_6	$P(X)$	$M_\beta(X)$	$M_\upsilon(X)$	COST
98	1	1	1	1	1	1	0.9965	304.55	5.6170	433.042
99	1	1	1	1	1	1	0.99	304.55	5.6170	433.042
99.9	1	1.2346	1	1.3371	1.3896	1	0.999	87.6	1.5952	404.428
99.99	1.4644	1.3481	1.2126	1.6519	1.9978	1.1220	0.9999	8.76	0.3717	558.457
99.999	2.1181	1.3425	1.8028	1.6596	3.0016	1.6650	0.99999	4.784	0.2503	807.364

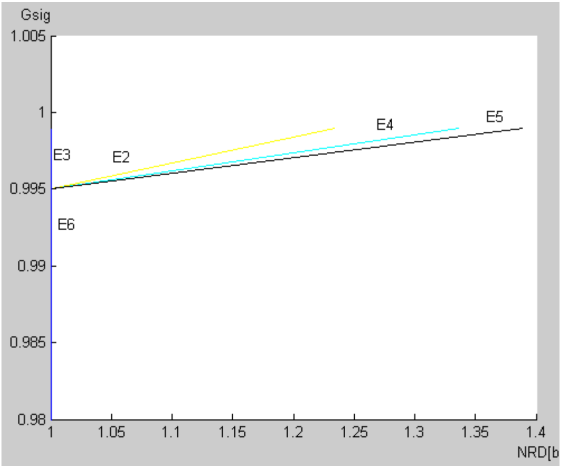

Figure 7 Increase safety supply system based on the number of redundant element for a reliability of 99.9

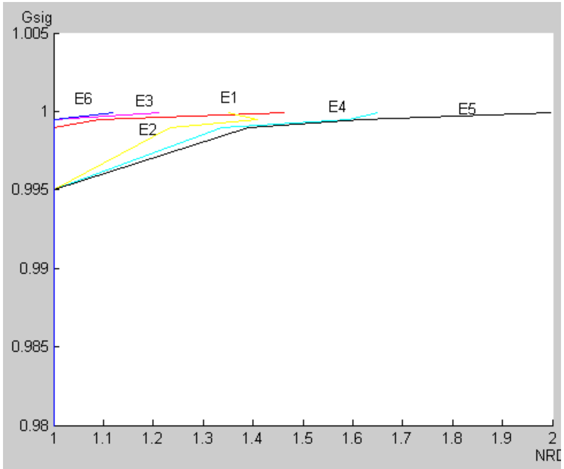

Figure 8 Increase safety supply system based on the number of redundant element for a reliability of 99.99

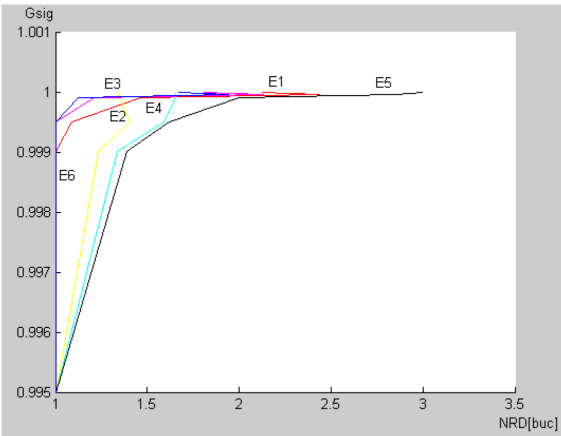

Figure 9 Increase safety supply system based on the number of redundant element for a reliability of 99.99

Note from the table 4 and Figure 7,8 and 9 that can achieve a degree of safety very big 0,9999 by introducing an element of reserve for X_4 and X_5, id by introducing an element of reserve for electric line in cable LEC1 and electric line in cable LEC2.

By comparing these two variants analyzed give us a degree of safety in operation of supply system of safety lighting very big 0.9999 through introduction of an element in reserve for transformer, electric line in cable LEC1 and electric line in cable LEC2.

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THE EVALUATION AND OPTIMIZATION CRITERIA OF RELIABILITY ELECTRIC SUPPLY OF EMERGENCY LIGHTING

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ABSTRACT

The paper develops criteria for evaluating and optimizing the reliability of electricity supply of safe lighting. Solving the problem consists in determining the optimal solution to supply electricity to a hospital on the basis of two criteria:

1. Determination of optimal reliability level at the terminals of the electric power supply of safety lighting in conditions of limited economic funds;
2. Establishing the optimal redundancy of the elements of supply safety lighting in terms of damage imposed by the downtime.

1. INTRODUCTION

For each activity and operational locations used in medical prescriptions are respected for securing private patient.

In most cases, patient safety can be ensured by the electric power plant with electricity and a default installation of electric lighting for safety. The use of electrical equipment in medical intensive treatments for patients in hospitals requires increased reliability and safety of electrical installations in order to improve safety and permanency such feeds.

According to IEC SR 60364 7 710:2005 defined four different classes of medical areas in a hospital as in Table 1.

Table 1 Medical areas classes in hospital

Class 0 (without interruption)	Food available automatically without interruption
Class 0.15 (very short pause)	Automatic food available in less than 0.15 s
Class 0.5 (short pause)	Automatic food available in less than 0.5 s
Class 15 (average interruption)	Automatic food available in less than 15s
Class >15 (long pause)	Automatic food available in over 15s

2. CASE STUDY

2.1. Hypothesis: determination of optimal reliability level at the terminals of the electric power supply of safety lighting in conditions of limited economic funds

The electric supply of safety lighting of a hospital is achieved through the scheme shown in Figure 1.
The electrical parameters of consumer are:

- average power required of consumer are Pc = 3 [MW];
- amount of damages caused to consumers by non delivery of a quantity of electricity by 1 [MW];
- operating planned during ten years, id Tp = 87.600 hours;
- intensity of damages and intensity repair of system elements.

Let establish the optimal reliability level at the terminals of the electric power supply of safety lighting in conditions of limited economic funds.

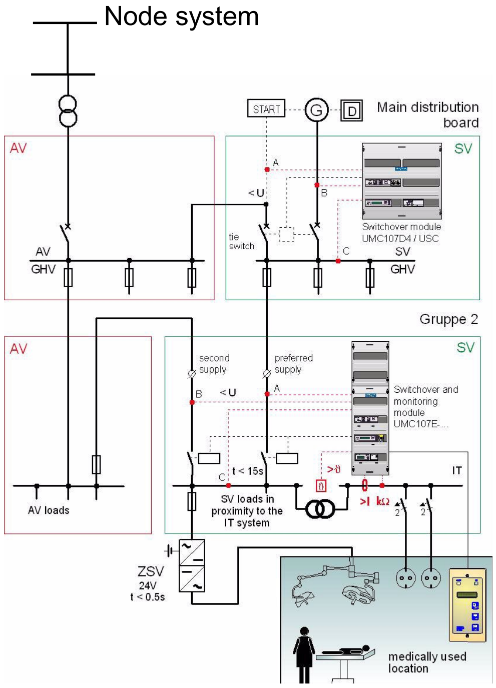

Figure 1 The electric supply of emergency lighting of a hospital

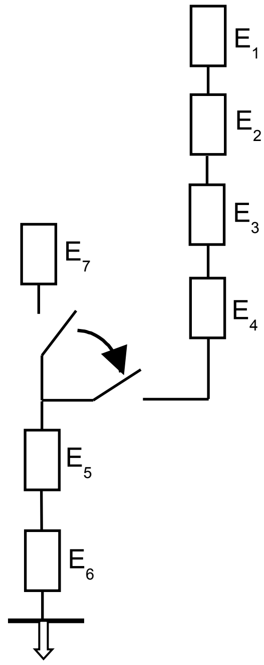

Figure 2 Block diagram of the electric supply of emergency lighting of a hospital

2.1.1. Structure

Mathematical model to optimize the redundancy elements of the scheme illustrated in Figure 3 variant I off base to include security lighting:

Optimized variables are the number of identical items in the reserve for each element of the scheme, or:

E_1 - Node system = $\mathbf{x}_1$; E_2 - Medium voltage bar = $\mathbf{x}_2$; E_3 - Transformer = $\mathbf{x}_3$;
E_4 - Electric line in cable LEC1 = $\mathbf{x}_4$; E_5 - Electric line in cable LEC2 = $\mathbf{x}_5$; E_6- UPS = $\mathbf{x}_6$.
- for E_i we will dipose of $\mathbf{x}_i$ identical elements in parallel with the element E_i $i = 1,6$

Vector of variables to be optimized:

$$\mathbf{X} = \left[\mathbf{x}_1\,\mathbf{x}_2\,\mathbf{x}_3\,\mathbf{x}_4\,\mathbf{x}_5\,\mathbf{x}_6\right]^T \quad (1)$$

Criterion function to optimize the model, is determined by condition: maximize reliability of system, or minimize non reliability of system:

$$max\{P(\boldsymbol{X})\} \quad (2)$$

or,

$$min\{Q(\boldsymbol{X})\} \quad (3)$$

with:

$$P(X) = \prod_{i=1,N}\left(1 - q_i^{x_i}\right) = \prod_{i=1,N}\left[1 - \left(1 - q_i^{x_i}\right)\right]$$
$$Q(X) = 1 - \prod_{i=1,N}\left(1 - q_i^{x_i}\right) = 1 - \prod_{i=1,N}\left[1 - \left(1 - p_i\right)^{x_i}\right] \quad (4)$$

Model restrictions are imposed two conditions:

a. The construction, under which the number of items in the reserve for each equipment E_i:

$$1 \le X_i \le 3 \quad i = 1,6 \quad (5)$$

b. Economic, by limiting funds for investment at a value VI, or:

$$C_E(\mathbf{X}) \le \text{VI} \quad (6)$$

with:

$$C(X) = \sum_{i=1,6} X_i \cdot I_i + X_4 \cdot \alpha_4 \cdot LEC1 + X_5 \cdot \alpha_5 \cdot LEC2 \quad (7)$$

where:

I_i is cost of specific equipment type E_i [m.u./ea];

α_4, α_5 represents specific cost per km of 0.4 kV [um / km];

c_i is specific costs [m.u./ea] and they have hypothetical values because the cost of equipments and electric lines varies depending on the manufacturer (performer), to admit their expression [m.u.] (currency units).

L_1 = 0,3 [km]; L_2 = 0.090 [km]

c_1 = 120 [m.u./ea] ; c_3 = 110 [m.u./ea]; $c_5 = 27.8*L_2$ [m.u./km];

c_2 = 5 [m.u./ea]; $c_4 = 51.8*L_1$ [m.u./km]; c_6 = 70 [m.u./ea].

Note: Since the cost of equipment and electric lines varies according to the manufacturer (performer), to admit their expression in monetary units [m.u.].

The model thus formulated was solved using the MATLAB programming environment (LABoratory Matrix), and for nonlinear optimization, *fmincon* function was used.

2.1.2. Results

Initial values in the tables were calculated for variant non optimized of system and optimal values were calculated for variants optimized redundancy elements.

Optimal values were calculated for s variants optimized redundancy elements.

Final optimal values were calculated for rounding to the nearest whole number, the optimal solution of the optimal rational.

Table 2 Investment value VI = 330 m.u.

	Initial Values						Optimum Values						Final Values						
	E_1	E_2	E_3	E_4	E_5	E_6	E_1	E_2	E_3	E_4	E_5	E_6	E_1	E_2	E_3	E_4	E_5	E_6	
X	1	1	1	1	1	1	1	1.052	1.042	1.098	1.191	1	1	1	1	1	1	1	pieces
$P(X)$	0.984346						0.9878						0.9843						
$M_\beta(X)$	1371.2						1071.3						1378.9						
$M_\upsilon(X)$	6.7614						4,7393						6.8075						
MTd	202.8089						226.0490						202.5541						
COST	323.0420						330						323.0420						m.u.

Table 3 Investment value VI = 430 m.u

	Initial Values						Optimum Values						Final Values						
	E_1	E_2	E_3	E_4	E_5	E_6	E_1	E_2	E_3	E_4	E_5	E_6	E_1	E_2	E_3	E_4	E_5	E_6	
X	1	1	1	1	1	1	1.083	1.376	1.756	1.686	1.480	1	1	1	2	2	1	1	pieces
$P(X)$	0.984346						0.9992						0.9984						
$M_\beta(X)$	1371.2						70.5293						141.7923						
$M_\upsilon(X)$	6.7614						0.8908						3.6100						
MTd	202.8089						79.1746						39.2772						
COST	323.0420						430						448.5820						m.u.

Table 4 Investment value VI = 800 m.u

	Initial Values						Optimum Values						Final Values						
	E_1	E_2	E_3	E_4	E_5	E_6	E_1	E_2	E_3	E_4	E_5	E_6	E_1	E_2	E_3	E_4	E_5	E_6	
X	1	1	1	1	1	1	1.258	1.202	3	1.629	1.276	1.020	1	1	3	2	1	1	pieces
$P(X)$	0.984346						0.9997						0.9985						
$M_\beta(X)$	1371.2						23.8720						128.3823						
$M_\upsilon(X)$	6.7614						1.0443						3.5790						
MTd	202.8089						22.8593						35.8714						
COST	323.0420						587.0175						558.5820						m.u.

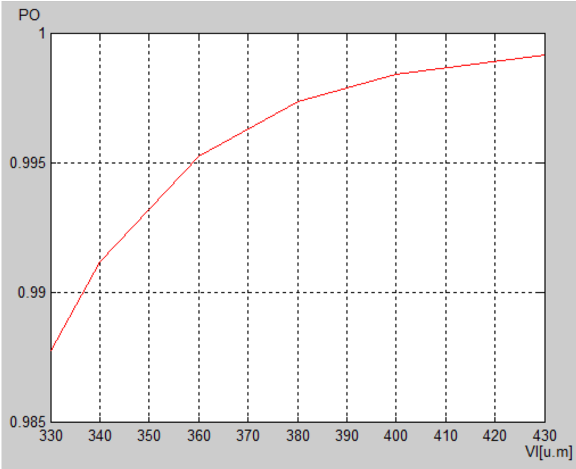

Figure 3 Increase the reliability system with increase investment VI = 430 m.u.

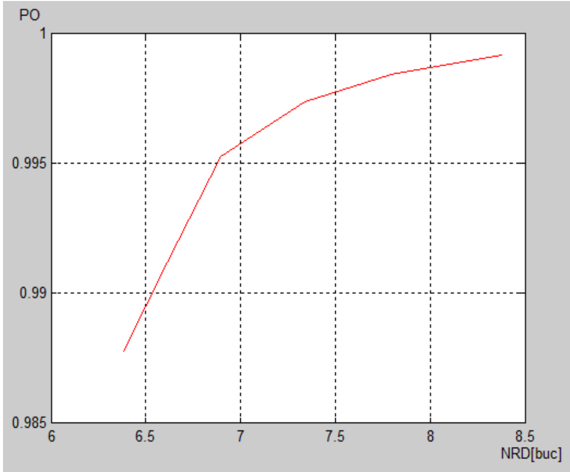

Figure 4 Increase the reliability system with increase the number of redundant element for investment VI = 430 m.u.

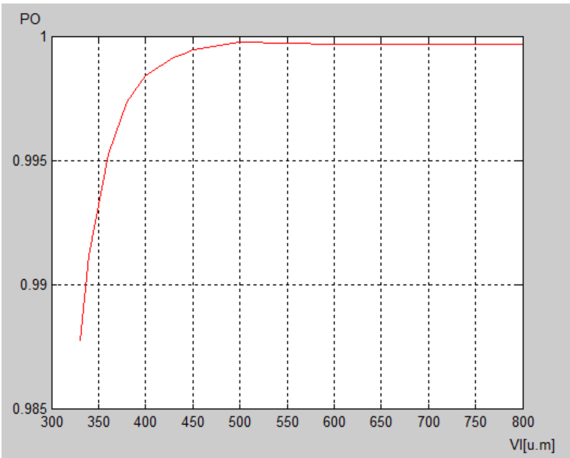

Figure 5 Increase the reliability system with increase investment VI = 800 m.u.

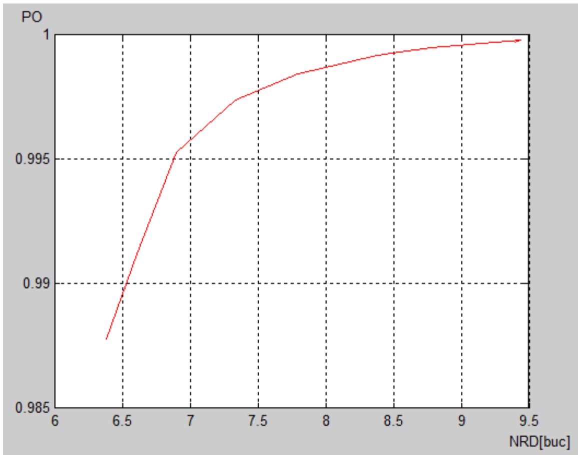

Figure 6 Increase the reliability system with increase the number of redundant element for investment VI = 800 m.u.

2.1.3. Conclusion

In Tables 1, 2, 3 and Figures 1, 2, 3 and 4 results increase the reliability system with the investment value. Optimum investment value is VI = 500 mu. Taking into account the reliability of electric supply system of safety lighting is not justified to increase investment over this value VI = 500 m.u.

2.2. Hypothesis: damages imposed during the downtime

Let establish the optimal redundancy elements of the radial system shown in Figure 2 in terms of damage imposed by the consumer, any time due to downtime of the system power.

2.2.1. Structure

Optimized variable are the number of identical items in the reserve for each element of the scheme, or:

$$\mathbf{X} = \lfloor \mathbf{x}_1\ \mathbf{x}_2\ \mathbf{x}_3\ \mathbf{x}_4\ \mathbf{x}_5\ \mathbf{x}_6 \rfloor' \tag{8}$$

Criterion function to optimize the model is:

$$min\{C(\boldsymbol{X})\} \tag{9}$$

$$C(\boldsymbol{X}) = \sum_{i=1,5} c_i \boldsymbol{X}_i \tag{10}$$

Model restrictions are imposed two conditions:

a. The construction

$$1 \le \boldsymbol{X}_i \le 3 \quad | \ i = 1,6 \tag{11}$$

b. Economic, imposed by the condition that damages the consumer does not exceed a time (VD^T), due to the time of interruption of supply.

$$P_c \cdot d_\beta \cdot Q(X) \cdot T_h \leq VD^T \qquad (12)$$

2.2.2. Results

The model thus formulated was solved using MATLAB programming environment, and for non linear optimization *fmincon* function was used. The results of this study variations are presented in Table 5.

Table 5 Amount of damages imposed

VD imposed	X_1	X_2	X_3	X_4	X_5	X_6	$P(X)$	$M_\beta(X)$	$M_\upsilon(X)$	COST
10000	1	1.2045	1.3341	1.2992	1.3578	1	0.9962	333.33	2.1448	356.362
8500	1	1.2288	1.3778	1.3298	1.3835	1	0.9968	283.33	1.9330	361.833
5000	1	1.3148	1.5328	1.4381	1.4744	1	0.9981	166.66	1.4096	381.221
1000	1,830	1.5405	1.9398	1.7222	1.729	1	0.9996	33.333	0.5927	454.085
100	1,4943	1.8388	2.4778	2.0977	2.0281	1.1577	0.99996	3.3333	0.1023	568.202
10	1,7998	2.1307	3	2.4663	2.3362	1.3745	0.999999	0.3333	0.0120	683.277

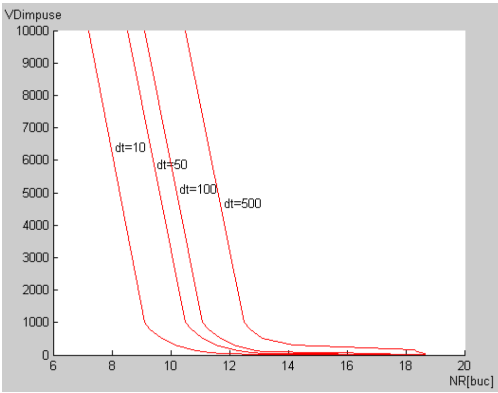

Figure 7 Variation of the total number of items, depending on the size of the damages imposed VD, for a different values of damage specific d_β

2.2.3. Conclusion

Note an increase in the number of redundant elements, with the decreasing amount of damages imposed or with specific growth damages.

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TUBULAR DAYLIGHT GUIDANCE SYSTEMS - ENERGY SAVING POTENTIAL IN RESIDENTIAL BUILDINGS IN ROMANIA

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ABSTRACT

Traditional vertical window can provide adequate daylight within about six meters of the window. Daylight levels decrease asymptotically with distance from the window so that a disproportionate amount of daylight/solar gain must be introduced into the front of the room to achieve small increases in daylight at the back. A number of systems exist to redirect daylight into areas of buildings that cannot be lit by conventional glazing. One major generic group is known as 'beam daylight' - redirects sunlight by adding reflective or refracting elements to conventional windows. The second major group is known as 'tubular daylight guidance systems (TDGS)'. These consist of a light transport section with, at the outer end, some device for collecting natural light and, at the inner end, a means of distribution of light within the interior.

TDGS daylight guidance systems are linear devices that channel daylight into the core of a building. The nature of the systems and the factors influencing the costs and various benefits that contribute value are identified. Lighting systems in residential buildings, lit by electric lighting and daylight guidance, were surveyed. Data on the physical characteristics of the systems, lighting conditions achieved, and user views were collected. The results formed the input to a cost and value analysis which permitted the economic limits of the systems to be evaluated. Some evaluations were made about the energy savings and the environmental benefits.

1 INTRODUCTION

Why is daylight not always a primary consideration in building design? There seems to be some common barriers, throughout the world, that hinder appropriate integration of the daylighting aspects: lack of knowledge on the performance of daylighting systems and lighting control strategies; lack of appropriate and user friendly daylighting design tools; lack of evidence of the advantages of daylighting [1].

The architectural volumes are evaluated by shades and light, either natural or artificial. Le Corbusier said about architecture that it is "the learned play, correct and magnificent of the volumes reunited under light". The underground spaces (metro, commercial galleries, passages) are architectural expressed in a theatrical manner, with the artistic effects realised by the artificial light of projectors, by the dynamics of environment, by the esthetical effects.

Windows – through which daylight is introduced to the interior, where the light is modified and controlled, and from which the views out beyond the building are obtained – are at the heart of the matter. There is a correlation between solutions to the control of sunlight for thermal reasons and for those of glare – cutting out sunlight from different directions to avoid overheating in summer will reduce glare for the interior – but it should be borne in mind that the reduction of glare may not by itself provide a solution to the provision of thermal comfort.

The natural environment aspects, the unique qualities of daylighting make their introduction into buildings as relevant as when there was no viable alternative in artificial sources:

1. *Change and Variety* – the direction of the light, which provides modelling to the interior, the nature of sun and sky;
2. *Color and View - the contact with the exterior beyond, such as a view through the window, an experience of the weather and the world outside, the natural colour associated with daylight which imparts reality to the interior;*
3. *Modelling and orientation, Sunlight effect - the mood created by the variation of light, from day to day, and time to time as affected by the weather and seasons, the dynamics of lighting.*

The avoidance of glare is a maximum priority for most architectural programmes, particularly those with fixed work positions, and 'add-ons' after the building is complete, such as internal shading devices, are not the solution. Much can be done by external shading or high-tech glass; what is important is that glare avoidance is an integral part of design strategy being planned for and executed at the design stage of the building. On certain elevations the window may require protection from solar radiation, either through the selection of the glass used or by external shading, or both. The use of internal shading is less efficient for thermal control, but is more easily managed. When used, external shading becomes a structural element and is both visually and structurally important: visually it has an impact on the external appearance of the building and structurally it must withstand all the external pressures applied to it.

The average Daylight Factor gives a measure of the overall level of daylight in a room. With a 5% average DF the room will have a well daylight appearance, whilst a 2% average DF may require supplementary artificial light in work spaces for much of the time. However a 2% average DF is very adequate in a domestic situation.

A difference in the perception of spaciousness occurs when penetration of the boundaries are windows, doorways, or other openings in the spatial envelope, providing mental engagement for the eye by connecting the space of the observer with outside activities. Ne'eman and Hopkinson (1970) found that the main determinant for people's preference for window openings was the amount of visual information provided by the outside view. Keighley (1973) stated that the most frequently preferred opening was a central, horizontally shaped window that provides a view to the skyline, and that the preferred window opening is a large horizontal aperture, that occupied 25% to 30% of the wall into which the window was cut.

2 DAYLIGHTING SYSTEMS

Daylighting systems can be classified [2], after their main function as systems with shading and systems without shading.

Two types of daylighting systems with shading are discussed: systems that rely primarily on diffuse skylight and reject direct sunlight, and systems that use primarily direct sunlight, sending it onto the ceiling or to locations above eye height.

Shading systems are designed for solar shading as well as daylighting; they may address other daylighting issues as well, such as protection from glare and redirection of direct or diffuse daylight. The use of conventional solar shading systems, such as pull-down shades, often significantly reduces the admission of daylight to a room. To increase daylight while providing shading, advanced systems have been developed that both protect the area near the window from direct sunlight and send direct and/or diffuse daylight into the interior of the room.

Daylighting systems without shading are designed primarily to redirect daylight to areas away from a window or skylight opening. They may or may not block direct sunlight. These systems can be broken down into four categories:

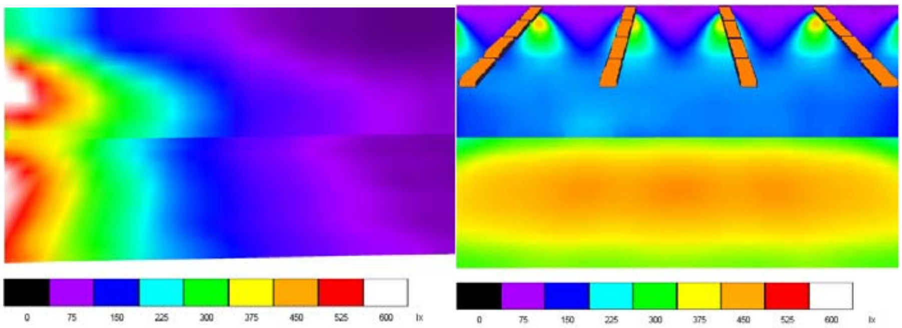
- Diffuse light-guiding systems redirect daylight from specific areas of the sky vault to the interior of the room. Under overcast sky conditions, the area around the sky zenith is much brighter than the area close to the horizon. For sites with tall external obstructions (typical in dense urban environments), the upper portion of the sky may be the only source of daylight. Light-guiding systems can improve daylight utilization in these situations
- Direct light-guiding systems send direct sunlight to the interior of the room without the secondary effects of glare and overheating
- Light-scattering or diffusing systems are used in skylit or toplit apertures to produce even daylight distribution. If these systems are used in vertical window apertures, serious glare will result
- Light transport systems collect and transport sunlight over long distances to the core of a building via fiber-optics or light pipes

Some systems can fulfil multiple functions and are therefore in more than one category. Light shelves, for instance, redirect both diffuse skylight and beam sunlight [3].

3 TUBULAR DAYLIGHT GUIDANCE SYSTEMS (TDGS)

Traditional vertical window can provide adequate daylight within about six meters of the window. Daylight levels decrease asymptotically with distance from the window so that a disproportionate amount of daylight/solar gain must be introduced into the front of the room to achieve small increases in daylight at the back. While this can increase energy savings over a larger room area by offsetting electric lighting energy, the corresponding increase in cooling due to solar heat gain, and/or heating due to structural heat loss, can negate these savings. The use of glazed areas on other parts of the building envelope including atriums, skylights and roof monitors may light some areas remote from windows but these are of limited use in lighting deep core areas [1].

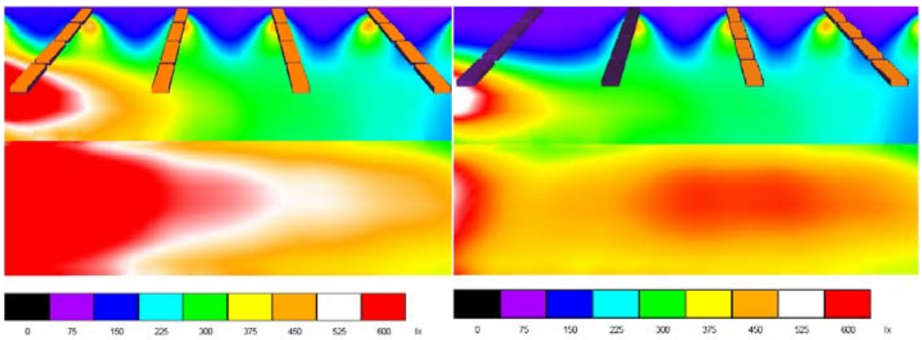
The estimated lighting level was simulated with Dialux 4.6 Software for a room (6*12 m) situated in Bucharest. The room has the windows orientation NE on the 6 m wall. In Figure 3.1 it can be seen the limited amount of daylight inside a 12 m deep room. The same figure illustrates the lighting level when there are used fluorescent 36 W lamps.



Daylight Artificial

Figure 3.1 Lighting levels for a room (l=6 m, L=12 m, windows on the left side NE, simulation for a building situated in Bucharest, summer time)

Figure 3.2 shows the simulated lighting level under the same conditions, first all the lamps on and second the one close to the window turned off.



Daylight + Artificial Daylight + Dimmed Artificial

Figure 3.2 Lighting levels for a room (l=6 m, L=12 m, windows on the left side NE, simulation for a building situated in Bucharest, summer time)

A number of systems exist to redirect daylight into areas of buildings that cannot be lit by conventional glazing. One major generic group is known as ‘beam daylighting’ - redirects sunlight by adding reflective or refracting elements to conventional windows. The second major group is known as ‘tubular daylight guidance systemsTDGS’.

TDGS consist of a light transport section with, at the outer end, some device for collecting natural light and, at the inner end, a means of distribution of light within the interior – Figure 3.3. Collectors may be mechanical devices that actively direct daylight (usually sunlight), or be passive devices that accept sunlight and skylight from part or whole sky hemisphere, and may be located at roof level gathering light from the zenithal sky or on the building façade. Zenithal openings capture light from the brightest sky region but may cause glare or overheating due to direct solar penetration. Orientation is a major determinant of collection efficacy in façade mounted collectors. The transport element is usually a tube lined with highly reflective silvered or prismatic material and may contain lenses or other devices to redirect the light. Light is distributed in an interior by emitters which differ little from conventional luminaires. Light transport is the feature that sets tubular guidance systems apart from other daylight redirection methods. The principal function of transport elements is to deliver light from the collector to the point of exit but some may additionally act as emitters. Recently considerable research effort has been directed at transport systems, a major factor being the availability of new low cost light redirection materials. Usually there are four different transport methods, namely, beam/lens systems, hollow mirrored pipes, hollow prismatic pipes, and solid core systems.

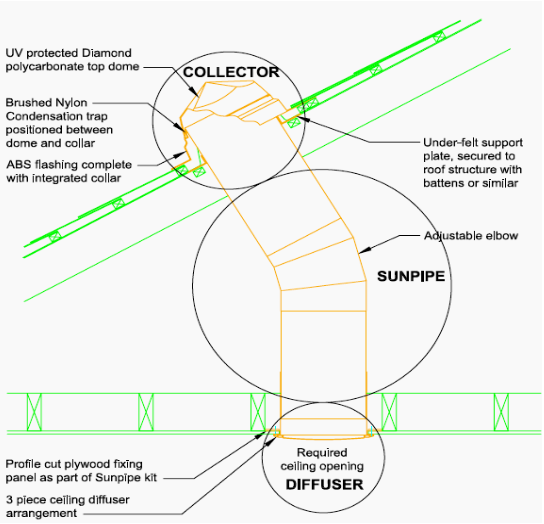


Figure 3.3 Tubular daylight guidance system with passive collector [4]

The light pipe, lined with highly reflective material, is used to guide sunlight and daylight into occupied spaces (Figure 3.3). Highly reflective materials include anodised aluminium and coated plastic film such as Silverlux, which have reflectance greater than 95%. Commercial light pipe are available from a number of manufacturers, in straight and bend sections for on-site assembly and installation. They allow the light pipe to go through complex roof spaces to reach rooms that are not easily accessible to skylights. A light pipe is normally fitted with a clear top dome which removes harmful UV radiation and prevents the ingression of rain water and dust. A diffuser fitted to the bottom of the light pipe ensures that light is distributed around the room it illuminates. Compared to skylight or windows, the light pipe transmits less solar heat on to the illuminated surfaces. This is particularly valuable in summer for preventing inhabitable hot spots in a building. In winter, a light collector (e.g., a sun-scoop) could be mounted above the top opening to allow significantly more sunlight from low angles to be collected [5].

4 CASE OF STUDY (PASSIVE TDGS – INSTALLED IN CLUJ-NAPOCA)

The experimental set up is shown schematically in Figure 4.1.

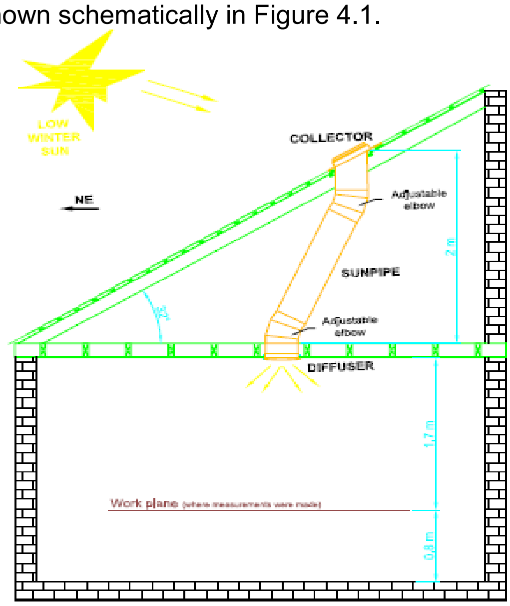


Figure 4.1 TDGS set-up for a pitched slate roof faceing NE

A light pipe produced by the Velux Company was mounted inside a 4.2*3.5 m room on the first floor of the building. The house is part of a duplex situated in Cluj-Napoca. The cylindrical light pipe has a length of 2 m and a diameter of 430 mm. A highly reflective film is laminated, using adhesives, to the interior surface which has a minimum reflectivity of 95%. The top of the pipe was sealed with a clear anti-yellowing acrylic plate. A pearl white diffuser was fitted to the lower opening of the light pipe for even light distribution within the room.

The owners of the house guide themselves in choosing the right device for their application using the technical support of Velux Company. The calculation were made using Velux Lux Software. The results provided by the software are shown in Figure 4.2.

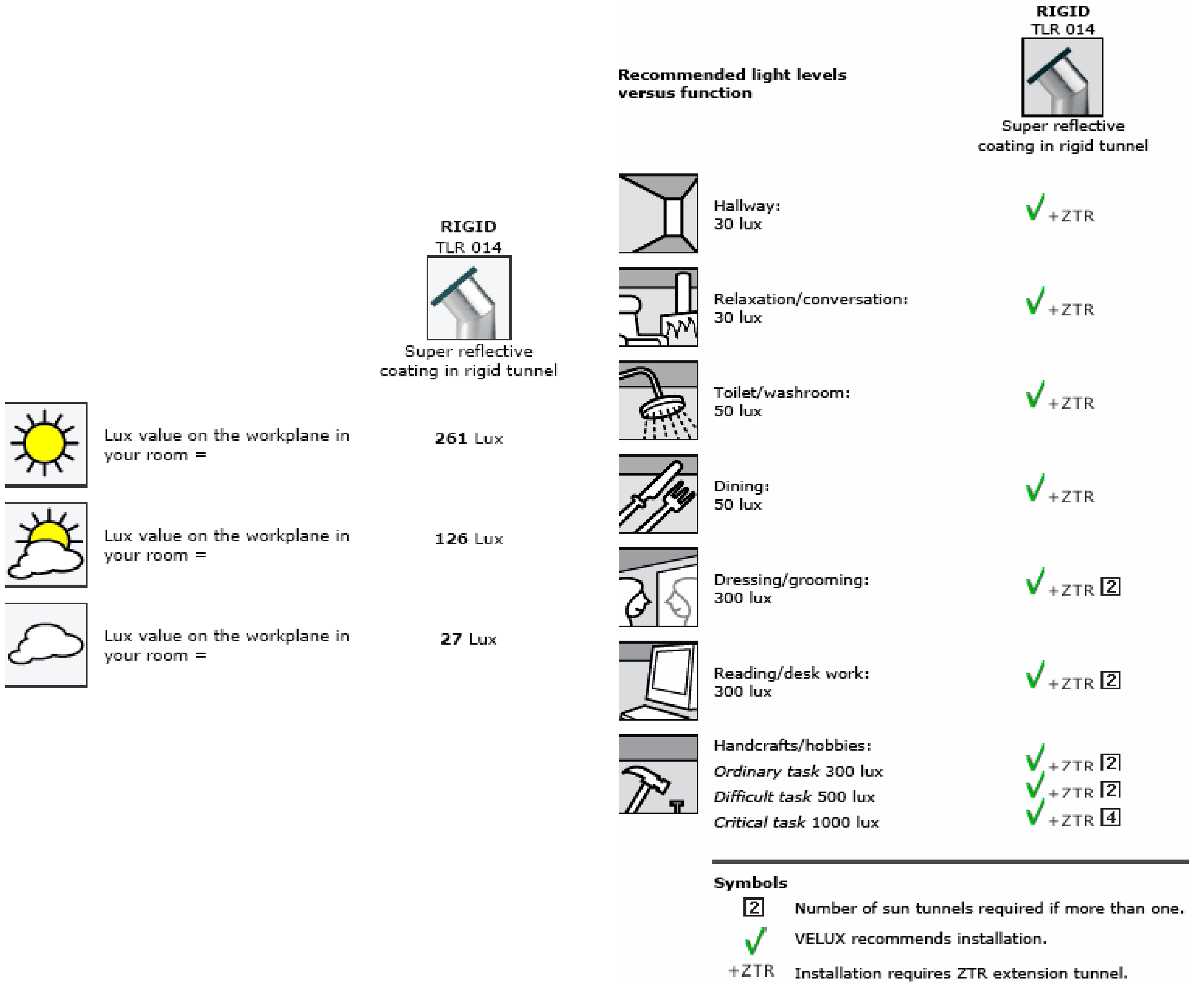


Figure 4.2 Velux Lux Software – results [6]

Illuminance measurement was carried out using a standard light meter which had a range of 0.05- 100,000 lux. The meter was based on a photovoltaic cell which has a spectral response similar to that of a standard human eye thus avoids the need for correction for various types of light sources.

Illuminance of the sun on the open field and that within the working plane inside the room were obtained using two separate photocells. The readings were recorded manually and cares were taken to ensure that there was no passing clouds or other significant changes of lighting condition between reading the two cells. The photocell within the room was normally placed in the centre, at a 0.8 m distance above the floor where the working plane is assumed to be. Measurements were carried out in three different days in the winter time. As shown in T 4.1, the readings made in the first day are not conclusive because of the ice covering the collector.

The lighting levels inside the room are poor but they match with the predicted results of the Velux Lux Software. The system has three big problems to be solved: the flat collector, the roof peek shadowing the collector and the NE orientation of the roof. The change of the collector with an acrylic dome and the extension of the sun pipe up to a level where the roof peek has no influence will also eliminate the orientation problem of the roof.

Table 4.1 Light pipe performance under cloudy and mix conditions.

Date	Hour	Work plane illuminance	External illuminance	Internal / External Ratio	Comments	Average work plane illuminance
		lx	lx	%		lx
29.12.08	8:35	7,5	1.200	0,63	 The collector was covered in ice	19,18
	9:00	10,0	2.300	0,43		
	9:22	14,0	2.900	0,48		
	9:46	19,0	4.500	0,42		
	10:00	20,0	5.000	0,40		
	10:17	22,5	5.500	0,41		
	10:30	22,5	5.500	0,41		
	11:00	27,0	8.000	0,34		
	11:30	30,0	8.300	0,36		
	12:00	25,0	7.500	0,33		
	12:40	23,0	6.500	0,35		
	13:50	21,0	5.150	0,41		
	14:50	20,0	5.000	0,40		
	15:50	7,0	1.150	0,61		
04.02.09	13:13	135,0	24.000	0,56		64,75
	13:33	85,0	10.000	0,85		
	13:50	60,0	4.400	1,36		
	14:15	34,0	3.200	1,06		
	14:30	40,0	3.600	1,11		
	15:00	69,0	5.000	1,38		
	15:20	55,0	4.500	1,22		
	15:40	40,0	3.500	1,14		
06.02.09	10:59	100,0	11.400	0,88		112,25
	11:15	88,0	7.500	1,17		
	11:20	92,0	19.000	0,48		
	11:39	98,0	20.000	0,49		
	12:02	120,0	26.000	0,46		
	12:10	130,0	28.000	0,46		
	12:38	140,0	18.000	0,78		
	13:23	130,0	12.000	1,08		

Some simulations were made for the same room using the Dialux Software. There were taken into consideration the four seasons, the 12:00 hour of 15 of January, April, July and October, plus the exact latitude and longitude of the building. The TDGS was assimilated with a roof light but the direct sun light was not taken into consideration for the calculation. Also the roof peek shadow was not considered for the simulation. Opposite to the measurements results, F 4.3 shows the lighting levels on the room floor.

5 CONCLUSIONS

Daylighting systems require a specific conception, very close related to the geographic context where they are built, to environment (natural and artificial obstructions), to imposed levels of visual comfort and to climate.

The development of new materials with better performance in light reflection and transmission has lead to various solutions of energy efficient lighting systems able to grow potential for future applications.

Any technical and economical analysis of these systems must take into account both energy efficiency, and visual comfort conditions for the lighted spaces. For example, these solutions present outstanding possibilities to improve visual comfort in underground spaces, which are energy efficient due to low thermal losses.

Perspectives offered by these solutions of integrated lighting systems lead to a higher visual comfort and to new possibilities of space utilization.

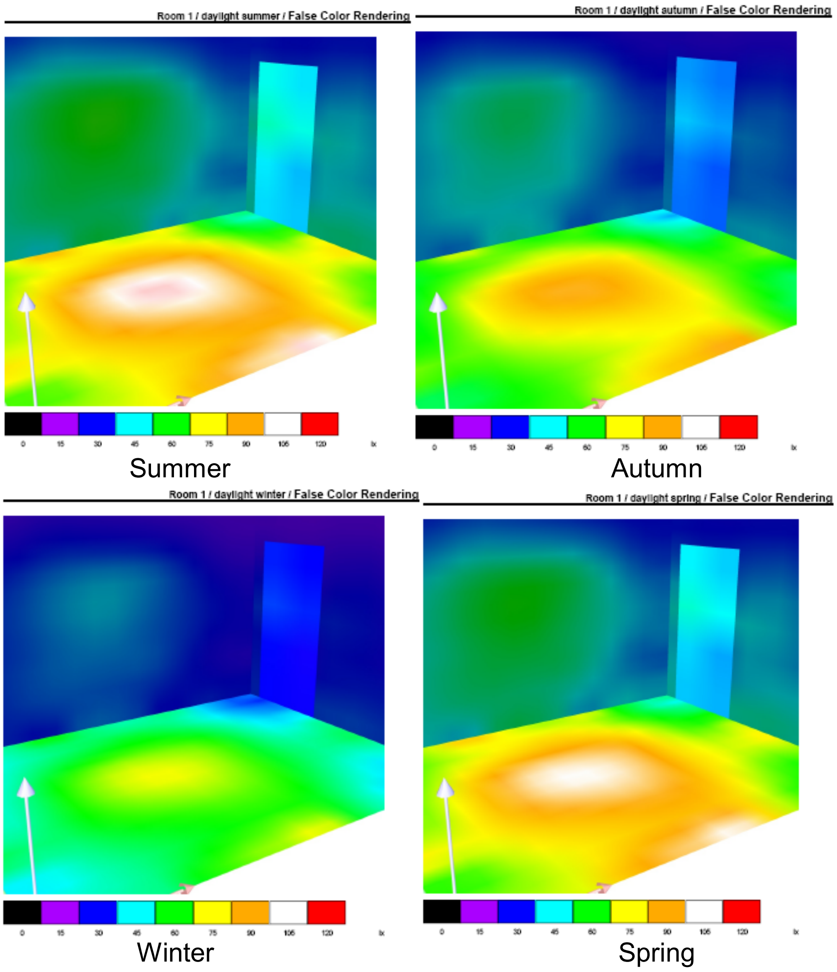


Figure 4.3 Dialux 4.6 simulations – results

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IMPLEMENTATION OF ARTIFICIAL INTELLIGENCE TECHNIQUES IN LIGHTING SYSTEMS

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ABSTRACT

The sustainable development concept has revived the interest for daylighting as any day lit area has very promising energy-saving opportunities; according to some specialists, the potential energy savings can exceed 40%. However, daylight is a dynamic source of lighting, i.e. the illuminance from the sky is not constant, and the variations in daylight can be quite large depending on season, location or latitude, and cloudiness. As a result, electric lighting control systems will be needed from time to time to adapt the lighting systems to changing lighting conditions.

Classic control systems, based on continuous dimming present some difficulties to adjust their performances to the rapid changes in daylight and to occupants' preferences. Taking into account these aspects, the control based on artificial intelligence techniques could be a better solution. The paper analyzes the possibility to implement the fuzzy logic in daylighting control and presents the structure of a fuzzy controller proposed by authors; its operation rules and the influence on the imposed value of the illuminance level are also studied.

Keywords: artificial lighting, energy management, daylight, control strategies, artificial intelligence, fuzzy logic, fuzzy controller

1 INTRODUCTION

During the last three decades, the electricity consumption in indoor and outdoor lighting systems has continuously increased. For instance, nowadays 30% to 45% of a building's electricity bill is typically for lighting. That is why the implementation of sustainable energy development has addressed this sector as having an important potential regarding energy savings.

Apart the behavior of human occupants, the lighting controls play a key role in this action. Lighting controls provide building operators with the means to manage the way lighting energy is used in buildings more efficiently. These systems use various control strategies to (1) reduce wasted hours of lighting in unoccupied spaces, (2) automatically adjust electric light levels in synchrony with available daylight or age-related changes in luminaire output or (3) selectively shed lighting loads to moderate peak demand. Lighting control systems have been installed in a number of buildings worldwide and have been shown significant energy savings when the controls have been properly designed, specified, installed, commissioned and maintained [1].

A variety of strategies and techniques have been developed to control lighting systems, all of them aiming one of the two following goals: energy management and esthetics. Energy-management controls provide energy saving through reduced illuminance or reduced time of use; esthetic controls provide the ability to change space functions and create emotional appeal [2]. In fact, the two sides are not totally independent: energy management control strategies may significantly improve the esthetic quality of a space, and controls installed for esthetic purposes may produce significant energy savings. Advanced lighting control devices and systems can be used to reduce ongoing costs for the owner and thereby increase profitability and competitiveness. According to [3], lighting controls can reduce lighting energy consumption by 50% in existing buildings and by at least 35% in new construction.

In recent decades, technological development in micro-electronics has improved the performance and the quality of equipment traditionally used in lighting controls and allowed integration of devices into larger, more flexible systems. The result is significantly expanding energy-saving opportunities, flexibility, reliability and interoperability between devices from different manufacturers. Simultaneously, new devices and control strategies have been tested and implemented in control practice.

The sustainable development concept has revived the interest for daylighting, i.e. for the use of daylight as a primary source of illumination in a space as any day lit area has very promising energy-saving opportunities. Unfortunately, daylight is a dynamic source of lighting, i.e. the illuminance from the sky is not constant, and the variations in daylight can be quite large depending on season, location or latitude, and cloudiness. As a result, electric lighting control systems will be needed from time to time to adapt the lighting systems to changing lighting conditions**.**

Classic control systems present some difficulties to adjust their performances to the rapid changes in daylight and to occupants' preferences. Taking into account these aspects, innovative control systems based on artificial intelligence techniques could be a better solution. The paper analyzes the possibility to implement the fuzzy logic in daylighting control and presents the structure of a fuzzy controller proposed by authors; its operation rules and the influence on the imposed value of the illuminance level are also studied.

2 INDOOR LIGHTING SYSTEMS

Nowadays, the fluorescent lamp is the primary light source for indoor applications. Unlike the incandescent lamp, which is a purely resistive load, the fluorescent lamp is a complex negative-resistance load requiring a ballast to maintain the proper electrical input for both starting and operation.

Uniform illuminances are often provided throughout a space. By definition, uniform lighting illuminates spaces and areas on and around the immediate work or task area equally. The use of uniform lighting has been criticized because of the potential for wasted energy from lighting in both task and non-task areas uniformly. Uniform lighting is frequently applied to areas in which the task or the task areas are not precisely defined; typical of these is 500 to 700 lux uniformly applied to speculative office space.

The principal applications for uniform lighting is in areas where the activity taking place occurs uniformly and continuously throughout the entire space and where task locations are quite close together, such as in classrooms or densely occupied office space. It should not be installed as a substitute for proper planning when it is not really required. Fixtures may be kept on site but not installed until the specific locations of workstations are known. An alternative approach, considering the 50 - 60 year life-cycle of a building during which time tasks may be performed anywhere in the space, is to install luminaries capable of supplying uniform illumination, but with switching controls that would allow a non-uniform lighting result in the space. With a task-tuning control strategy, the lighting system can be adjusted, or tuned, to provide local illumination as needed; considerable savings are possible through task tuning. This strategy results in the efficient use of energy for lighting without sacrificing occupant visual performance.

Typical spaces where uniform illuminance can be used to best advantage include:

- Densely occupied office space;
- Data processing centers;
- Classrooms;
- Gymnasiums;
- Mass merchandising stores;
- Sports fields.

In order to promote energy efficiency in uniform lighting installations, consideration should be given to multiple-level switching that uses two-level ballasts, switching one of a pair of ballasts in luminaries, switching of small areas of luminaries, and switching to lower lighting levels near windows, which can be utilized as a light source during daylight hours.

Coefficients of utilization values that are published by luminaries' manufacturers are used to calculate average illumination levels for uniform lighting. Actual illumination values in a real space will be higher than average in the center of the space and lower near the edges of it. In small rooms, illumination may be 30% higher than average in the center, varying to near average in very large rooms. Consequently, uniform illumination can be reduced if tasks are located near the center of small and medium-sized rooms. Conversely, work locations near walls should be avoided unless task lighting is provided.

3 FUZZY LOGIC AND DAYLIGHTING CONTROL

Daylight is a dynamic source of lighting, i.e. the illuminance from the sky is not constant, and the variations in daylight can be quite large depending on season, location or latitude, and cloudiness. Different skylight levels can be found under the same sunlight conditions, and, even when the sky pattern remains the same, the range of solar illuminances may increase as a result of a momentary turbidity filter or scattering of particles over the sun. In consequence, any prediction system has to be flexible to allow for the multivariate changes that characterize the combination of sunlight and skylight

[6]. At this moment it is important to underline that daylight is the diffuse ambient light consisting of light reflected in the atmosphere and from the ground; it is not direct sunlight.

In recent years, the control technology has been well developed and has become one of the most successful tools in the industry. However, due to above mentioned aspects, traditional control systems, based on mathematical models, and often implemented as "proportional-integral-derivative (PID)" controllers, have shown their limits as daylighting energy-management controls. Taking into account the random pattern of potentially available daylight and rapid change of its characteristics, fuzzy control has proved to be a more convenient solution.

A. Fuzzy Control

Fuzzy logic is a computational paradigm originally developed in the early 1960's and represents a natural, continuous logic patterned after the approximate reasoning of human beings. It allows for partial truths and multivalued truths, and is therefore especially advantageous for problems that cannot be easily represented by mathematical modelling because data is either unavailable, incomplete, or the process is too complex. The real-world language used in fuzzy control enables engineers to incorporate ambiguous, approximate human logic into computers and technical applications proved that fuzzy logic represents a very valuable way of interfacing inherently analog processes that move through a continuous range of values, to a digital computer, that likes to see things as well-defined discrete numeric values. Using linguistic modeling, as opposed to mathematical modelling, greatly simplifies system design and modification. Fuzzy control and conventional control have similarities and differences. They are similar in the sense that they must address the same issues that are common to any control problem, such as stability and performance. However, there is a fundamental difference between fuzzy control and conventional control. Conventional control starts with a mathematical model of the process and controllers are designed based on the model. Fuzzy control, on the other hand, starts with heuristics and human expertise (in terms of fuzzy *IF-THEN* rules) and controllers are designed by synthesizing these rules.

For many practical problems, the mathematical model of the control process may not exist, or may be too "expensive" in terms of computer processing power and memory, but there are human experts who can provide heuristics and rule-of-thumb that are very useful for controlling the process. For these kinds of problems, a system based on empirical rules may be more effective and, consequently, the fuzzy control is most useful. If the mathematical model of the process is unknown, we can design fuzzy controllers in a systematic manner that guarantees certain key performance criteria.

B. Fuzzy Controllers

Fuzzy controllers are very simple conceptually. They consist of an input stage, a processing stage, and an output stage. The input stage maps sensors or other inputs, such as switches, thumbwheels, and so on, to the appropriate memberships functions and truth values. The processing stage invokes each appropriate rule and generates a result for each, then combines the results of the rules. Finally, the output stage converts the combined result back into a specific control output value.

The internal structure of a fuzzy controller is presented in Figure 1 and contains the following four basic components:

- Fuzzification unit: converts the crisp input variables into fuzzy ones so that they are compatible with the fuzzy set representation of the process state required by the inference unit.
- Knowledge base, consisting on two parts: a rule base that describes the control actions and a database that contains the definition of the fuzzy sets representing the linguistic terms used in the rules.
- Inference unit: generates fuzzy control actions applying the rules in the knowledge base to the current process state.
- Defuzzification unit: converts the fuzzy control action generated by the inference unit into a crisp value that can be used to drive the actuators.

C. Daylighting Fuzzy Control

The daylighting fuzzy control uses a fuzzy controller as the logic circuit of the lighting control and continuously electronic dimming ballasts controlled by low-voltage analog signals as power controllers. The ballast receives a signal from the control device and subsequently changes the current flowing through the lamp, thereby achieving a gradual controlled reduction in lamp output. The characteristics of the control signal affect the duration and extent of the change in current and subsequent lamp output. Most commercially available dimming ballasts for operation of these lamps are electronic rapid-start or programmed-start ballasts, and all linear lamps operated by these ballasts feature bi-pin bases typical of rapid-start lamps. As the sensing device, different types of photo-sensitive devices, commercially available, can be implemented.

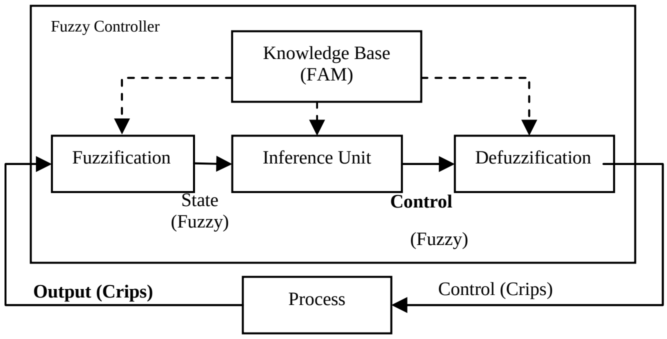

Figure 1 Basic structure of fuzzy logic controller

For the studied room (20x10 m), the indoor pendant-mounted lighting system, designed by DIALUX software package, consist of 30 luminaires containing two 54WT16 linear fluorescent lamps. They are mounted in five rows of six pieces, parallel to the daylit side of the room, and assure an average illuminance level of 500 [lx], and a ratio E_{min}/E_{max}=0.62.

An important task consists in the proper selection of control zones; a control zone is a group of luminaires or individual lamps within luminaires that are controlled by one signal. The goal in creating a control zone is to define an area that receives a consistent amount of daylight at any given time and has consistent light level requirements. Important factors in defining control zones [8]:

a. Identify areas that receive consistent daylight contribution;
b. Define areas with consistent light level requirements;
c. Identify different architectural finishes;
d. Create zones that are visually and logically connected.

In our case, taking into account the windows head height, the pattern of the daylight is presented in Figure 2; accordingly, three control zones have been identified. They are parallel to the long side of the room, as follows: *zone 1*, near the windows, consist of two rows of luminaries; *zone 2*, in the middle of the room, consist of one row; *zone 3*, near the opposite side, consisting of two rows.

Figure 3 shows the characteristics of the combined daylight and electric lighting system, without any control. The actual values of illuminance levels exceed by far the required figures, showing the energy saving potential of a control system for the artificial lighting structure.

4 PROPOSED CONTROL SYSTEM

The proposed daylighting fuzzy control uses three sensing devices (an occupancy/motion sensor and two photosensors), continuously electronic dimming ballasts for every luminaries aiming the control of the electric lighting output, and a fuzzy controller; the two photosensors are placed in the control zones 1 and 3. Figure 4 presents the control algorithm for the proposed control system, implemented into a fuzzy controller.

A. Fuzzyfication

The input linguistic variables (signals provided by the photosensors *A* and *B*) of the fuzzy controller are the level of the illuminance measured by the two photosensors while the output variables are the level of the DC control signal sent to electronic ballasts in the three control zones. Every linguistic variable has five fuzzy values with triangular or trapezoid membership functions, as follows:

- For input variables – Fig. 5: *D* – dark; *HD* – half dark; *H* – half; *HL* – half light; *L* – light;
- For output variables – Fig. 6: *VL* – very low; *L* – low; *M* – medium; *H* – high; *VH* – very high.

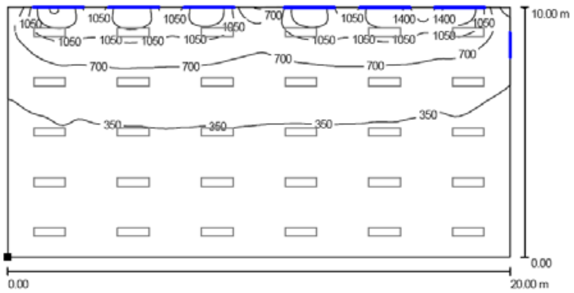

Figure 2 Illuminance levels assured by daylighting

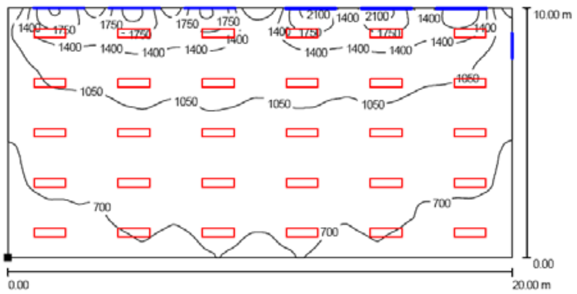

Figure 3 Illuminance levels for the combined daylighting and electric lighting (without any control)

Until *a person is present*
if *illuminance is between 500 and 550 lux*
then *hold constant all lamp parameters*
else *use the fuzzy controller for lighting control*
after 5 min turn off all lamps.

Figure 4 Algorithm for daylighting fuzzy control

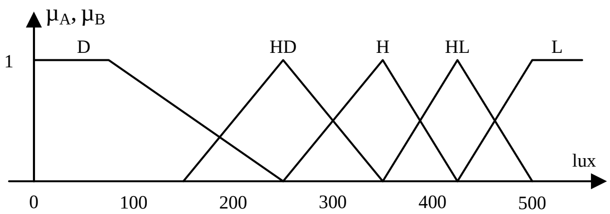

Figure 5 Input variables fuzzyfication

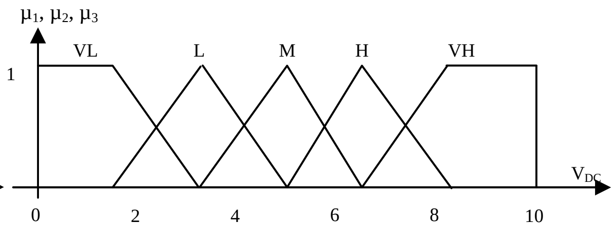

Figure 6 Fuzzyfication of output variables

B. Knowledge base
The knowledge base used by the control system is presented in Table 1 where μ_i (i = 1…3) represents the membership functions for the DC control signals corresponding to the three control zones.

Table 1

μ_1		A				
		D	HD	H	HL	L
B	D	VH	M	M	L	VL
	HD	VH	H	M	L	VL
	H	VH	H	M	L	VL
	HL	H	M	L	VL	VL
	L	H	M	L	VL	VL

μ_2		A				
		D	HD	H	HL	L
B	D	VH	H	H	M	H
	HD	H	H	N	N	L
	H	H	N	N	N	L
	HL	M	M	M	L	L
	L	M	M	L	L	VL

μ_3		A				
		D	HD	H	HL	L
B	D	VH	VH	VH	VH	VH
	HD	H	H	H	H	H
	H	M	M	M	M	M
	HL	L	L	L	L	L
	L	VL	VL	VL	VL	VL

The processing stage invokes each appropriate rule and generates a result for each, then combines the results of the rules; this mechanism was implemented by the max-min inference method.

C. Defuzzyfication
The results of all the rules that have fired are defuzzified to a crisp value by the centroid method and gives different crisp values of DC control signals corresponding to each control zone (see Figure 7 for zone 2). Simulated results have been obtained by the FuzzyTech tool.

The illuminance levels provided by the proposed fuzzy control system are presented in Figure 8 and highlight a good quality of illumination combined with a significant energy saving.

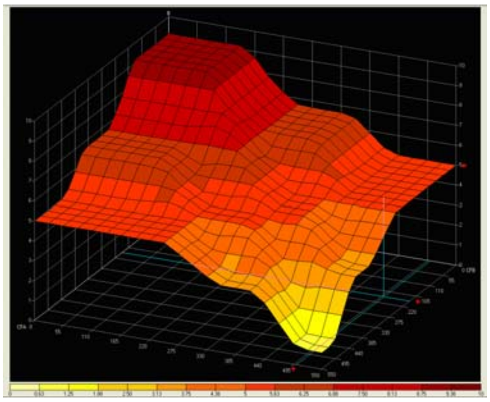

Figure 7 Output signal for control zone 2

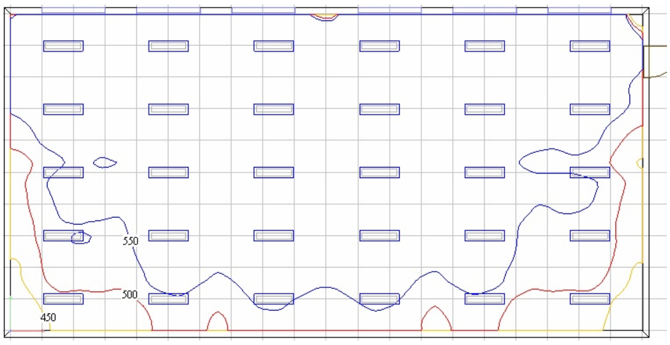

Figure 8 Illuminance levels for the combined daylighting and electric lighting using fuzzy logic controller

5 CONCLUSIONS

Daylighting has a very promising energy-saving potential and became an attractive alternative to conventional indoor electric lighting systems. Classic control systems, based on continuous dimming, present some difficulties to adjust their performances to the rapid changes in daylight depending on season, location or latitude, and cloudiness.

Taking into account these aspects, fuzzy control could be a better solution in implementation of daylighting, an issue that cannot be easily represented by mathematical modeling because data is unavailable, incomplete, or too complex.

The proposed system uses three sensing devices (an occupancy/motion sensor and two photosensors), continuously electronic dimming ballasts for every luminaries aiming the control of the electric lighting output, and a fuzzy controller. Data obtained by simulation proved the correctness of the proposed solution.

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RENEWABLE ENERGY LABORATORY FOR LIGHTING SYSTEMS

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ABSTRACT

Nowadays, the electric lighting is an important part of our lives and also represents a significant part of the electric power consumption. Alternative solutions such as renewable energy applied in this domain are thus welcomed. This paper presents a workstation conceived for the study of photovoltaic solar energy for lighting systems by students of power engineering and civil engineering faculty.

The proposed system is realized to study the generated photovoltaic solar energy parameters for lighting systems. For an easier way to study the most relevant parameters virtual instrumentation is implemented. National Instruments' LabWindows / CVI environment is used as a platform for virtual instrumentation. For future developments remote communication feature intends to be added on which currently remote monitoring of solar photovoltaic energy and electric energy parameters are monitored.

1 INTRODUCTION

Solar energy is one of the renewable energies on which nowadays scientists interested in energy sources are focused. Considering the significant level of lighting energy consumption: home 25%, commercial buildings, schools, businesses 60% [1], renewable energy represents a viable alternative applicable in saving money spent on energy bills but also in reducing green house effect caused by emissions of classical power plants.

The efficient use of system based on solar energy involves the knowledge of solar datum and equipment characteristics from a studied area. By didactical point of view it is very handful allowing students to access real datum and concentrate on phenomenology using adequate tools. Authors of this paper have developed such a tool presented below.

2 SOLAR PHOTOVOLTAIC ENERGY DATUM AND CONVERSION

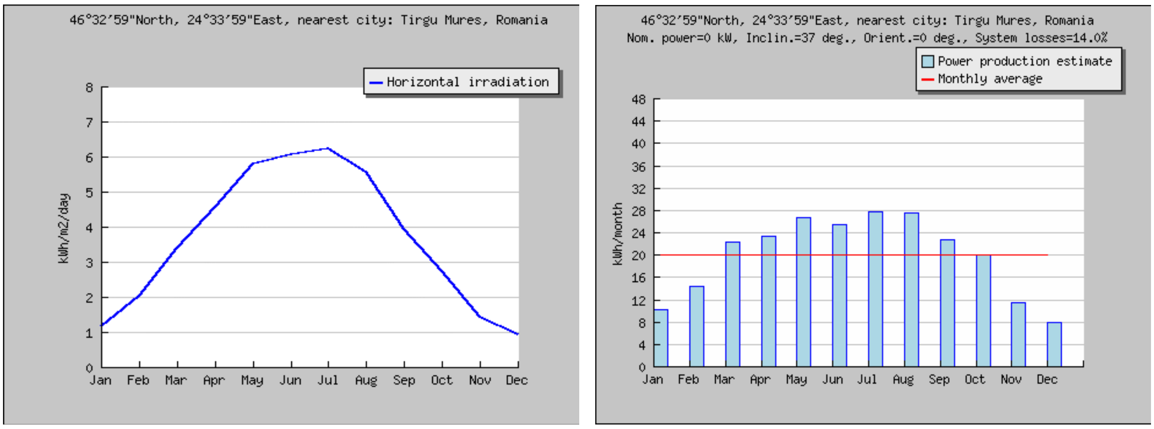
As the photovoltaic (PV) technology is an environmentally friendly method of generating electric power energy it represents an alternative to the present more and more expensive energy sources and therefore its study is an important key for future specialists. Following we will mention some characteristics that must be taken into consideration by those interested in study and implementation of photovoltaic solar energy, so that represents a preliminary approach before starting the so-called study on proposed workstation.

The solar energy availability depends on season, weather conditions, pollution or geographical position as Figure 1a illustrates for Tîrgu Mureş City [13].

Once a system is set up, the user only needs to monitor the proper operation and to check the energy yield. Regular checks ensure that the system delivers optimum yields and thereby achieves high efficiency levels. The user should check and record the meter readings and any special events for early recognition of faults and their cause [3].

Autonomous renewable systems, such as solar energy powered networks, experience real-time variations of input energy. By taking into account the variations of the load, control methods are required to maintain stability and achieve maximum penetration from the solar resource.

Considering Tîrgu Mureş as location, in Figure 1b is illustrated the (estimated) amount of electric power that can be expected each month from a PV system studied in this paper [13].



a b

Figure 1 (a) Monthly solar energy availability in Tîrgu Mures; (b The monthly amount, the expected average monthly and yearly production of electric power in Tîrgu Mures for a 0,2 kW solar panel [13]

3 PHOTOVOLTAIC LABORATORY

The proposed workstation for the study of lighting system based on photovoltaic solar energy is represented by a basic Lucas-Nulle workstation extended with monitoring system based on virtual instrumentation and possibility to study different lighting sources.

The workstation contains two types of solar energy converters: solar cells and photovoltaic solar panel.

Solar cells are represented by integrated SO 32107 M Lucas-Nulle modules. There are two types of solar cells: 2 modules of 6 Volts which can be connected serial or parallel configurations, and a 3 Volts module.

Solar panel is of ET-M53620 type characterized by the following parameters:
- Peak power (P_{max}) 20 W
- Maximum power point voltage (V_{mpp}) 17.82 V
- Maximum power point current (I_{mpp}) 1.15 A
- Open circuit voltage (V_{oc}) 21.96 V
- Short circuit current (I_{sc}) 1.27 A

Energy conversion at a level usable by consumers is realized with two 12VDC-230VAC-50 Hz-150W inverters supplied by two solar charge controller SOLSUM 5.6 and SOLAR 18122. Supplemental energy is stored in a 12 V accumulator.

For lighting sources the workstation is adapted to host DC and AC lamp types.

On DC side primarily it can be found an incandescent lamp, a halogen lamp, a LED at 12V and a 12 V socket for connecting other type of lamps. The inverter offers the possibility to connect different types of AC lighting sources. For testing purposes is used as standard equipment a 230V/150W LEDs lamp.

For time analysis of solar energy availability a MacSolar device from Solarc is used.

The parameters of produced electric energy are monitored and then studied with virtual instrumentation module built by authors. This module consists from two parts: a hardware part for data acquisition and a software part for data analysis.

4 PARAMETERS MONITORING USING VIRTUAL INSTRUMENTATION

The presence of multiple parameters to be measured and recorded from one or more renewable energy sources or from one or more consumers leads to necessity of using computing systems. Therefore nowadays trend is to use on a large scale the virtual instrumentation.

Virtual Instrumentation represents the use of customizable software and modular measurement hardware to create user-defined measurement systems, consisting by virtual instruments.

Unlike the traditional measurement instruments, the virtual instruments do not have hard-coded functions; these systems are less limited in their versatility than virtual instrumentation systems.

The primary difference between classical instrumentation and virtual instrumentation is the software component of a virtual instrument. The software enables complex and expensive equipment to be replaced by simpler and less expensive hardware. [4]

5 ARCHITECTURE OF THE SYSTEM

The main objective of proposed system is to provide the status of the solar panel and consumers parameters.

The architecture of the proposed system is presented in Figure 2.

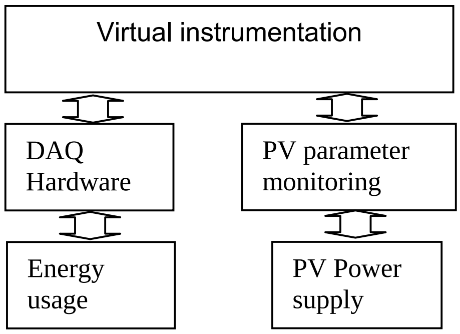


Figure 2 Architecture of the laboratory workstation

In the proposed architecture, the virtual instrumentation allows to preset the used devices and to view values of significant parameters. All data can be stored for future references and analysis.
The DAQ hardware purpose is the data acquisition. An ADVANTECH PCL711 DAQ card connected to a PC represents this module.

PV parameter monitoring module on hardware side consists from a MacSolar device.
Energy usage involves all lighting sources and PV power supply block refers to the main source of energy, PV ET-M53620 panel type.

6 HARDWARE IMPLEMENTATION OF THE MONITORING MODULE

In Figure 3 is presented the data acquisition system for monitoring of the solar energy parameters.
The acquisition system is built around a computer that obtains through a serial bus from the MACSOLAR electronic device the parameters available at solar cells and solar panel level.

In Figure 4 is presented the data acquisition system for monitoring of the electric solar energy parameter from solar panel output circuits.

This part is composed by a data acquisition board (PCL711) placed in a IBM compatible computer and a device (Figure 5) which adapts the voltage and current signals to the input of DAQ board.

Figure 3 Experimental workstation for study of lighting system based on renewable energy

Figure 4 Hardware part of the acquisition system configured for monitoring of the electric solar energy parameter from solar panel output circuits

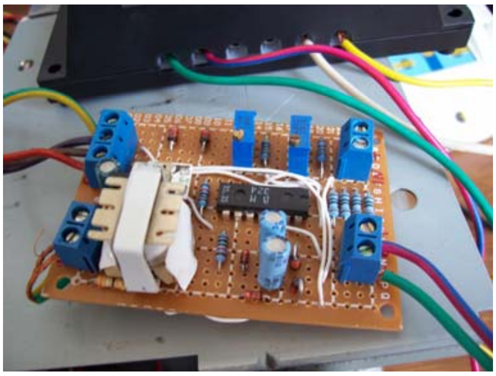


Figure 5 Conditioning device of the DAQ system configured for monitoring of the electric solar energy parameter from solar panel output circuits

7 SOFTWARE DEVELOPMENT FOR VIRTUAL INSTRUMENTATION

Software development was realized using National Instruments' LabWindows / CVI. It can be noted that this programming environment has been chosen because of its facility to develop applications in a productively manner allowing also to focus mostly on implementing the computation methods. By didactical point of view it is very handful allowing students to concentrate more on phenomenology with basics programming knowledge.

Software architecture (Figure 6) is based on 4 modules: acquisition module (AM), processing module (PM), communication module (CM) and user interface module (UI).

The AM module implements the function for setting-up the DAQ board and acquisition control.

PM module is designed for data processing and conditioning.

CM module assures the support for network communication.

In the UI modules are grouped the visual command panels with virtual instruments.

It must be noted that currently CM module is implemented with the support for DataSocket that is a data network programming technology, which simplifies data exchange between computers and applications. By using this technology, data from photovoltaic systems is accessed and shared from remote locations allowing the use of the workstation in a remote e-learning system or remote laboratory. In industrial application when distributed photovoltaic systems are available, data can be accessed and shared from remote locations for the final goal of proper system operation [5].

In Figure 7 is presented a generic sequence diagram of the data acquisition software module operation, where it can be observed the main object of the software modules and theirs interactions.
Figure 8 shows the main window of developed application. The window contains virtual instruments for voltage, current and power measurements.

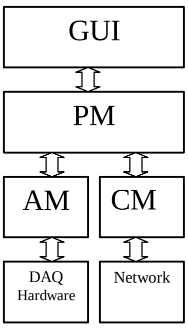


Figure 6 Main architecture of the software

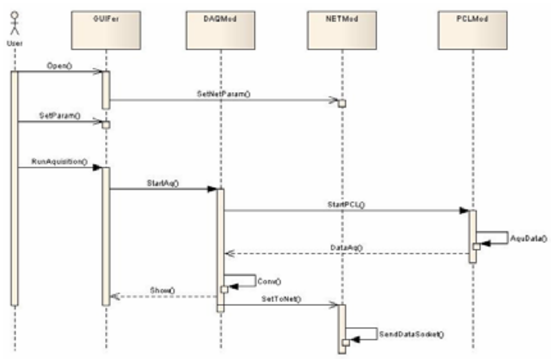


Figure 7 Generic sequence diagram of the data acquisition software module operation

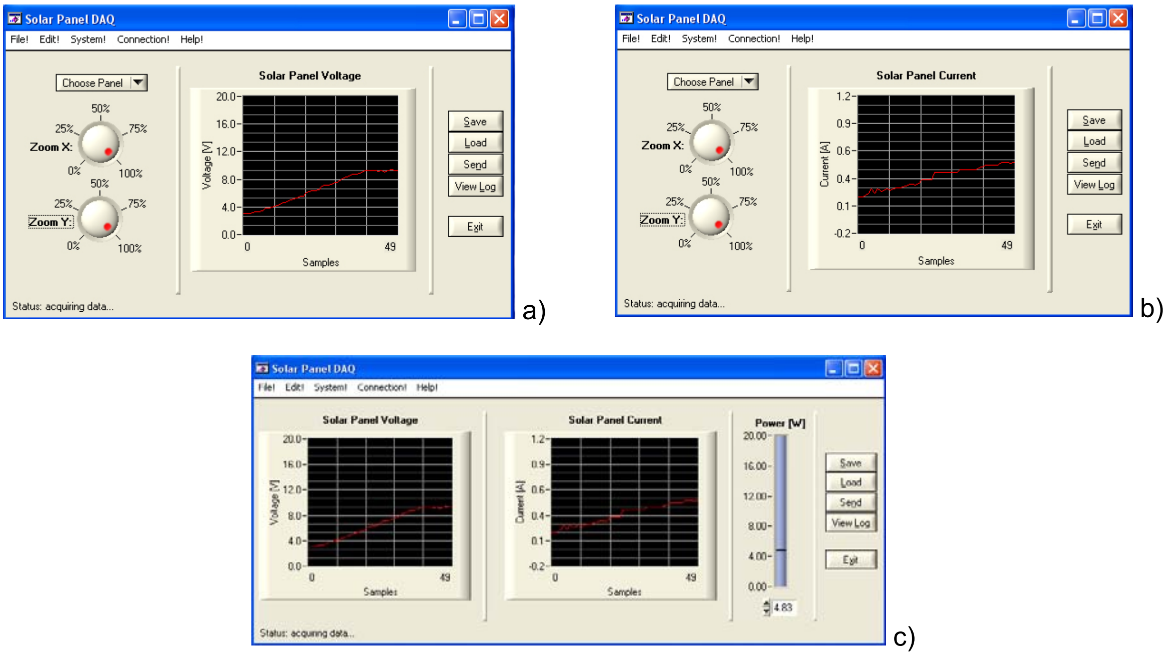


Figure 8 Solar panel a) current, b) voltage and c) power measurements window

8 CONCLUSIONS AND FUTURE WORK

In this paper was presented a laboratory workstation based on virtual instrumentation for study of lighting system supplied by photovoltaic solar energy. A few types of measurements and studies can be performed: measurement of irradiance, open circuit voltage and short-circuit current from photovoltaic cells, study of power, temperature, voltage and current characteristics from the power cells or modules, study of serial and parallel connection of solar modules and the partial shading of a photovoltaic generator, study of lighting sources directly fed or fed by stored power.

As a future work we intend to develop this application as a virtual laboratory accessible over computer network to study lighting system supplied by renewable energy.

Experimental stand presented can be used by students in: energy using laboratory and renewable energy laboratory for study of artificial lighting systems supplied by renewable energy.

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DC VOLTAGE LIGHTING SYSTEMS

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ABSTRACT

The paper presents some general considerations regarding energy distribution in the low voltage dc networks as an alternative to the ac distribution systems.

Most applications of direct current occurred as a result of development and growth in importance for techniques used for obtaining electricity using renewable sources. To avoid some conversion processes witch are carried out with a specific performance, questions arise regarding the use of direct current for various suitable applications.

A dc lighting system shows real interest regarding efficiency in lighting applications. Equipment needed to such a system exists in the markets (lamps and lighting fixtures) and in addition, some of them are more efficient than those in alternative power.

1 INTRODUCTION

Loads that meet today are very different from those that existed 100 years ago and were mainly represented by resistive loads and electric machines. In the late 1880s, George Westinghouse and Thomas Edison became adversaries due to Edison's promotion of direct current (DC) for electric power distribution over alternating current (AC) advocated by Westinghouse and Nikola Tesla. The latter won this confrontation known as "War of Currents" due to fact that ac distribution had the transmission for long distances advantage. Now the scenario is completely changed because of the the influences of electronic equipments and eir requirements in terms of the electric power supply.

Rapid development of semiconductors made electronic equipments to become dominant as a share of applications for residential buildings and offices; because they use a different voltage level of the network, both in frequency and amplitude, the ariseing issue is the change of the voltage level, respecting the quality requirements. These efforts involve costs and energy losses. Since most electronic equipment used dc voltage, the question arise regarding the use of dc distribution systems instead of ac distribution systems. The dc systems are classified by means of voltage level in High Voltage DC systems (30 kV < U ≤ 1 500 kV), Medium Voltage DC systems (1500 V < U ≤ 30 kV) and Low Voltage DC systems (U ≤ 1500 V). The following is a brief description of Low Voltage DC systems in witch lighting systems may find applications.

2 LOW VOLTAGE DC SYSTEMS [1, 2]

Equipments such as computers, fluorescent lamps with electronic ballast, televisions use dc voltage. They have in their structure a rectifier, which converts the ac voltage into dc voltage. The conversion process introduce in the ac network harmonics which have different negative effects (currents in the null conductor, inadequate protection functioning). Such equipment can be supplied directly to dc voltage. Problems occur for the electrical machine with rotating magnetic field or other equipment, witch, for normal functioning need to be supplied in ac voltage. The supply of the ac loads will be achieved through an inverter witch can supply directly the load or the bus where more loads are connected.

In the context of the new worldwide energy policy, which seeks to take measures to produce electricity using renewable energy sources, a low voltage dc network can interconnect distributed generation units. Moreover, by using renewable energy sources can be obtained directly dc voltage. A diagram of a LVDC network (Low Voltage Direct Current) witch interconects distributed generation units is shown in Figure1.

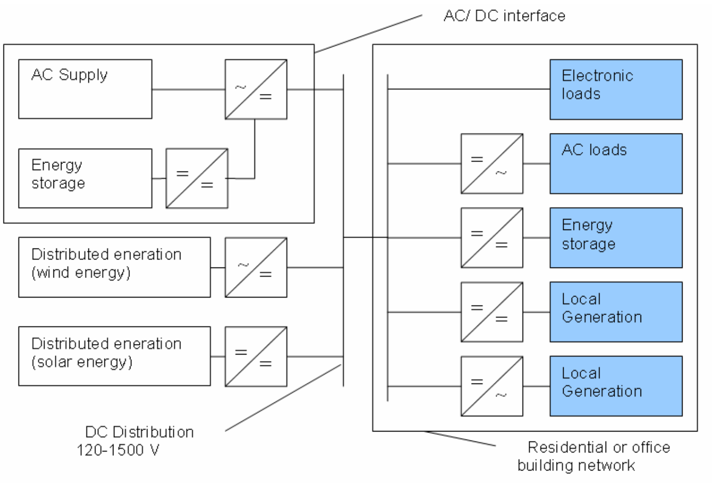
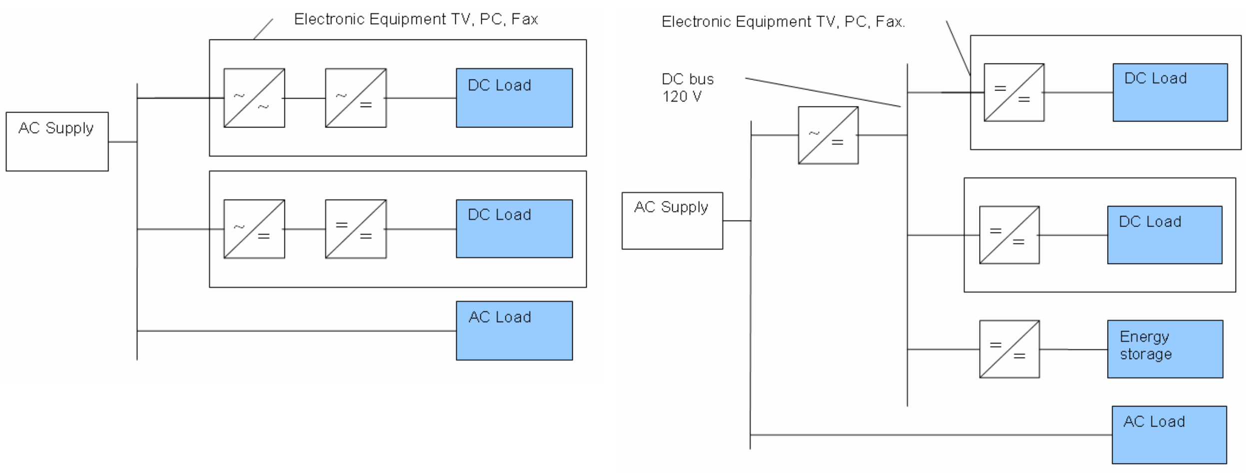


Figure 1 LVDC network with distributed generation units [1]

There are Ultra Low Voltage Direct Current Systems (ULVDC) witch are characterized by a voltage level up to 120 V. In practice, this system is used only in case of electronic equipment for offices and residential buildings.

Lot of equipments have in their composition a rectifier and a transformer which converts and transform the ac voltage to the dc voltage at the necessary operating level (Figure 2a) [2]. Increasingly fewer equipment in these buildings are subject to operation in ac voltage.



a) b)

Figure 2 a) AC voltage Supply and b) AC and DC Voltage Supply [2]

Moreover, most of new electronic equipment have in their composition a transformer followed by a rectifier. The transformer is supplied even when the equipment is in stand-by, therefore, losses occur during the period the equipment is not on. One solution proposed for dc and ac voltage distribution is shown in Figure 2b. [2].

By waiving the process of conversion and use a scheme such as that proposed in Figure 2b, the number of converters is reduced compared with the classical solution and when the power losses of the electronic equipment are also reduced. Basically, only one rectifier in needed, located before the dc bus; power sensitive loads can be supplied also through a battery storage.

LVDC networks presents several advantages:

- safety: for human body the dc voltage is not as hazardous as the ac voltage because it dosen't leads to involuntary muscle contractions. The dc voltage must be less than 50 V to avoid this danger to the human body. Moreover, by choosing for the voltage level a sufficiently small value, a completely safe system may be realized in this regard;
- magnetic fields are reduced;
- since for the whole system just one rectifier is needed, we can chose a better quality one (a IGBT based converter) in witch case with a proper control, the impact of electronic equipment in the ac network can be reduced by lowering the harmonic content;

- a converter that allows a bidirectional flow can introduce energy into the ac network when there is a surplus produced in the dc network due to the existence of an increased potential of renewable energy.

3 AC AND DC LOW VOLTAGE HIBRID SYSTEMS

Most applications of dc voltage in residential and office buildings occurred as a result of developement in technologies used to produce electricity using renewable sources. Using photovoltaic modules admits dc voltage production. To avoid some conversion processes witch are carried out with a specific performance, questions arise regarding the use of direct current for various suitable applications.

Although recently technical developments in this area are significant, although there is real potential for such a system to provide energy to a whole facility often a hybrid solution is chosen. There are high power loads (washing machine, air conditioning unit) witch have to be supplied in ac voltage for normal operation. For this reason, in most cases a hybrid energy supply sistem is accomplished (ac and dc low voltage system). Such a system can interconnect the renewable energy sources and allows energy storage in the batterie. Figure 3 presents a simple hybrid system.

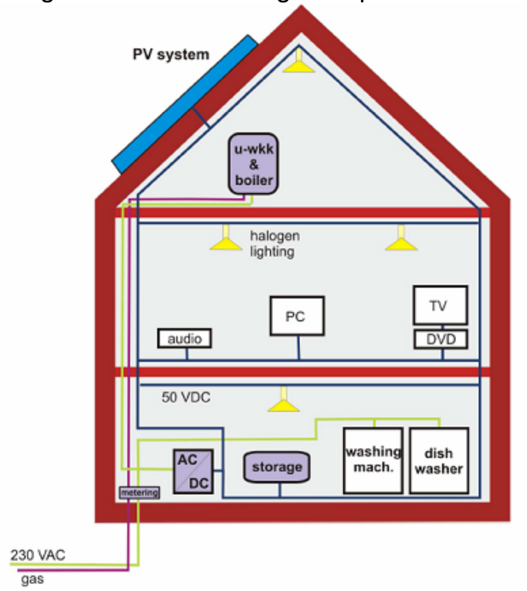


Figure 3 AC and DC low voltage hibrid system [3]

4 DC LIGHTING SOURCES [4]

Lighting is a popular use for renewable energy. There are several methods to achieve a lighting system using dc voltage and establishing the best solution is quite easy even for particular requirements.

Nearly all lighting systems connected to the public network uses ac voltage for witch the accessories are obtained easily and at relatively low costs. However there are impediments in terms of a ac lighting system using renewable energy sources. First, to be able to use the energy stored by a battery system an inverter needes to be installed. This can significantly increase the overall system cost. Another aspect that can be taken into account is the fact that in some cases, an ac lighting system may be less energy efficient than the one supplied in dc voltage. Since DC lighting can be powered directly from the battery bank, the added expense of purchasing and installing an inverter is not necessary.

The issue is the analysis of the dc lighting solutions available and their possibilities of implementation in terms of reliability. Incandescent lamps, fluorescent lamps, halogen lamps and LED's can be used for indoor lighting.

4.1 INCANDESCENT LAMPS

Incandescent lamps are some of the cheapest solutions but also some of the least energy efficient. However, incandescent lamps supplied in dc voltage are approximately 30% more efficient than supplied in ac voltage. There are incandescent lamps supplied in dc voltage with a power rating of 5 – 100 W. These lamps can be used in dc and ac voltage by means of the same fixtures (socket, base lamp).

4.2 HALOGEN LAMPS

These types of lamps are more expensive than incandescent lamps however, for the same power of the lamp they are 30% more efficient than incandescent lamps. A halogen lamp with a lower power can produce the same luminous flux as a higher power incandescent lamp. Halogen lamps produce a "brighter" light than incandescent lamps. These lamps can be used in the same way as incandescent lamps, directly or with adapters. The fixtures should only be connected to a dc power source.

4.3 FLORESCENT LAMPS

Fluorescent lamps used in a 12 V dc lighting system are generally 3 – 4 times more efficient than halogen or incandescent lamps. Their disadvantages consist in reduced possibilities of fixture choice and components required in a dc voltage system. If for halogen and incandescent lamps you can use the fixtures from ac lighting systems, for fluorescent lamps specific 12 V ballast is required.

While for incandescent and halogen lighting in dc voltage specific lamps are needed, all fluorescent lamps are essentially the same. If an armature is purchased, any fluorescent lamp can be used. An exception is represented by compact fluorescent lamps, where the ballast is attached to the lamp in witch case a special lamp in dc voltage is required.

a)

b)

Figure 4 a) 10 – 50 W Halogen lamps and b) 15 – 30 W florescent lamps [4]

4.4 LIGHT EMITTING DIODES

A light-emitting diode (LED) is a semiconductor diode that emits light in direct polarization of the p-n junction. The effect is a form of electroluminescence. The color of light emitted depends on the composition and the semiconductor material used, and may be in the range of infrared, visible or ultraviolet. A light-emitting diode is small light source, most often accompanied by an electrical circuit that allows the modulation of the light radiation shape. They are used as indicators within the electronic devices, but increasingly more often are used in power applications, such as lighting sources.

Compared with other sources presented, they are three times more efficient than halogen lamps and one of the most efficient ways of transforming energy into light. Light-emitting diodes are a good choice for local applications and with a low illumination level. Due to low consumption, they are viable and economic applications, especially in lighting systems using photovoltaic modules.

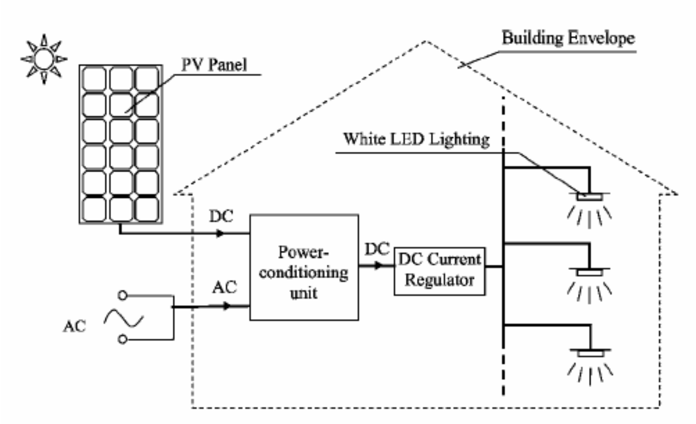


Figure 5 DC Lighting System using LED’s [5]

5 BATERRIES [6]

Batteries are electrochemical cells that store energy in chemical bonds. If the battery is connected to an electrical load and discharged, the chemical energy is converted to electrical energy. By reversing the flow of current, the battery is restored to its initial state corresponding to the charged condition.

The following is a presentation of some types of batteries that are applicable in the lighting systems using dc voltage produced by photovoltaic modules.

There are different types of flooded lead-acid batteries: lead-antimony batteries, lead-calcium batteries, lead-antimony-calcium hybrid batteries.

The structure of a lead-acid battery is presented in Figure 6.

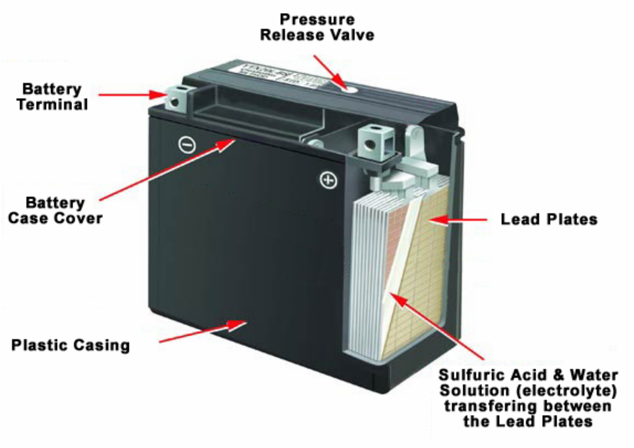


Figure 6 Lead-acid battery structure [6]

In these types of applications are also used Captive electrolytic Lead-acid and nickel-cadmium batteries. Captive electrolytic Lead-acid batteries are lead-acid batteries with "captive" electrolyte, which are similar to lead-acid batteries; the difference consists in the semi-solid electrolyte structure (using silica gel). The electrolyte immobilization may also be achieved by its absorption in a fiberglass mat which is placed between the electrodes plates (absorptive glass matting). Captive electrolytic Lead-acid batteries maintenance is low due to the fact that electrolyte gassing is reduced.

In Table 1 are listed some aspects regarding the advantages and disadvantages of this batteries.

Table 1 Advantages and disadvantages of batteries used in lighting systems supplied by dc voltage

Battery Type	Advantages	Disadvantages
Lead-antimony battery	Low cost. Good performance at high temperatures. Wide availability. Good cycle life. Can replenish electrolyte.	High water loss. Require regular maintenance.
Lead-calcium battery	Low cost. Wide availability. Low water loss. Can replenish electrolyte.	Does not ensure proper operation at high temperatures and overloading. Require regular maintenance.
Lead-antimony-calcium hybrid battery	Medium cost. Low water loss. Good performance of the chargind-discharging cycle. Good cycle life.	Limited availability. Require regular maintenance.
Captive electrolytic Lead-acid battery	Medium cost. Medium cycle life. Low ar no maintenance.	Limited availability. No proper operation at high temperatures and overloading.
Nickel-cadmium battery	Wide availability. Low ar no maintenance. Good performance at high/low temperatures and overloading.	High cost. Limited availability.

The batteries main functions in these systems: are to store the energy produced by photovoltaic modules during the day and supply it to the lighting load at night, to supply the loads with stabile dc voltage (no fluctuation) and to establish a suitable operating voltage to maximize the energy produced by photovoltaic system.

For dc lighting systems using photovoltaic modules, batteries are subjected to repeated cycles of charging and discharging. Batteries must resist to these conditions to maximize their performance and cycle life. In such a system, the main operating cost is represented by batteries replacement. Therefore, the battery cycle life has to be as high as possible. Battery cycle life is influenced by several factors like: the assessment conditions in battery design and production, temperature, battery discharge level and discharge frequency, the average charging value, charging methods. From all of the mentioned factors, the temperature has a particular importance: high temperatures leads to electrolyte losses and on the other hand, low temperature extend the battery cycle life but reduce its capacity.

In any application, battery cycle life can be optimized through an appropriate charging (without over-charging and bellow limit discharging), maintaining a high charging level, limiting the discharge level and the discharge frequency, ensuring an average temperature and by following the maintenance program.

6 CONCLUSIONS

The paper presents some general considerations regarding energy distribution in the low voltage DC networks in witch lighting systems may find applications. Most applications of direct current occurred due to the development of techniques used to obtain electricity using renewable sources. To avoid some conversion processes witch are carried out with a specific performance, questions arise regarding the use of direct current for various suitable applications.

In this paper are also presented a hybrid dc lighting system and a dc lighting system using the energy produced by photovoltaic modules. In the case of the hybrid system some loads are supplied by dc voltage and other loads needing ac voltage are supplied from the ac network. Stand-alone photovoltaic lighting systems are independent, fully integrated power supplies with the primary function to operate lighting equipment. They are simple to install, and if properly designed and maintained, can provide years of service.

Important components in stand-alone dc lighting systems using energy produced by photovoltaic modules are the batteries. Some aspects regarding batteries (advantages, disadvantages, life cycle, optimal operating conditions) are presented.

A dc lighting system shows real interest regarding efficiency in lighting applications. Equipment needed to such a system exists in the markets (lamps and lighting fixtures) and in addition, some of them are more efficient than those in alternative power.

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Neural daylight control system

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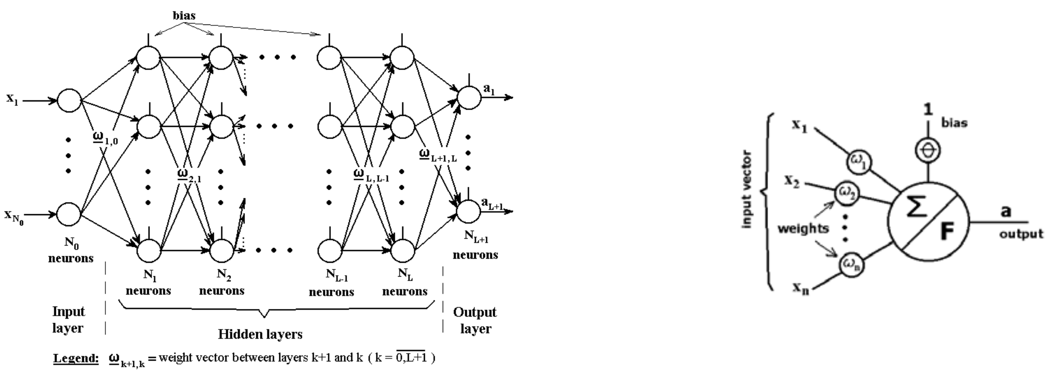
ABSTRACT

The paper describes the design, the implementation of a neural controller used in an automatic daylight control system. The automatic lighting control system (ALCS) attempt to maintain constant the illuminance at the desired level on working plane even if the daylight contribution is variable. Therefore, the daylight will represent the perturbation signal for the ALCS. The mathematical model of process is unknown. The applied structure of control need the inverse model of process. For this purpose it was used other artificial neural network (ANN) which identify the inverse model of process in an on-line manner. In fact, this ANN identify the inverse model of process + the perturbation signal. In this way the learning signal for neural controller has a better accuracy for the present application.

1 INTRODUCTION

Neural networks have been proved a powerful tool in intelligent control. Numerous successful applications have been found in supporting and improving the control industry.[6] Artificial neural networks have been applied very successfully in the identification and control of dynamic systems. The universal approximation capabilities of the multilayer perceptron make it a popular choice for modeling nonlinear systems and for implementing general-purpose nonlinear controllers.[2] Multi layer perceptron (MLP) networks are composed of perceptron "type" units or nodes, which are arranged into layers where the outputs of the nodes in one layer constitute the inputs to the nodes in the next layer. The signals received by the first layer are the training inputs and the network's response is the outputs of the last layer (Figure 1a). Each of the nodes has associated with it a weight vector and a transfer (or activation) function (denoted by *F*), where the dot product of the weight vector and the incoming input vector is taken, and the resultant scalar is transformed by the activation function (Figure 1b). For a suitable arrangement of nodes and layers, and for appropriate weight vectors and activation functions, it can be shown that this class of networks can reproduce any logical function exactly and can approximate any continuous nonlinear function to within an arbitrary accuracy. [1, 5]



a b

Figure 1 Multi layer perceptron network (a) and the configuration of the perceptron (b) [5]

2 THE ALCS BLOCK DIAGRAM

In Figure 2 is presented the block diagram of the ALCS where, are denoted with: $E_{desired}$ – the desired illuminance on the working plane; $E_{measured}$ – the measured illuminance on working plane; E_{real} – the illuminance on the working plane; $E_{daylight}$ – the daylight illuminance on working plane; $E_{electric}$ – the illuminance on working plane due to electric light; ε - control error; $\Delta\varepsilon$ - change in control error; U – control action (command).

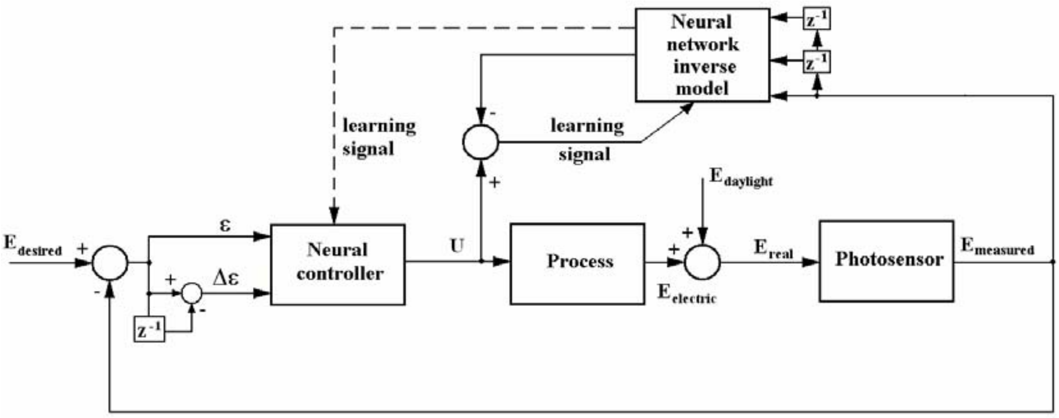


Figure 2 Block diagram of the ALCS

The neural controller is implemented as position type. The controller, based on the values of ε (control error – the difference between $E_{desired}$ and $E_{measured}$) and $\Delta\varepsilon$ (change in control error - the difference between current control error and anterior control error) will generate the control action denoted by *U*. The control action *U* will be applied to the process, in the purpose to maintain the illuminance in working plane close to the desired illuminance $E_{desired}$. At step *k* the ANN of controller is trained using the values of $\varepsilon(k-1)$, $\Delta\varepsilon(k-1)$ and $U_{IM}(k)$, where U_{IM} is the command generate when apply to the ANN of inverse model the current and the last two values of desired illuminance . At step *k* the ANN of inverse model is trained using the values of $U(k)$ and $E_{measured}(k)$, $E_{measured}(k-1)$, $E_{measured}(k-2)$.

3 EXPERIMENTAL RESULTS

The behavior of the proposed ALCS (Figure 2) was simulated using Matlab. For this purpose, the process block was implemented with a look-up table (LUT) of measured data at the input and the output of process during night condition (Figure 3). The process encapsulates a digital ballast and two 36 W fluorescent lamps [4, 5].

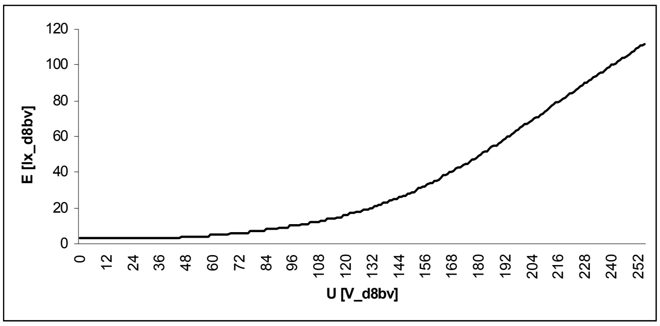


Figure 3 The experimental model of process [4, 5]

The meaning of abbreviation *d8bv*, used in Figure 3, is "digital 8 bits value". The value 100 lx_{d8bv} represents the equivalent value obtained by conversion with 8 bits A/D converter of the 500 lx, which represents the illuminance on working plane measured by an analog luxmeter. The value 127 V_{d8bv} represents, by conversion with 8 bits D/A converter, the equivalent for a d.c. voltage with value $5V_{dc}$. [5].
The controller and the inverse model was implemented with ANNs (using nnet toolbox of Matlab) with three layers (input layer, hidden layer, output layer). For controller, the ANN has two inputs and for inverse model the ANN has three inputs. Both ANNs, has in the hidden layer three neurons and in the output layer has one neuron.
The neurons from hidden layer has the hyperbolic tangent function as activation function:

$$F(x) = \frac{e^x - e^{-x}}{e^x + e^{-x}} \tag{1}$$

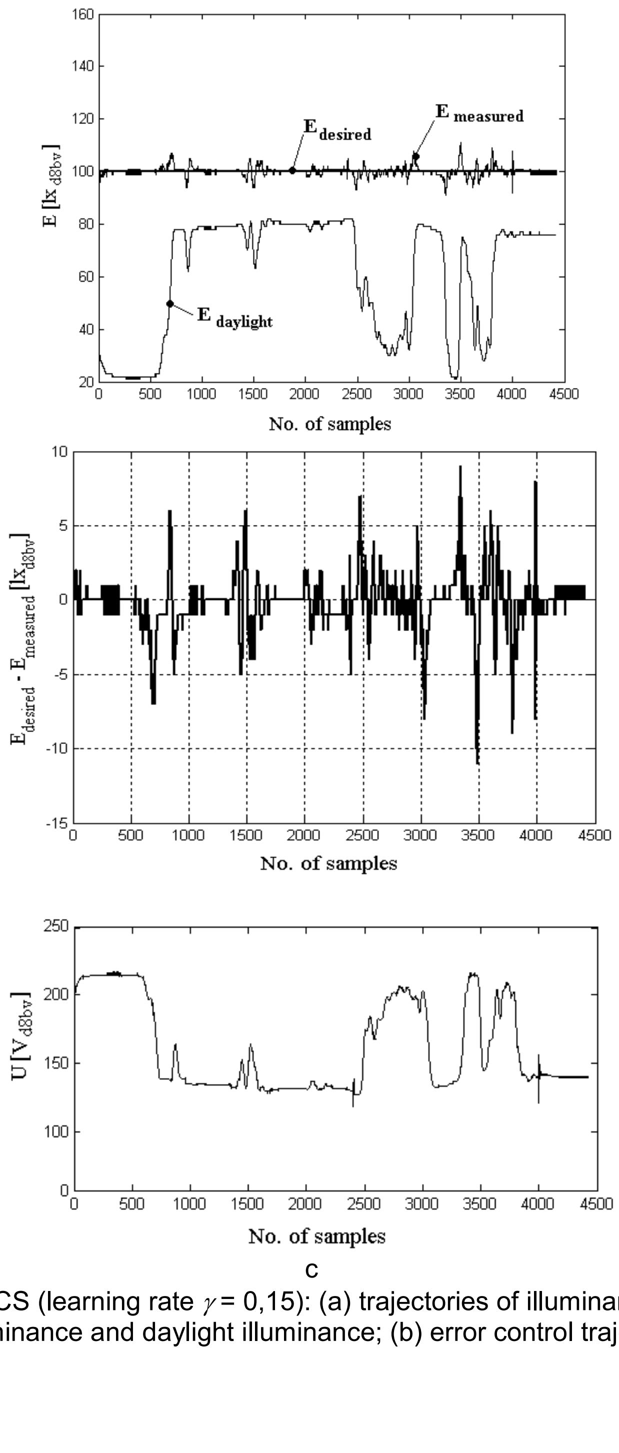
The neuron from the output layer has linear function as activation function:

$$F(x) = x \tag{2}$$

Both ANNs are trained on-line using the back-propagation training rule. The learning rate for both ANNs was set to $\gamma = 0{,}15$.

The universes of discourse of $E_{desired}$ and $E_{measured}$ are fixed to the interval of integers [0 ; 255] (lx_{d8bv}), due to the 8 bits A/D and D/A converters. The inputs and the output of ANNs are scaled [3], which implies the conversions of the universes of discourse of the $E_{desired}$ and $E_{measured}$ variables in the intervals [-1 ; 1]. The output values of the ANN of controller was limited to the interval [-1 ; 1] (the values greater as 1 or smaller as –1 became 1 or -1).These values are converted in values in the interval [0 ; 255] (V_{d8bv}), which represents the universe of discourse of the U variable of the neural controller and of the inverse model.

In Figure 4 is presented the behavior of the ALCS. The desired illuminance has the value $E_{desired}$ = 100 lx_{d8bv}. The daylight trajectory [4] presents fast changes. The measured illuminance has an oscillatory behavior.



a b

c

Figure 4 Behavior of ALCS (learning rate $\gamma = 0{,}15$): (a) trajectories of illuminance: measured illuminance, desired illuminance and daylight illuminance; (b) error control trajectory; (c) control action (command) trajectory

Experimentally [5], a variation of measured illuminance in the interval [93;107] lx_{d8bv} was not perceived by the human user. Analyzing the graphic from Figure 4b the steady-state error control has values in the interval [-11; 9] lx_{d8bv}. The extreme values of this interval are met rarely. The majority values for error control are in the interval [-5; 5] lx_{d8bv}. So, from the human eye perception, the human user of the ALCS does not perceive these oscillations.

4 CONCLUSIONS

The proposed structure used to control the lighting process, need an inverse model of the process. The mathematical model of the process is unknown. To solve the problem, an artificial neural network was trained on-line to reproduce the inverse model of the process. The controller was implemented with an artificial neural network too. In this way, the designer of the control scheme does not need any a priori information about the model of the lighting process. The control quality is not influenced by the precision of the experimental model of process that was used in [4, 5]. This control structure may be implemented on microprocessors because the structures of ANNs are not complicated, because the number of inputs and the number of neurons are small.

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DESIGN PRINCIPLES FOR COVE LIGHTING

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ABSTRACT

The purpose of this paper is to analyse cove lighting systems in different aspects: the main application areas, the reasons to apply them, the effects on the environment and on the people, and the design rules.

In common practice, we often see cove lighting applied in a wrong way, or with not effective results, or with no clear meaning. Many different variables have to be taken into account to have a good result, that can fulfil the requirements, have a great impact and satisfy the wishes of the architect, the lighting designer, the customer, the end user.

This paper is going to be an "information instrument", to give you a good overview on cove lighting solutions, and at the same time will hopefully be an "inspirational instrument" giving you application ideas and reasons to create cove lighting systems, including the impact on people's mood.

Furthermore, it is going to be an "instructions instruments", explaining the cove dimensions and design rules to follow to achieve a certain result in terms of light effect.

1 INTRODUCTION

We talk about a cove lighting installation when the luminaires are hidden behind a panel or a special construction.

It is a very frequently used way to create architectural lighting: the perceptual effect of glowing edges, indirect soft light, surface illumination, moulding the space, natural light simulation, dynamic lighting or color changing systems are all examples of what can be achieved by using a cove lighting installation.

It is indeed a lighting installation that can bring a strong result in terms of perception of the space and atmosphere creation.

Figure 1

2 APPLICATION AREAS

2.1 Home

The home environment can greatly benefit by applying a varied lighting scheme. So many different activities take place in a house, very often in the same area.

A cove lighting system can perfectly fulfil the needs of aesthetic, soft illumination and controllable lighting. Its lighting is adaptable to the different activities and times of the day.

Figure 2

2.2 Hospitality

When we enter a hotel, a good lighting system will support a favourable impression. Bright, dim, glary, lively, dull, stimulating, impersonal.. all these impressions are evoked from the lighting in first place. A magnificent architecture is nothing without a good lighting installation.

Cove lighting system are widely used in hotel environments, both in the rooms and in public areas, because of their flexibility, softness and elegance.

Figure 3

2.3 Entertainment

The places for entertainment are very often a playground for lighting designers: many lighting effects are created to enhance and influence the experience of the users.

Cove lighting in this case can be very effective, as it's hidden and can be integrated in the architecture. Especially with the use of LED an unlimited range of effects can be created.

Figure 4

2.4 Office

Office lighting must fulfil strict requirements, that often limit the possibilities of a creative lighting design.

However, in many situations the "task lighting" and the "general lighting" can be enhanced by using "accent" and "architectural" lighting.

Figure 5

In these situations, coves are used to create architectural lighting effects, such as indirect lighting of common areas, surface illumination, natural light simulation.

2.5 Healthcare

Light can also be used as a tool: in a hospital environment, effective communication is of great importance.

In this example of the CT scanner room, we can see cove lighting used as a tool for AMBISCENE creation. With variable coloured light an ambience is created to relax patients during their examination. It can also help to communicate with the patient. By using a specific colour for example the doctor can give a signal: "hold your breath for few seconds", "breathe normally".. and so on.

Figure 6

2.6 Retail

Shopping has become a social and entertaining activity, therefore the appearance of the shop is very important to create the right atmosphere for a pleasant and exciting shopping experience.

A shop must be lively, inviting, attractive, and lighting plays of course a primary role in the atmosphere creation

Cove systems can underline the architecture, create attention points, enhance the elegance and improve the pleasantness of the shopping experience.

Figure 7

3. WALLWASHING, GRAZE, GLOW

3.1 Wall washing

Wallwashing is the perceived effect of a uniform illumination on the surface.

When we install a luminaire with narrow beam light distribution close to the wall, we can create grazing effects: a perceived effect of strong shadowing that reveals the texture of the surface.

Figure 8 Wall washing **Figure 9** Grazing

3.2 Glow

Glow is the perceived effect of a line of light, that can be wide or narrow but always clearly stops at a certain height, suddenly or with a softer gradient.

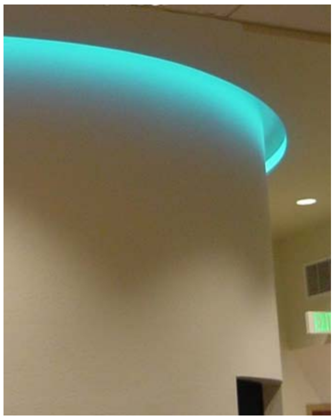


Figure 10 Glow **Figure 11** Glow

4 EXPERIMENTAL SETUP

In order to develop design guidelines for coves, the functionality of several luminaires in cove application, has been tested. The test cove was 3,6 meters long, mounted at 2,5m height. The general lighting was provided by a Strato Sky, ceiling mounted.

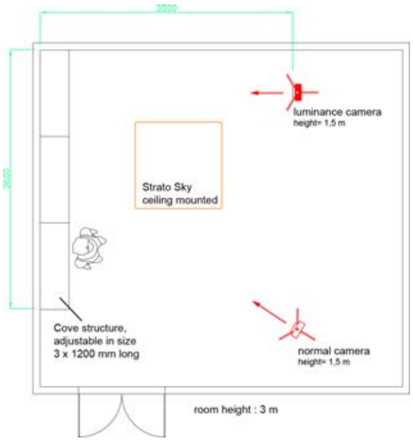


Figure 12

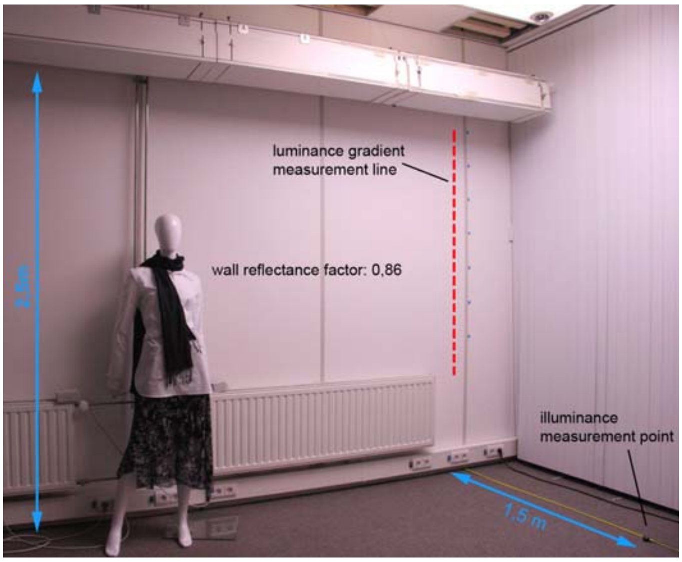


Figure 13

4.1 Testing procedure

Different set-up versions were created, varying the dimensions of the cove and the position of the luminaire inside the cove. Below the setups are given which have been analysed in detail; they are all multi-colour installations.

For each setup version, all the colors were tested singularly, then all together to generate the white light, and in three different general lighting situation: darkness, medium level (250 lux) and high level (750 lux). These lux values are measured at floor level, 1,5 meters from the wall.

4.2 Influence of cove dimensions

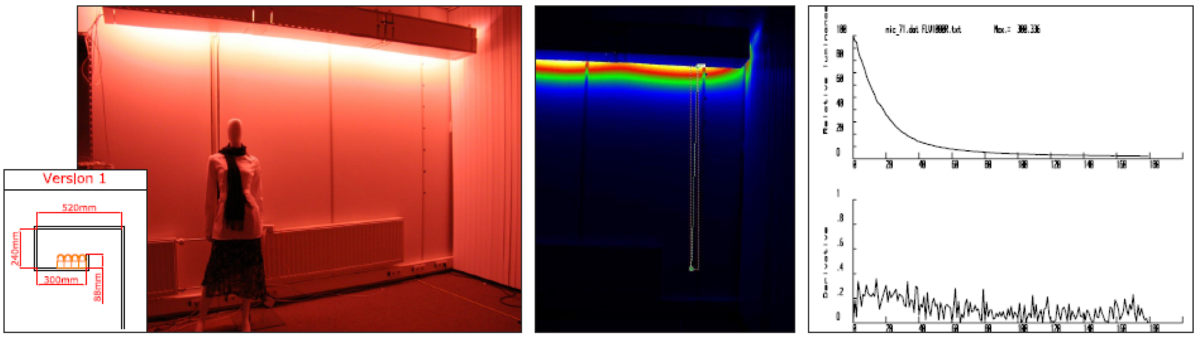


Figure 14

Comparing two situations that differ only in the size of the opening, the effect on the light distribution can be analysed using the picture obtained with the luminance camera, the graph of the luminance distributions on the wall, and the graph on the derivative showing how the light distribution is changing over the distance from the cove.

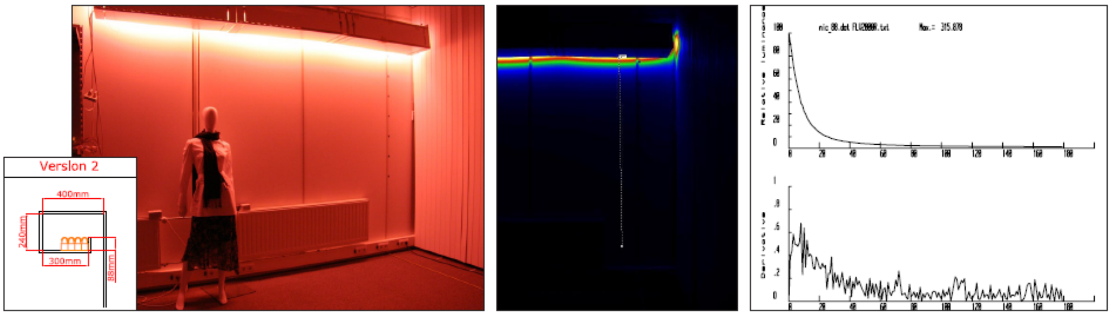


Figure 15

4.3 Influence of luminaire position

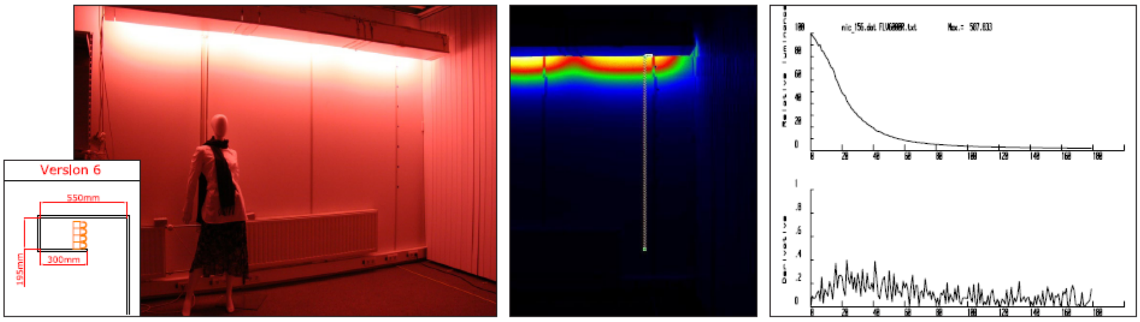


Figure 16

In this case, a comparison is made between two situations in which the cove has the same opening size, but the luminaires inside are placed in a different position.This is a highly influencing factor, due to the fact that in one case the light on the wall is mainly indirect, in the other case the position of the light sources allows much more direct light to fall on the wall, thus increasing the luminance level.

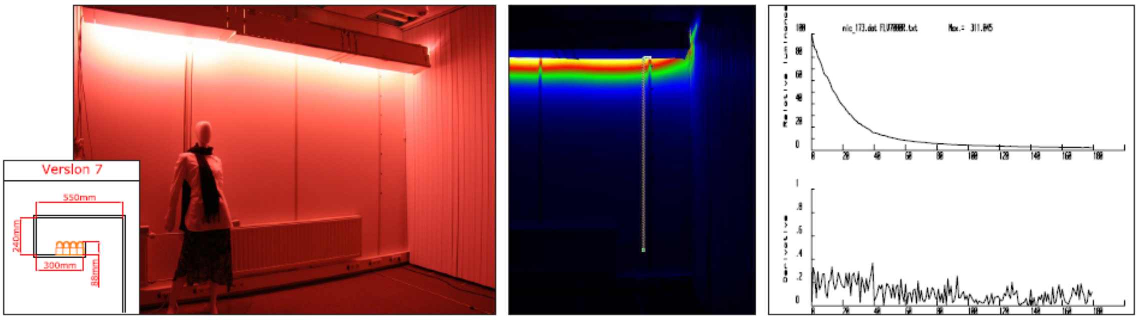


Figure 17

4.4 Influence of general lighting

Figure 18 General lighting level: 250 lux

The level of general lighting in the room is also a very important factor that can influence the effect of the cove. If the light flux of the luminaires used for the cove is too low, the effect can greatly change. In this example with fluorescent battens, the cove setting is the same, and the difference is in the general lighting level: of 250 lux and a level of 750 lux.

Figure 19 General lighting level: 750 lux

4.5 Application remarks

4.5.1 Horizontal position

-When the luminaires are in a horizontal position, pointing upwards, an 'uprise' is needed to screen off direct light that would create harsh shadows (especially in multi-lamp system). The height of such screen must be at the same level as the lamp.

-In this indirect lighting situation, some distance from the ceiling is recommended to avoid dark spots in between the lamps, and a good color mixing.

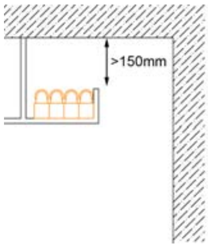


Figure 20

4.5.2 Vertical position

-When the luminaires are in a vertical position, pointing directly to the wall, they must be placed on the edge of the cove to avoid harsh shadows and weird color lines. Depending on the situation, they can be placed even a bit further close to the wall if they are not visible.

-To avoid dark spots in between the lamps, some distance from the wall is recommended (see sketches).

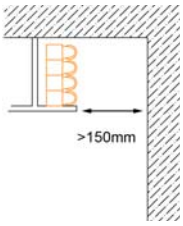


Figure 21

4.5.3 From glow to wallwasher

-By increasing the size of the opening, the light effect changes from glow to wallwashing.

-Placing the luminaires in a vertical position allows to use much more direct light, and the brightness is doubled compared to the solution in horizontal position .

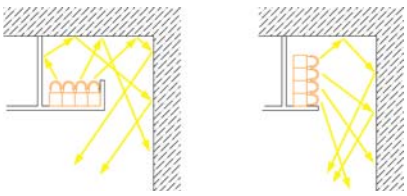


Figure 22

4.5.4 Brightness contrast and color contrast

The influence of general lighting can be analysed also from another aspect: the contrast that is generated against the cove light effect: it is interesting to notice how different can a cove lighting effect be according to different general lighting settings.

This is of course a very important factor to keep into account when designing cove lighting systems. In case of white cove lighting we distinguish brightness contrasts.

In this case, general lighting :

-gives its contribution to the uniformity of the wall illumination.
-can make a glow effect be perceived as a wall washing effect
-visual impact of the cove will decrease.In case of colored cove lighting we can speak about color contrast. In this case, the general lighting: -gradually turns the cove effect from wallwasher to glow, -will generate a color contrast that will still give strength to the light effect. In general, we can say that color contrast has a bigger perceptual impact than brightness contrast.

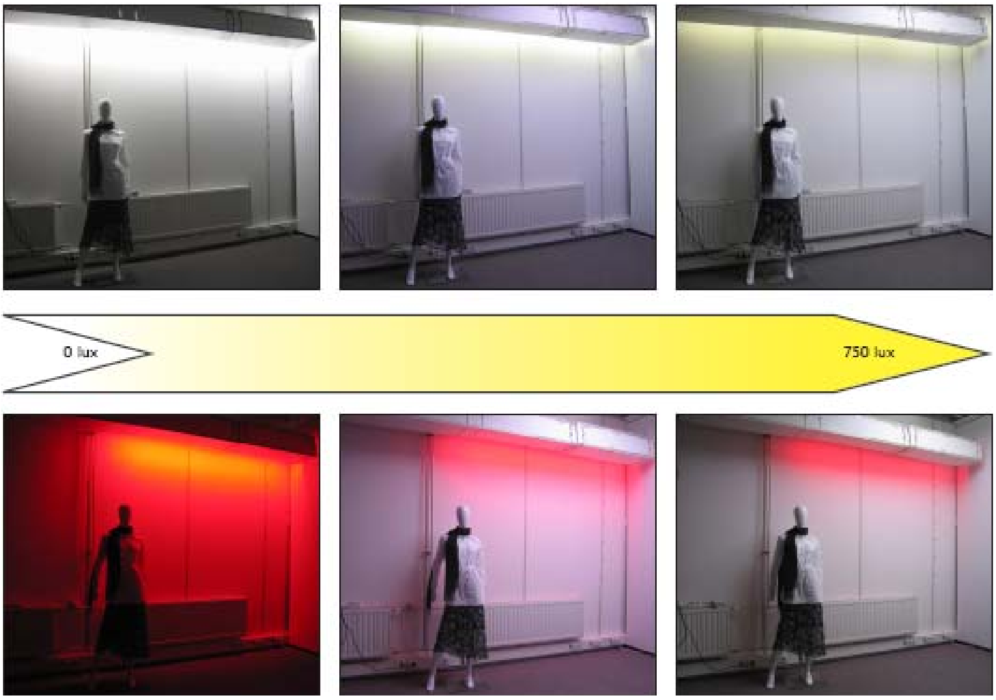
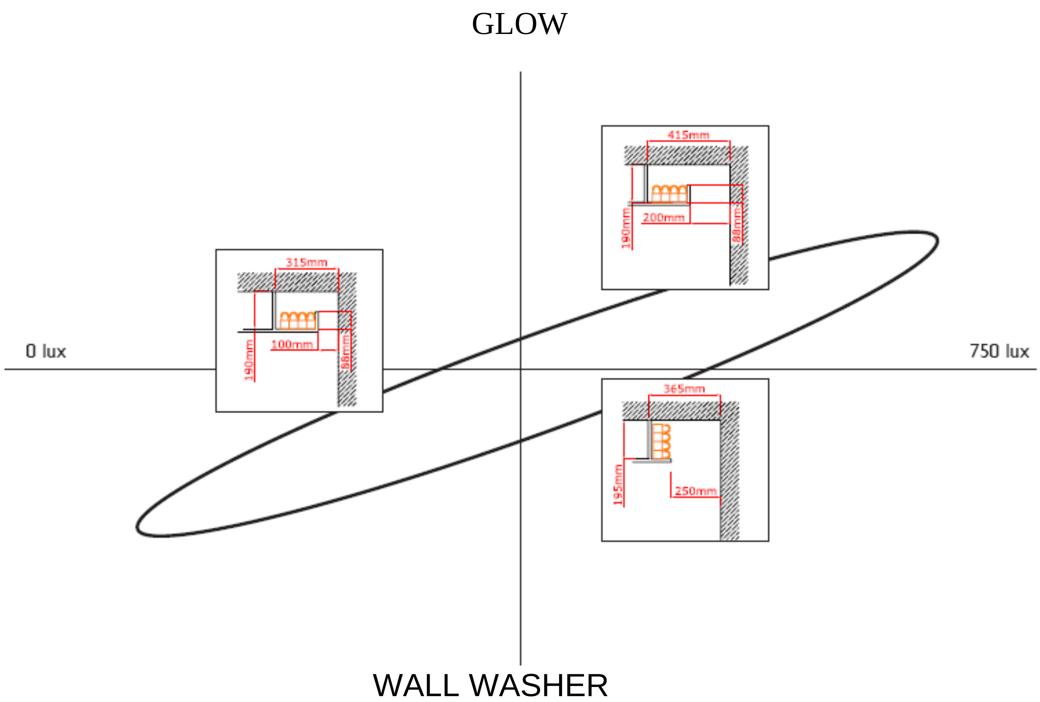


Figure 23

5 DESIGN RULES



In this section are represented some design rules for the creation of cove lighting systems.

For the luminaire that has been tested, graph reports two main factors: the desired lighting effect in the vertical axis, and the general lighting level in the horizontal axis.

Due to these factors, the oval area is the "range of application" of each luminaire. For different positions in this range of applications, a number of examples coves are shown. They should be considered as minimum cove size to obtain that specific effect in that specific general lighting condition.

An arrangement of fluorescent battens is nowadays the most common way of creating cove lighting systems. Due to the high amount of luminous flux available, and according to the shape of the cove, the range of effects that we can create is quite wide, varying from a wall washer or a glow, in different general lighting conditions.

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CONSIDERATII CU PRIVIRE LA SOLUȚILE DE ALIMENTARE A SISTEMULUI DE ILUMINAT DE SIGURANȚĂ -TIPUL 2a

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REZUMAT

Analiza atentă a modului de expunere a problematicii sistemului de iluminat de siguranță în reglementări tehnice şi manuale de referință evidențiază necorelări, reprezentări neconforme cu enunțul, precum şi posibilitatea de interpretări neadecvate.

Ca urmare, această lucrare îşi propune să analizeze modul general de abordare a sistemului de iluminat de siguranță şi cazul concret al soluției de realizare a alimentării definită Tip 2a.

I CONSIDERATII GENERALE

1. Asigurarea unui nivel de iluminare în anumite incinte, în eventualitatea indisponibilității Sistemului de iluminat normal, SIN, se realizează cu diferite Categorii de subsisteme de iluminat de siguranță (evacuare, veghe). Ca urmare, în cadrul acestei lucrări se va folosi sintagma Sistem de iluminat de siguranță, SIS, care va fi format din unul sau mai multe subsisteme, categorii, de iluminat de siguranță.

2. Sistemul de iluminat de siguranță este alimentat dintr-un tablou propriu, denumit -de iluminat de siguranță $T_{ilum\ sig}$;

3. Coloanele şi circuitele subsistemelor de iluminat de siguranță sunt pozate pe trasee diferite de cele ale Sistemului de iluminat normal. Pe cale de consecință, corpurile de iluminat ale celor două sisteme sunt diferite, marcate astfel încât să poată fi diferențiate, fiind amplasate, de regulă, pe plafonul aceleiaşi incinte de iluminat.

4.În toate cazurile, în regim normal, $T_{ilum\ sig}$ este alimentat, printr-o coloană, de la sistemul extern de alimentare, definit conform PE 124/ 95.

5. Sistemul de iluminat de siguranță, pe seama soluției de separare a alimentării de Sistemului de iluminat normal, va intra în funcțiune NUMAI la indisponibilitatea sursei de bază a Sistemului de iluminat normal, care este sursa de bază şi pentru SIS.

6. Dacă se adoptă varianta funcționării permanente, atât cât sunt persoane în clădire, a sistemului de iluminat de siguranță (concomitent cu sistemul de iluminat normal), acesta va fi alimentat de la sursa de bază, SB.

7. În caz de indisponibilitate a sursei de bază, Sistemul de iluminat de siguranță va continua să funcționeze, urmare a unei comenzi automate sau manuale, fiind alimentat de la o sursă *de intervenție,* aşa cum este definită în NP I7-2002.

8.O eventuală indisponibilitate locală a SIN nu va determina intrarea în funcțiune a SIS.

9.SIS intră în funcțiune numai la disparitia tensiunii în amonte de punctul de racord a capătului dinspre sursă al coloanei de alimentare a, $T_{ilum\ sig}$, de la sistemul extern de alimentare, Figura 1, (sursa de bază-firidă de branşament sau secundarul transformatorului din Postul Trafo).

10.Deoarece, aşa cum se precizează în PE 124/ 95 şi cum se stipulează în contractele de furnizare a energiei electrice, sistemul extern-sursa de bază, nu garantează neântreruperea alimentării, datorită cerințelor impuse de receptori, determinate de daunele provocate de o eventuală întrerupere a alimentării, consumatorul îşi prevede şi un sistem intern de alimentare, care conține, conform NP I7-2002 :

- *Alimentarea cu energie electrică- prevăzută pentru a se asigura menținerea în funcțiune, neîntreruptă sau o perioadă de timp, a unor receptoare electrice ale consumatorilor, la întreruperea alimentării normale*. Această sursă se realizează cu grupuri electrogene ;

-*Alimentarea de rezervă de siguranță-alimentarea de rezervă cu energie electrică prevăzută pentru a se menține în funcțiune echipamentele necesare asigurării siguranței utilizatorilor.*

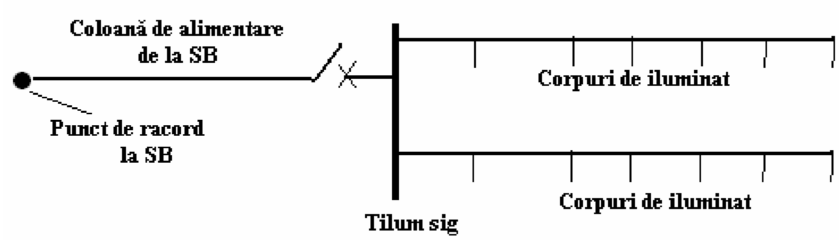

Figura 1

11.Corpurile de iluminat ale Sistemului de iluminat de siguranță sunt receptori care impun o sursă de asigurare a energiei electrice de siguranță în eventualitatea indisponibilității sursei de bază.

12.Compatibilizarea cerințelor sistemului de iluminat de siguranță cu cele două surse de alimentare a determinat, la nivelul reglementărilor tehnice specifice, în special a NP I-7, definirea a patru tipuri de soluții de coexistență a sursei de bază, cu sursa internă, de siguranță şi cu tabloul electric $T_{ilum\ sig}$, de la care sunt alimentate subsistemele de iluminat de siguranță.

13.În editările succesive ale NP I-7, abordarea problematicii SIS a suferit modificări, din punct de vedere a locului alocat în cuprinsul lucrării dar şi a variantelor de soluții.

14.Aceeaşi tematică a SIS este abordată, în mod firesc şi în alte lucrări de specialitate, dintre care de referință este MANUALUL DE INSTALATII ELECTRICE Vol. ELECTRICE editat sub egida AIIR.

II STUDIU DE CAZ

O analiză atentă a modului de abordare a SIS în cele două lucrări a pus în evidență mai multe necorelări.

Practica proiectări, dar mai ales cea de verificare a proiectelor tehnice a evidențiat că, de regulă, nu sunt înțelese corect soluțiile de realizare practică a alimentării $T_{ilum\ sig}$ aşa cum sunt doar enunțate, nu şi însoțite de scheme electrice adecvate, în NP I-7.

În MANUALUL DE INSTALATII ELECTRICE Vol. ELECTRICE, sunt prezente însă şi aceste scheme, dar nu în toate cazurile aceste scheme respectă conținutul textului din NP I-7, care este obligatoriu.

Aceste considerații au determinat abordarea acestei teme, care îşi propune o prezentare mai extinsă a soluțiilor cu care se realizează tipurile de alimentări ale $T_{ilum\ sig}$, în concordanță cu enunțul acestora din NP I-7/2002.

În primul rând în NP I-7/2002 nu se subliniază faptul că atât cât sursa de bază este disponibilă $T_{ilum\ sig}$ este alimentat de la aceasta, enunțul fiind următorul :
« Iluminatul de siguranță (SIS - n.a) după condițiile de alimentare de siguranță cu energie electrică şi condițiile de funcționare, este de următoarele tipuri »
«Tipul 2a, la care alimentarea iluminatului de siguranță este asigurată din baterie centrală de acumulatoare sau baterie locală cu dispozitiv de comutare automată (pile, luminoblocuri);

În NP I-7/2002, nu se precizează de unde se alimentează coloana care constituie, concomitent, SB şi sursa de încărcare, dar se precizează ca "Durata de comutare admisă pentru conectarea iluminatului de siguranță trebuie să fie mai mică de 0,5 s "

În MANUALUL DE INSTALATII ELECTRICE Vol. ELECTRICE, conform Figurii II 5.14a, punctul de racord la SB, este înaintea întrerupătorului de pe intrarea în tabloul general al consumatorului, dar nu se precizează durata de comutare admisă pentru conectarea iluminatului de siguranță.

Această soluție de alimentare corespunde deziderattului " Sistemul de iluminat de siguranță, pe seama soluției de separare a alimentării de Sistemului de iluminat normal va intra în fncțiune NUMAI la căderea sursei de bază a Sistemului de iluminat normal, care este sursa de bază şi pentru SIS"

Pe de altă în NP I-7/2002 se preconizează ca sursă de *intervenție* baterie locală.

Aceasta presupune ca SIS va fi alimentat doar de la o baterie locală. Enunțul este incoret deoarece această soluție NU este aplicabilă. Caracterul de local defineşte solutia corespunzătoare şi Tipului 1a şi constă, fie în folosirea de corpuri de iluminat cu sursă proprie, Figura 2, fie de folosirea câte unei baterii montate în fiecare tablou electric secundar, Figura 3. [2]

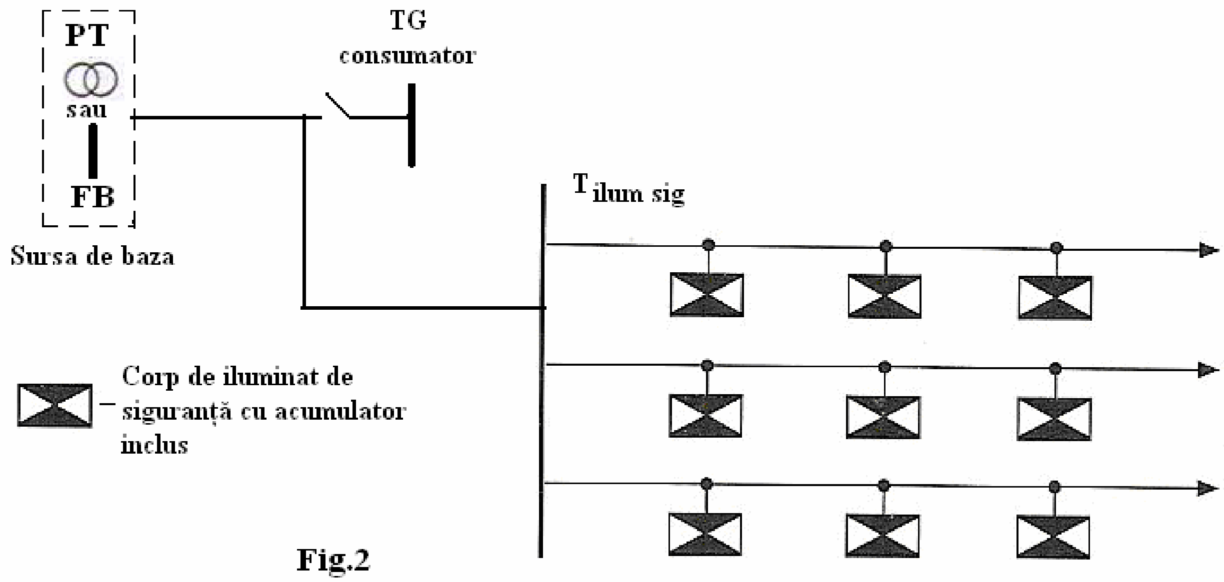

Fig.2

În MANUALUL DE INSTALATII ELECTRICE Vol. ELECTRICE, pentru Tipul 2a enunțul este: "baterie centrală de acumulatori" Deci în aceasta lucrare NU se preconizează si bateria locală.

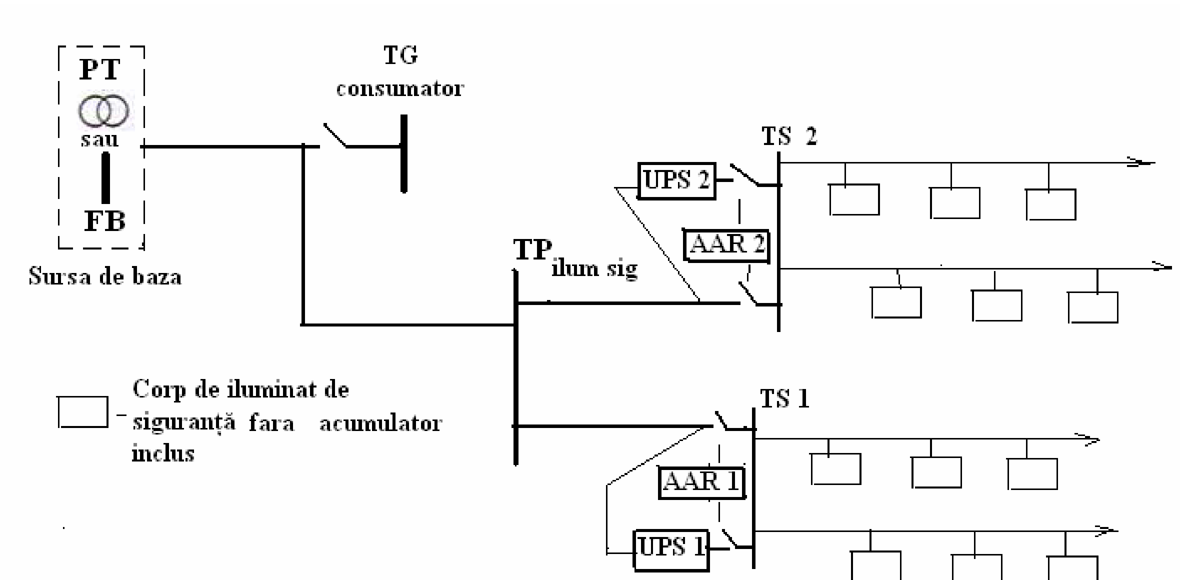

Fig.3

III CONCLUZII

1. Abordarea soluțiilor de alimentare corespunzător Tipului 2a este diferită în cele două lucrări menționate.
2. Enunțurile sunt, pe de o parte diferite, iar pe de altă parte generează interpretări.

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CONSIDERATIONS REGARDING THE SUPPLY SOLUTIONS OF THE SAFETY ILLUMINATION SYSTEM – TYPE 2a

ABSTRACT

The careful analysis of the expounding way of the safety illumination system problematic in the technical standards and references manuals underlines incorrelations, inagreement representations with the terms, as the possibility of inappropriate interpretations.

Thus, this work proposes to analyze the general mean of approach of the safety illumination system and the concrete case of the realization solution of the supply defined Type 2a.

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DEALING WITH LIGHT POLLUTION

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ABSTRACT

This paper presents the role of lighting in modern society taking in consideration the positive aspects and underlining the negative aspects excessive artificial lighting can have. The negative aspects can be put together forming what has become known as light pollution. The main means of causing light pollution are presented and illustrated with actual examples. In the past two decades there have an increasing number of studies linking artificial light with human health. Following aspects of light pollution, some of the findings in those studies are presented. In the paper's last section, some possible solutions for decreasing light pollution levels are exposed and there is also presented a benefit worldwide economy can have in the same time: energy saving, which in the past years has become an ardent issue.

1 LIGHTING IN CONTEMPORARY SOCIETY

1.1 Setting the backgrounds

Lighting up the night has become a way of life. Our round-the-clock society demands that outdoor spaces be lit up for safety and security. There is no denying that outdoor lighting has become an inescapable part of life. Streetlights adorn our roads, billboards stud our freeways, shopping-center parking lots are aglow from dusk to dawn, businesses obsess over late-night security, and convenience stores outdazzle one another to compete for customers. By taking a glance on a city's quarter, one can see a sight like that presented in Figure 1.

Figure 1 Example of public lighting [9]

1.2 Public lighting and safety

It is a widespread belief that heavy illuminated outdoor spaces during the night increases the safety of people walking in the streets. In some circumstances, poorly designed illumination might actually increase personal vulnerability: The problematic relationship between lighting and crime increases when one considers that offenders need lighting to detect potential targets and low-risk situations. Consider lighting at outside ATM machines, for example. An ATM user might feel safer when the ATM and its immediate surrounding area are well lit. However, this same lighting makes the patron more visible to passing offenders. Whom the lighting serves is unclear.

It can be easily demonstrated that too much light or poorly directed causes a loss of visibility. Vision and safety can be compromised by glare, which results when a light source forces the eye to adapt to a brighter scene than is actually present. Lighting engineers make a distinction between discomfort glare, which may not necessarily affect visual performance, and disability glare, which does (disability glare is experienced, for example, with the “high-beam” headlights of an oncoming vehicle). When someone looks toward a glaring, poorly shielded fixture, the pupils of his eyes constrict in response to the bright light — despite being in otherwise dark surroundings. As even novice skywatchers know, eyes require several minutes to readapt before they can again see properly in the dark. Such glare can temporarily incapacitate one’s vision, making it uncomfortable (if not impossible) to view anything near its bright source. Worse, overly bright lights cast harsh shadows in which intruders can hide from view. This is another argument in support of the fact that inefficient lighting favors offenders and doesn’t necessarily increase public safety.

In recent years the role of glare on visual performance has taken center stage in lighting research. New studies on glare, task-specific lighting, and their environmental context are driving major revisions in the society’s approach to establishing recommendations.

2 LIGHT POLLUTION

2.1 General aspects

Inefficient design and use of public lighting leads to light pollution. This comes in many forms, such as skyglow, light trespass, glare, and overillumination. Skyglow is the bright halo that appears over urban areas at night, a product of light being scattered by water droplets or particles in the air. Light trespass occurs, as described before, when unwanted artificial light from a floodlight or streetlight spills onto an adjacent property, lighting an area that would otherwise be dark. Glare is created by light that shines horizontally. Overillumination refers to the use of artificial light well beyond what is required for a specific activity, such as keeping the lights on all night in an empty office building.

2.2 Skyglow

Skyglow is a consequence of poorly designed public lighting systems throughout a city. Instead of having a dark sky, the light spread into the air illuminates water drops or other particles in the air and produces a glow over the city. One way to measure its intensity is by comparing it to the night sky's natural background light. The sky does have a certain minimum surface brightness even in the most unspoiled environment. This natural skyglow has four sources: faint airglow in the upper atmosphere (a permanent, low-grade aurora), sunlight reflected off interplanetary dust (zodiacal light), starlight scattered in the atmosphere, and background light from faint stars and galaxies. It is commonly known how a natural skyglow appears. However, a typical suburban sky today is about 5 to 10 times brighter at the zenith than the natural sky. In city centers the zenith may be 25 or 50 times brighter than the natural background. A picture taken over the city of Los Angeles, US, presented in Figure 2, reveals the intensity of skyglow in a metropolis.

Figure 2 Skyglow over Los Angeles, USA [12]

Some of the first proponents of reducing outdoor light at night were astronomers, both amateurs with backyard telescopes and professionals whose work is impeded by too much light in the environment. If one looks over a “skyglow map”, as the one in Figure 3, he can notice that truly dark skies have become somewhat of a rarity in most urban areas, which makes astronomers engaged in a long, difficult effort to fight light pollution and regain dark, starry skies.

Figure 3 Image of Europe captured at night by satellites of the US Airforce Weather Agency [13]

2.3 Glare and light trespass

Residential lighting comes as a necessity of securing homes’ surroundings. However, due to poor design of illumination systems, glare and light trespass appear in this situation. Reducing the glare from the public lighting is a common-sense courtesy to all the neighbors, who have every right to a dark bedroom at night. The poorly directed, overly bright light can spill light far from its intended target — onto a neighbor’s house or up into the sky. It is in designers’ best civic interest to promote a safe, pleasant nighttime environment, especially considering that many jurisdictions around the world are passing laws that prohibit light trespass (rays that shine from one property onto another). With this measure taken, situations like the one presented in Figure 4 should disappear. This measure has financial benefits coming along: by ensuring that all the fixtures direct their light onto the ground, instead of spraying it up and all around, the desired level of illumination can be achieved using less energy and consequently smaller energy bills have to be paid.

Figure 4 Glare as a result of inefficient residential lighting [10]

Public residential lighting is not the only factor in light trespassing. As the picture in Figure 5 shows, individual lighting of private houses - or any other outhouses - can lead to light trespass.

Figure 5 Common example of light trespass from a property to another [10]

2.4 Overillumination

Overillumination occurs, for example, in public outdoor spaces where there is too much light comparing with the necessary amount of it. An illuminated indoor space outside working hours is another example of overillumination; this sometimes comes as an effect of shop design, safety rules in banks or the common belief that a higher amount of light provides a safer public space. Architectural lighting leads in most cases to overillumination.

The picture in Figure 6 shows how much light is wasted by the architectural lighting of a large building; the huge amount of light creates an unnecessary glow around the building. It is needless to mention the waste of energy occurring in this case.

Figure 6 Overillumination caused by architectural lighting [12]

The picture in Figure 7 illustrates overillumination in a public square; its causes may not be only due to architectural lighting, but also to the public opinion that well-illuminated public spaces provide a higher level of security during nighttime. It can be seen as well that all shops have their lights turned on, this contributing to the area’s overillumination.

Figure 7 Indoor lighting outside working hours and excessive public lighting [3]

3 LINKING LIGHT POLLUTION TO HEALTH

3.1 Melatonin synthesis and sleeping disorders

Melatonin, a hormone produced by the pineal gland, is secreted at night and is known for helping to regulate the body's biologic clock. Melatonin triggers a host of biologic activities, possibly including a nocturnal reduction in the body's production of estrogen. The body produces melatonin at night, and melatonin levels drop precipitously in the presence of artificial or natural light.

The 24-hour day/night cycle, known as the circadian clock, affects physiologic processes in almost all organisms. These processes include brain wave patterns, hormone production, cell regulation, and other biologic activities. Disruption of the circadian clock is linked to several medical disorders in humans, including depression, insomnia, cardiovascular disease, and cancer. Studies show that the circadian cycle controls from ten to fifteen percent of our genes. Therefore, the disruption of the circadian cycle can cause a lot of health problems. One of the defining characteristics of life in the modern world is the altered patterns of light and dark in the built environment, made possible by use of electric power.

Difficulties with adjusting the circadian clock can lead to a number of sleep disorders, including shift-work sleep disorder, which affects people who rotate shifts or work at night, and delayed sleep–phase syndrome, in which people tend to fall asleep very late at night and have difficulty waking up in time for work, school, or social engagements. The connection between artificial light and sleep disorders cannot be effectively demonstrated, but there are currently many studies linked with this problem.

Researchers in the US have conducted experiments involving the effects artificial light has on melatonin synthesis. Two decades ago, they were able to shut down melatonin production in men by waking and exposing them to 2.500 lux of white light at 2 a.m., when synthesis of the hormone was at its peak. (For perspective, 100 lux may be found in a comfortably dim living room, whereas sunlight at high noon on a cloudless day can blast the eyes with 100.000 lux). A decade later, they have found that just 50 lux can have the same effect if green light is used in the same experiment. Studies now under way are also testing which wavelengths—or colors—are most biologically active. For instance, blue and green light appear especially effective at inhibiting melatonin synthesis in healthy young men. According to some studies, 17 lux was sufficient to produce strong melatonin suppression in these men—and some had full suppression with exposure to as little as 5 lux (5 lux is a little more illumination than the illumination provided by full moonlight).

3.2 Melatonin and cancer

One groundbreaking study implicated melatonin deficiency in what could be called “a rational biologic explanation for the increased breast cancer risk in female night shift workers”. The study involved female volunteers whose blood was collected under three different conditions: during daylight hours, during the night after 2 hours of complete darkness, and during the night after exposure to 90 minutes of artificial light. The blood was injected into human breast tumors that were transplanted into rats. The tumors infused with melatonin-deficient blood collected after exposure to light during the night were found to grow at the same speed as those infused with daytime blood. The blood collected after exposure to darkness slowed tumor growth. The study has shown that melatonin can slow down tumor growth and not necessarily that suppression of melatonin is a risk in developing breast cancer.

3.3 Can light pollution be linked with health disorders?

The evidence that indoor artificial light at night influences human health has become fairly strong, but how does this relate to light pollution? The work in this area has just begun, but two studies in Israel have yielded some intriguing findings. A team of researchers has used satellite photos to gauge the level of nighttime artificial light in 147 communities in Israel. After this, they overlaid the photos with a map detailing the distribution of breast cancer cases in Israel. The results showed a statistically significant correlation between outdoor artificial light at night and breast cancer. Women living in neighborhoods where it was bright enough to read a book outside at midnight had a 73% higher risk of developing breast cancer than those residing in areas with the least outdoor artificial lighting. However, lung cancer risk was not affected.

4 REDUCING LIGHT POLLUTION AND SAVING ENERGY

Artificial light is part of modern society and has benefited society by, for instance, extending the length of the productive day, offering more time not just for working but also for recreational activities that require light. When artificial outdoor lighting becomes inefficient, annoying, and unnecessary, it causes light pollution. Unnecessary indoor lighting contributes to light pollution and wastes energy. Misdirected outdoor lighting leads to energy waste and can reduce the safety of the area. Considering the increasing worldwide demand of energy and the negative effects light pollution has, scientists and designers are making efforts in order to reduce light pollution. By doing so, not only the outdoor environment can become more pleasant by night, but a lot of energy can be spared by not wasting light and using it more efficiently. Cities around the world are implementing strategies that successfully curb light pollution and conserve energy through the use of well-designed lighting and simple acts such as turning off unnecessary lights when not in use.

4.1 Solutions for light trespass

An example of using well-designed lighting is given in the figure below, where light trespass is solved by using shielded lights. Shielded lights, especially those with “full-cutoff” designs, minimize glare and make neighborhoods safer and easier on the eyes at night.

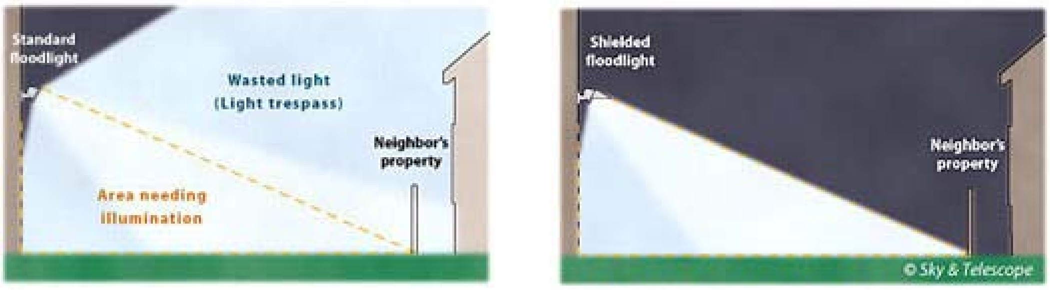

Figure 8 The difference of light distribution between standard floodlights and shielded floodlights [10]

4.2 Implications unnecessary lighting has

Home lights waste even more energy when they shine unneeded throughout the night. By looking at a 200-Watt security light which operates continuous from dusk to dawn we can find that it will be turned on about 4.100 hours over the course of a year and use 820 kilowatt-hours of electricity. Considering the huge amount of families that practice this, the amount of energy wastes rises incredibly. This problem can be solved by using motion sensors on a wide scale. It leads to a higher investment at first, but the amortization period is very short as energy costs are continuously rising in the past years.

Lighting office spaces or shops outside the working program leads to energy waste as well. Even if it may look aesthetically better in shops’ case or they comply with security measures, light pollution and energy waste are side effects of continuous indoor lighting.

4.3 Energy savings

Various estimates state that lighting accounts for about 8–9% of the electricity used in the United States. In unpublished calculations, the IDA Technical Committee recently estimated that 17,4 billion kilowatt-hours of electricity is wasted each year. This waste arises, for instance, from lighting that is directed upward, illuminating nothing but sky or that is left turned on when not needed. According to the Energy Information Administration, it takes more than 9 million tons of coal or 32 million barrels of oil to produce that amount of energy. This translates into annual CO_2 emissions of nearly 1 ton or 2,5 tons, depending on the fuel, according to EPA conversion factors.

By implementing efficient design in outdoor lighting and educating population to rationally use lights, we can reduce lighting pollution and energy waste, thus solving another problem in the long path of creating a safe and "healthy" environment for us and future generations.

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OPORTUNITIES TO REDUCE CONSUMPTION OF ELECTRICITY IN LIGHTING SYSTEMS

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ABSTRACT

The present paper's goal is to underline possibilities to reduce electricity consumption in lighting systems. Energy saving has a positive contribution to both environment (by reducing CO_2 emissions) and society.

Research guidelines will be presented to fulfill the increase of the lighting network performances like: increasing energy efficiency in existing systems (fluorescent tubes, electronic ballasts use), usage of presence sensors and voltage control devices, natural lighting and possibilities of achieving new lamps which have improved features and lower power consumption (LED, Krypton lamps, metal halides lamps).

1 INTRODUCTION

Artificial lighting is one of the basic components in achieving normal living conditions (study, work, entertainment) when the natural lighting does not provide the necessary level of illumination. Choosing the necessary level of illumination and the lighting quality presents a great influence in the daily activities.

Almost 10% of the total electrical power is used by lighting systems. Even if lighting systems are responsible for a small part of energy consumption, concentration around them is justified by:

- great influence on the level of civilization of society;
- important percent of the energy bill of households and tertiary.

According to studies, electric lighting is a consumer of electrical power with reduced efficiency. The most efficient light source currently generate 200 lm/W compared to 682 lm/W, value that would yell for full conversion of electricity into light.

Performance analysis of electric light sources, that are currently marketed, show that the new generation of products provide, for the same illumination, energy savings of 10 - 35%.

On the other hand, as particular issue for Romania, the household lighting is represented in nearly all cases by incandescent light sources. If evolved countries have over 80% of the luminous flux obtained by appropriate sources, based on discharge in metallic vapor and gas, in Romania less than 10% of necessary light flux is obtained by fluorescent sources [7].

2 DIRECTIONS TO INCREASE THE PERFORMANCE IN LIGHTING SYSTEMS

The main directions of research for increasing performance in electric lighting installations are set out below:

2.1 Increase of energy efficiency in usage of lamps [1, 5, 7]

2.1.1 Usage of compact fluorescent lamps

If incandescent lamps convert 90-95% of electricity in heat and only 5-10% of electricity in light, compact fluorescent lamps use 80% less electricity achieving the same features lighting - Table 1 (calculations performed estimating a cost of 0.07 EURO/kWh).

Compact fluorescent lamps combine high luminous efficacy and colorimetric characteristics with a low power consumption and high life expectancy (an average 8000 hours versus 1000 hours for incandescent lamps). Compact fluorescent lamps have rated power values between 9 - 23 W, with a luminous efficiency between 45 - 85 lm/W. Adjustment (decrease) of light flow is possible till 50% of the nominal luminous flux is reached.

Table 1 Incandescent and compact fluorescent lamp comparison

	Incandescent lamp	Compact fluorescent lamp
Power [W]	60	11
Lifetime [hours]	1.000	8.000
The cost of electricity for 8000 hours of operation, [EURO]	34,3	6,3
Economy: 28 EURO		

Lamps are made in various designs, shown in Figure 1:

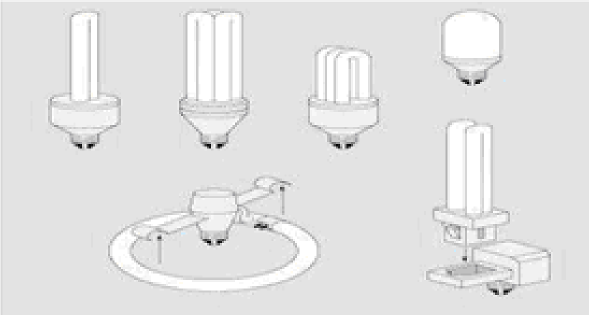

Figure 1 Compact fluorescent lamps types [1]

2.1.2 Usage of electronic ballasts

Fluorescent lamps operate on the principle of the arc discharge in mercury vapor and inert gases at low pressure. A novel alternative is the implementation of the new generation of T5 fluorescent lamps. They are highly efficient both in terms of consumption and the lifetime.

Using electronic ballast (Figure 2) with fluorescent lamp type T5, energy losses are reduced (power factor is at least 0.94) and lifetime will be increased (over 15,000 hours). The costs of power consumption will be reduced by 64%.

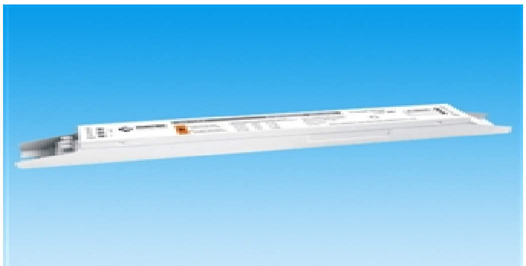

Figure 2 Electronic ballast [5]

This solution gives a continuous stable light, with no flicker and silent in operation. As construction solutions, T5 fluorescent lamps have different rated powers: 14 W, 28 W and 35 W.

A comparison study between T8 fluorescent lamps and T5 fluorescent lamps with electronic ballast is presented in Table 2:

Table 2 T8 and T5 lamps comparison

	T5 – 28 W	T8 – 36 W	T5 – 35 W	T8 – 58 W
Voltage supply [V]	230	230	230	230
Active power [W]	32.8	43.1	40	78
Apparent power [VA]	34.4	89	43	129.1
Power factor	0.95	0.48	0.95	0.57
Energy [kWh/an]	289	377	351	649

It is noted that the performances reached by using T5 lamps with electronic ballast are net superior against the case of T8 fluorescent lamps.

2.2 Reducing energy consumption through usage of sensors and voltage control devices [1, 2, 5]

2.2.1. Using motion sensors

Outdoor lighting installations, with high installed power, have a significant consumption of the total electrical power destined for lighting. Building economical lightning systems requires usage of lamps equipped with motion sensors (shown in Figure 3).

Figure 3 Lamp with sensors [5]

Motion sensors ensure that the lamp works only when is dark and when the sensor detects movement within its range. Through an integrated switch movement in the dark will lead starting of the lamp.

These lamps work with infrared sensors. They record sudden temperature oscillations (in the surveyed zone) and then send a signal to start the lamp.

In comparison with the permanently active systems, using lamps equipped with motion sensors have as result the saving of a considerable amount of power. Some lamps have sensors with a circular surveying capacity of 360° through "multi-system lens". By moving the lens, the surveillance area narrows or widens.

Economic lamps with technology based on motion sensors are characterized by:

- ideal for long lighting time in the outside area;
- starting and stopping automatically at sunset/sunrise;
- low energy consumption (energy saving up to 80%).

2.2.2. Automatic control of lighting levels

One of the advantages for using voltage control devices is to extend the operation time of lighting sources. Experimental researches shown that a reduction of only 5% from the supply voltage caused doubling the lifetime of the lamps (classical incandescent or halogen lamps), supplied at 230 V or at very low voltage.

Another important advantage is saving of power. Light perception by the human eye is not carried out in linear mode; hence reduction of at least 10% of the light flow will be observed and realized. Reduction in the level of luminous flux represents energy saving of almost 10%. For a 50% decrease in the lamp's level flow will provide energy saving of about 40%.

It is noted that not all light sources are adjustable. Today's practical solutions are presented in Table 3.

Table 3 Types of adjustable light source

LAMP TYPE	ADJUSTABLE	VOLTAGE CONTROL DEVICE TYPE
Classical incandescent lamp	Yes	Any type
Incandescent with halogen lamps 230 V	Yes	Any type
Incandescent with halogen lamps at very low voltage, with ferro-magnetic transformer	Yes	Device with upward change of phase (thyristor / triac)
Incandescent with halogen lamps at very low voltage, with electronic transformer	Yes	Device with downward change of phase (the transistor)
Fluorescent lamps with conventional ballast	Yes, for certain types of ballast, within certain limits (up to 50%)	Device with upward change of phase (thyristor / triac)
Fluorescent lamps (tube and compact) with electronic ballast	Yes, depending on the type of ballast, within certain limits (up to 50%)	Device with upward or downward change of phase (thyristor / triac)
Compact fluorescent lamp socket E27	Yes, within certain limits (up to 50%)	Device with upward or downward change of phase (thyristor/triac)

2.3 Strategies for natural lighting [3]

Natural lighting systems can supplement or replace electric lighting. This solution will not provide direct electrical power savings, but them usage lowers the electrical light sources consumption.

One of the solutions for caption of natural light is the light tube. This is a secondary light source that transmits flux from the primary source (environment/Sun) in the habitat, to a specific objective or to certain areas (Figure 4).

Figure 4 Natural light systems [5]

Light tube transmits radiation through the phenomenon of total internal reflection. The material inside has a reflection of 0.98, and internal reflection occurs in the structure of 0.5 mm thickness of the optical film, made of transparent acrylic or polycarbonate.

There are light tubes specially designed for roofs, known as solar tubes. These systems maximize energy use by reflecting and concentrating sunlight and even diffuse light of the sky through a tube of aluminum high-reflecting mirror.

The top of the tube is closed with a dome of transparent polycarbonate. Focused light is then reflected by a mirror to the vertical pipe, as close as possible to the central axis. Bottom, located at the ceiling, is closed with a polycarbonate dome transparent, which diffuse uniform light into the interior.

When the light passes through the tube, losses occur because of: tube absorption, by reflecting the way, the light is referred back to the source and absorption by the mirror located at the end of the tube.

Using natural light in buildings is benefic for the comfort of occupants. An important role can be observed by the minimization of the power consumed for lighting systems.

2.4 Lamps with improved features [4, 5, 6]

2.4.1 LED

LED (Light Emitting Diode) is a semiconductor that converts electricity into photons, and then in light. The conversion is cold, which attracts an extremely high efficiency compared to ordinary light sources. Light is basically generated inside a semiconductor crystal, which is passed by an electric current. The crystal consists of a semiconductor junction of aluminum, indium, gallium and phosphorus. It can produce up to four basic colors like Red, Yellow, Green, Blue, with shades around them and White (Figure 5).

Figure 5 Constructive variants of LED [5]

Studies have shown that a regular bulb uses only 10% of electricity, while 90% of energy is wasted through heat. This gives the name of “incandescent light source”. Probability of failure of incandescent source is around 50% only after 2000 hours of operation. This and the extremely high fragility (body glass and thin filament) make LED technology to provide clearly a novel solution.

Among the advantages of light sources based on LED are noted as follows:

- small dimensions;

- energy consumption may reach only 10% of the usual incandescent sources;
- very resistant to weathering and chemical agents;
- do not generate heat, essential in the air-conditioning systems;
- duration of operation extremely long (at least 10 years) which is not associated with failure, but with light attenuation performance;
- offers a wide range of colors, is essential for display panel;
- light is concentrated on a specific direction that can eliminate the use of reflectors or other optical systems;
- large application areas such as medicine and biotechnology.

LED lamps will find great utility for mobile devices, such as car headlights or flashlights. They are used in urban life for outdoor lighting, traffic signs or traffic lights. On the other hand, LED lamps have found various uses in electronic, using the screen with LED lighting.

Due to their low consumption, LED lamps began to be increasingly used in housing, both in directional spot lights and ambient lighting or in night-time.

LED technology is at its beginning and in short time, more and more systems will use this type of lamps. In addition, new types of lighting systems based on LED are at various stages of development. Some examples would be polymers LED's or OLED with sites that will lead to flexible lighting systems, and ultra mobile.

2.4.2 Krypton lamps

The Krypton lamp is an incandescent lamp (balloon type E) filled with Krypton, with considerable improved luminous flux. The life of lamp is larger and has higher energy efficiency than incandescent lamp.

Krypton gas allows a higher filament temperature of combustion, providing white light with high brightness versus ordinary incandescent lamps.

2.4.3 Metal halide lamps

The metal halide lamps are part of discharge lamps at high pressure gas, being a compact and efficient source. Like most vapor discharge at high pressure gas lamps, metal halide work under high pressure and temperature conditions, which include special lighting fixtures for a safe opperation. Them relatively small size, allows good optical control and successful usage in applications that requires light flow concentration. Being a discharge lamp, this too is connected to the grid via ballast. Generally, is used the same type of ballast like the mercury discharge lamps at high pressure.

One of the disadvantages of this source is long restart time. When the power source is off the pressure of the discharge tube is too large to allow instant restart at 0.5-5 kV.

Ignition is possible again, after 5-10 minutes, depending on the cooling source efficiency. This is an important issue for applications where long restart time may cause a production stops or security issues. There are metal halide lamps with instant ignition by using ballast with high voltage operation (30 kV) that will ignite the lamp.

Metal halide sources were initially preferred to the mercury vapor in applications where natural light is needed (sources of mercury vapor generating a blue light). However, today slight differences can be yelled between different types of discharge lamps. By the introduction of gas mixtures are now available for these lamps, color temperature between 3000 and 20,000 K.

3 CONCLUSIONS

Considerable electrical and light-technical advantages for lighting systems using lamps based on electrical discharges can not be valued sufficiently if no measures are taken to limit them operating inconvenient. Hence, the main negative aspects are:

- the need for ballast to limit the intensity of electric current discharge;
- long time to release (4-5 minutes) and revival (6-7 minutes) for metal discharge lamps in high vapor pressure;
- emergence stroboscopic effect;
- reactive energy consumption using inductive ballast;
- lamps are harmonic source because of the nonlinear of the electric arc discharge.

Current lamps still have high power consumption versus modern lighting solutions. One measure that can be taken is the replacement of the lamps with low energy efficiency with others that have superior qualities in means of energy consumption, or their endowment with equipments designed to reduce electricity consumption.

A second solution would be efficient use of natural light that will provide electrical energy savings.

The concern for the environment demands rational usage of global energy sources. This way, saving 1 kWh will reduce both CO_2 emissions by up to 1 kg and methane up to 0.011g.

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MODEL TO DETERMINE LIGHTING ENERGY SAVINGS IN COMMERCIAL BUILDINGS

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ABSTRACT

The awareness of limited resources as well as the increasing political interest in energy-efficiency demand models for estimating the energy consumption of systems. World-wide activities look at the energy consumption of various economical sectors including buildings. This paper outlines an approach for estimating the energy consumption for lighting in a new building. Models like these face the challenge that they base their assumptions on the data provided by early design stages of a particular building. The estimate needs to be reasonably precise to enable a reliable comparison between a set of options. At the same time, the amount of input data should be minimized to allow for a good and easy usability.

The model described in this paper uses the installed lighting power density, the area of the daylit and non-daylit section and the effective operational times during daytime and night-time for each building zone. The calculations (based on the German standard DIN 18599 and the North-American standard ASHRAE-IESNA 90.1) allow a trade-off within the field of lighting technologies. This methodology forms the basis for the lighting trade-off compliance path of the next edition of the National Energy Code of Canada for Buildings (NECB).

I INTRODUCTION

The energy consumption for lighting in buildings depends on the (variable) demand within a (given) time interval t_1 to t_2 as shown in (1):

$$Q = \int_{t_1}^{t_2} p(t)\, dt \qquad (1)$$

When using daylight dependent or occupancy dependent lighting control, the computation of the energy consumption for lighting can also be based on the installed electrical power for the lighting system 0. The factor □ in (2) represents the average dimming level (ranging between 0 and 1), derived from the sensor signal x_{Sensor}.

$$Q_{light} = \int_{t_1}^{t_2} P_{\max} \cdot \delta(x_{sensor}, t)\, dt \qquad (2)$$

In a simplified manner, the computation of the energy consumption for lighting Q_{light} can be expressed as a product of the installed lighting power P_{max} and a quantity named effective operational time t_{eff}.

$$Q_{light} = P_{\max} \cdot t_{eff} \qquad (3)$$

Figure 1 shows the transition from representing the energy consumption by the time-changing demand to the simplified multiplication in (3). The blue area in the graph represents the energy as calculated in the integrating approach and the red area represents the concept using the equivalent time of operation. Both areas are equal in size.

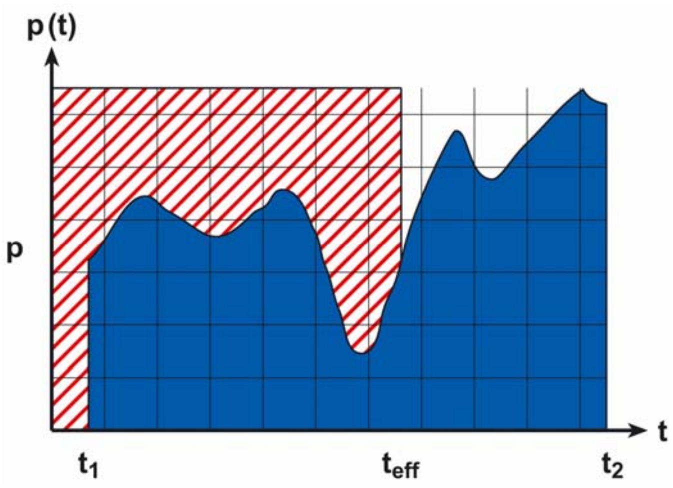

Figure 1 Transition to a simplified calculation of the energy consumption 0

The advantage of this approach is the easy way of handling the electrical lighting system. It is characterized by the installed lighting power only. Note that this number represents the use of lamps, ballasts and luminaires but it excludes the effect of any lighting control system which will be accounted for in the equivalent time of operation.

The methodology needs to consider influences of daylighting and electrical lighting for a building zone. For this, the algorithm differs between daytime and night-time operational times. Within this methodology daytime is defined as the time during which the sun altitude is greater than 0˚. Conclusively, the daytime operational time or simplified operational time (day) is the daytime during which the building zone is operational. Daylight related savings can only occur during the operational time (day) and in those parts of the building zone that are classified as the daylit zone.

The effective operational times consider all applicable influences that limit the energy consumption for lighting, i.e. all operating control systems in a building zone. Equation (4) shows the basis of the lighting energy budget calculation:

$$Q_{light} = \sum_{j=1}^{J} p_j \left[A_{DL,j} \cdot \left(t_{eff,day,DL,j} + t_{eff,night,j} \right) + A_{NDL,j} \cdot \left(t_{eff,day,NDL,j} + t_{eff,night,j} \right) \right] \quad (4)$$

where:

- p_j = Installed lighting power density for the electrical lighting system
- $A_{DL,j}$ = Area within the building zone that can be daylit
- $A_{NDL,j}$ = Area within the building zone that cannot be daylit
- $t_{eff,day,DL,j}$ = Effective daytime operational time for the area within the building zone that can be daylit
- $t_{eff,day,NDL,j}$ = Effective daytime operational time for the area within the building zone that cannot be daylit
- $t_{eff,night,j}$ = Effective nighttime operational time for the the building zone

Parasite effects such as energy consumption for standby luminaires are not being considered.

II OVERVIEW OF CANADIAN STANDARDS

Canada has implemented several energy conservation standards that recommend/regulate the use of energy-efficient lighting starting with the Model National Energy Code of Canada For Buildings in 1997 0. Since then, a few other standards have been installed to push the bar for energy-efficient technologies higher. Figure 2 illustrates the impact of various standards on the overall energy-efficiency. The timeline is not to scale and the numbers are of general nature and might differ for different building/space types.

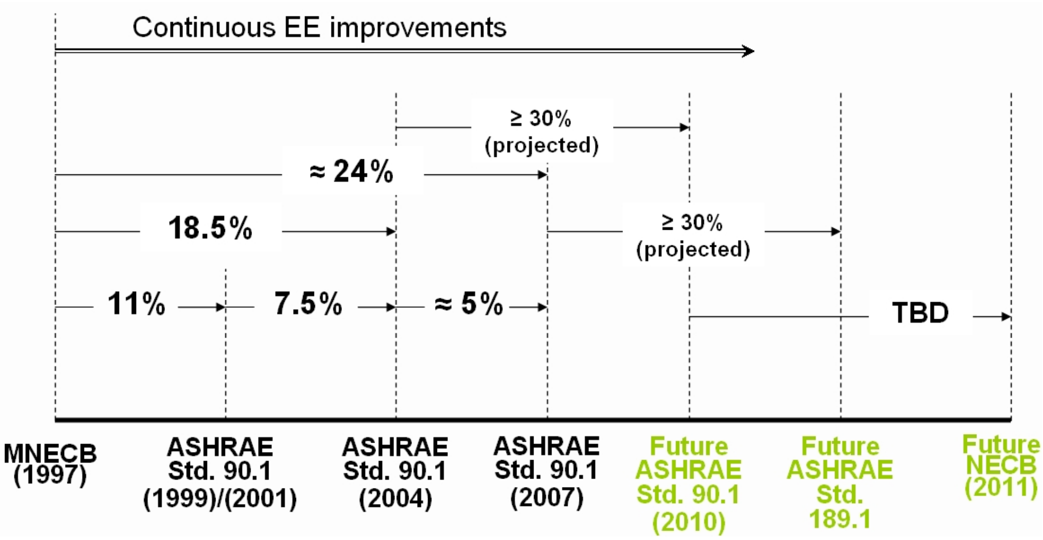

Figure 2 Overview of the main codes implemented in Canada to target energy-efficiency 0

The main influence to date came from the implementation of updated versions of ASHRAE/IESNA Standard 90.1 by various municipalities. Recently, work on updating the National Energy Code for Buildings has started aiming at a new version of that code in the near future (the official release of the NECB is expected in 2011). In parallel to the prescriptive compliance path, cope compliance can also be achieved by the lighting trade-off compliance path. This path evaluates the energy consumption of the current building design and compares it with the energy consumption of a baseline building. For this path the design complies with the code if the energy consumption is less than or equal to the baseline consumption (as shown in Figure 3).

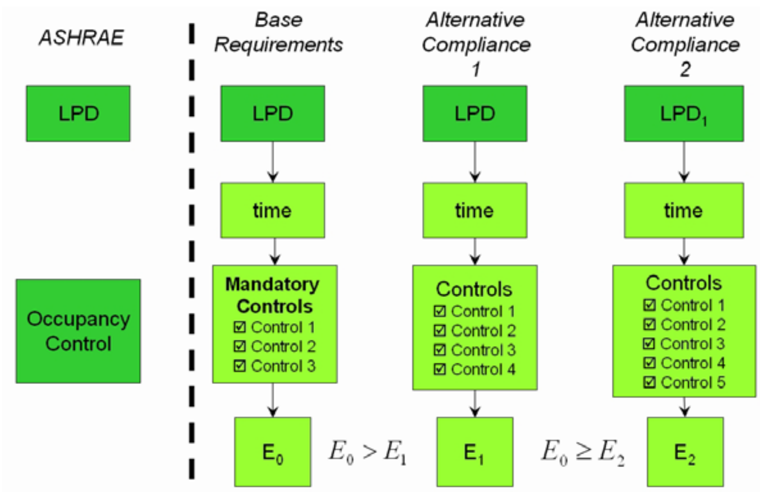

Figure 3 Comparison of the ASHRAE Compliance to the new Lighting Trade-off Compliance path

III DETERMINING THE INSTALLED LIGHTING POWER DENSITY

There are different ways of determining the installed lighting power density. One way would be to use the recommended lighting power density given by the ASHRAE/IESNA standard 90.1 0. This number could be challenged by a more detailed lighting design approach using standardized lighting design methods.

By allowing these two approaches, the lighting power density can be derived by either a table (prescriptive path) or, in order to challenge the resulting energy consumption, a different lighting power density could be used it can be backed up by lighting design methods. Hence, this methodology has an interface for new lighting technologies that are more energy-efficient 0.

Within the overall process of determining the energy consumption for lighting in a building, a hybrid approach of using the lighting power density from the standard ASHRAE/IESNA 90.1 in some building zones and using a detailed lighting design in other zones is acceptable.

IV DETERMINING THE DAYLIT AREA

The total area A_j of a building zone consists of two sub-zones: one sub-zone $A_{DL,j}$ that could benefit from daylighting and the other one $A_{NDL,j}$ that cannot benefit from it (not in a daylit zone). The total zone area is the sum of the two sub-zones:

$$A_j = A_{DL,j} + A_{NDL,j} \tag{5}$$

Areas are considered daylit if the ratio of area depth and the difference between the top of the window and height of the working plane is less than or equal to 2.5. If the building zone has more than one transparent external wall, the determination of the sub-zones should be based on the largest fenestration area.

Zones uniformly equipped with skylights are considered daylit. For single skylights or wide spacing of skylights, the area $A_{DL,j}$ is defined as the area that meets the following criterion:

$$a_{DL,\max} = 2 \cdot \left(h_{c,j} - h_{wp,j}\right) \tag{6}$$

where:

$a_{DL,max}$ = Maximum length/width of the daylit area
$h_{c,j}$ = Height of the ceiling of the building zone
$h_{wp,j}$ = Height of the work plane

V CALCULATION OF THE EFFECTIVE OPERATIONAL TIMES

The impact of daylight depends on the following quantities:

- Geographical location
- Meteorological situation, e.g. local sunshine probability
- obstruction
- daytime times of utilization
- relative activation level of shading systems during daytime
- installed daylight system
- daylight control system
- occupancy control system

The effective times of operation are the sum of the time of operation (day) and time of operation (night). Both quantities are weighted by operation factors accounting for the control system(s):

$$t_{eff,day,DL,j} = t_{day,j} \cdot F_{DL,j} \cdot F_{occ,j} \tag{7}$$

$$t_{eff,day,NDL,j} = t_{day,j} \cdot F_{occ,j} \tag{8}$$

$$t_{eff,night,j} = t_{night,j} \cdot F_{occ,j} \tag{9}$$

where:

$t_{day,j}$ = Operational time of the building zone j at daytime
$t_{night,j}$ = Operational time of the building zone j at night-time
$F_{DL,j}$ = Factor to account for daylight harvesting in building zone j
$F_{occ,j}$ = Factor to account for occupancy control in building zone j

A. Operational time

The operational time is divided into day- ($t_{day,j}$) and night-time ($t_{night,j}$). This allows accounting for daylight harvesting only during those times when daylight is available. Daytime is defined as the time when the sun altitude at the location of the building in greater than 0.

The operational times depend on the start time and end time of the operation in the building. These times depend on the geographical location of the building. For Canada, there will be a few different geographical zones. For each geographical zone there is a set of tables to determine the operational times during day- and night-time. The tables assume 5 working days per week. Different operations need to correct these values linearly.

B. Factor $F_{DL,j}$ for Daylight Harvesting

The factor for daylight harvesting depends on two auxiliary quantities:

$$F_{DL,j} = 1 - C_{DL,\sup,j} \cdot C_{DL,ctrl,j} \quad (10)$$

where:

$C_{DL,ctrl,j}$ = Factor to account for the daylight dependent control system
$C_{DL,sup,j}$ = Daylight supply factor

The daylight supply factor $C_{DL,sup,j}$ is a measure for the amount of daylight available in the building zone. This quantity is the same as the relative annual exposure 0, 0. The factor to account for the daylight dependent control system $C_{DL,ctrl,j}$ relates to the performance of the lighting control system.

The values for these factors can be determined by simulation and sensitivity analyses. The data for the German standard has been computed by Jan de Boer of the Fraunhofer Institute for Building Physics 0. For this, the daylight supply is evaluated using the daylight factor or another estimation method. The daylight suppy factor consists of two partial daylight supply factors $C_{DL,sup,SA,j}$ and $C_{DL,sup,SNA,j}$. These factors describe the daylight supply for the situation with an activated (SA) and a non-activated (SNA) sun shading system. These two factors are weighted by the relative times $t_{rel,DL,SA,j}$ and $t_{rel,DL,SNA,j}$ describing the relative time the daylight system is in either of the two states. The daylight supply factor is calculated as follows:

$$C_{DL,\sup,j} = t_{rel,DL,SA,j} \cdot C_{DL,\sup,SA,j} + t_{rel,DL,SNA,j} \cdot C_{DL,\sup,SNA,j} \quad (11)$$

where:

$t_{rel,DL,SA,j}$ = Relative time that the sun shading system is activated
$t_{rel,DL,SNA,j}$ = Relative time that the sun shading system is not activated
$C_{DL,sup,SA,j}$ = Daylight supply factor for the building zone j if the sun shading system is activated
$C_{DL,sup,SNA,j}$ = Daylight supply factor for the building zone j if the sun shading system is not activated

For a non-activated sun protection system the effective luminous transmittance for the daylight system is:

$$\tau_{eff,SNA,j} = \tau_{D65,j} \cdot k_{1,j} \cdot k_{2,j} \cdot k_{3,j} \quad (12)$$

where:

$\tau_{eff,SNA,j}$ = Effective luminous transmittance for non-activated sun protection
$\tau_{D65,j}$ = Luminous transmittance for illuminant D65 for the glazing type
$k_{1,j}$ = Window frame factor
$k_{2,j}$ = Dirt factor
$k_{3,j}$ = Factor to account for non-orthogonal light incidence

The daylight supply factor can be looked up in a matrix with two variables: effective luminous transmittance and the target illuminance in the building zone. This factor can vary a lot for different systems. A simple table looking at product classes (e.g. sun protection systems, automatic blind systems, light redirecting systems) can only point out an estimate. For a more detailed calculation, the relative annual exposure needs to be calculated.

The factor to account for the daylight dependent control system $C_{DL,ctrl,j}$ is derived in a similar way as the daylight supply factor by using tabulated data. The factor depends on the control system for the electrical lighting system, the qualitative daylight supply (good, medium, bad/none) and the target illuminance. The controls systems are divided into:

- building management system,
- automated control system with the ability to switch off the light,
- automated control system without the ability to switch off the light and
- manual control.

C. Factor to account for occupancy control

The factor $F_{occ,j}$ accounts for the influence of an occupant's absence from the building zone j on the energy consumption for lighting. This factor is being derived from the two other auxiliary factors $C_{A,j}$ and $C_{occ,ctrl,j}$:

$$F_{occ,j} = 1 - C_{A,j} \cdot C_{occ,ctrl,j} \tag{13}$$

where:

$F_{occ,j}$ = Factor to account for occupancy control in building zone j
$C_{A,j}$ = Relative absence from the building zone j
$C_{occ,ctrl,j}$ = Efficiency of the occupancy control to determine absence in the building zone j

Absence in the context of this methodology describes the relative time during the operational time during which the building zone is unoccupied. The factor $C_{occ,ctrl,j}$ models, how quickly and how accurately this absence is detected by the control system in place. For automated occupancy sensors, this factor is significantly greater than for the situation where the lighting is controlled manually by the occupant.

These values cannot be used for all room types under any circumstance. For instance, for the evaluation of a large open office space these numbers can only be applied if there is an individual lighting controls for every workstation. For a large open office space that is only illuminated with a general lighting system, $C_{occ,ctrl,j}$ is equal to 0.

D. Factor to account for individual controls

Following the same approach as for occupancy sensors, the model contains a factor $F_{ind,j}$ to account for the influence of individual controls. Individual controls enable an occupant to dim down his task light individually. Research has shown that there are significant savings (approx. 10%) due to this approach 0. The model accounts for these savings if they apply. If the space has no individual controls, $F_{ind,j}$ is set to 1.

VI SUMMARY

The model as described in this paper allows the calculation of the energy consumption for lighting in a building. Equation (4) summarizes the general approach. A flowchart of the model based on this equation is illustrated in Figure 4.

For every building zone, the influences of electric lighting, daylighting and the lighting control system are being evaluated. This methodology uses the installed lighting power density, the area of the daylit and non-daylit section and the effective operational times during daytime and night-time for each building zone.

This methodology fits into the general building approach of the German standard DIN 18599 0 forming the national implementation of the European directive on energy efficiency in buildings 0. The calculations allow a trade-off of the energy consumption in between different technical areas such as lighting, heating and cooling. It also allows comparing the energy consumption of these different technical areas and to monitor the influence of different choices (e.g. installing a different technical system).

To evaluate the energy savings of a design, two situations, a defined base case and the current design, need to be evaluated. The difference in the energy consumption defines the energy savings to be expected.

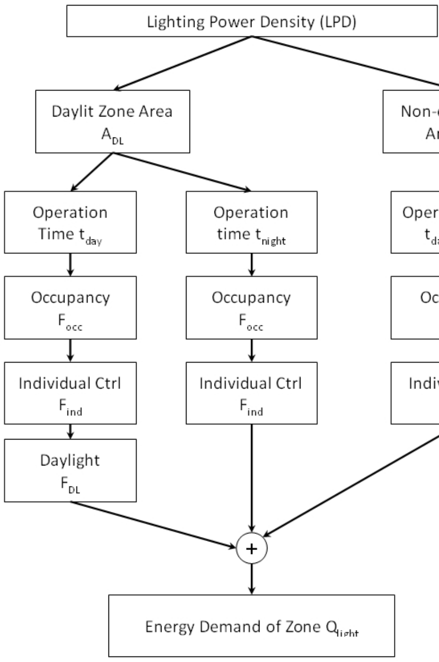

Figure 4 Flowchart of the methodology to determine the energy consumption for lighting of a building zone

VII ACKNOWLEDGMENT

Most of the methodology described in this report has been developed at the Fraunhofer Institute for Building Physics and the Technical University of Berlin. The results of the combined research activities have become part of the German standard DIN 18599 allowing the energetic budget for buildings.

This paper also represents some of the current work of the task group lighting of the National Energy Code of Canada for Buildings. The model has partly been refined to fit into the general approach of the Code and to meet Canadian requirements.

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PHOTOVOLTAIC ARCHITECTURAL LIGHTING - CENTRAL UNIVERSITY LIBRARY CASE STUDY

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ABSTRACT

The paper presents a study case of a PV installation that ensures the power generation for the architectural lighting at „Lucian Blaga" Central University Library, in Cluj-Napoca. The project was intended to be an example for the other institutions in Romania and also as an experiment for improving the future projects, giving the fact that there is not much local experience with working in such a field. This kind of approach supports the idea that the integration of photovoltaic systems in buildings can be started with secondary consumers/installations – this case architectural lighting – and extended further on, to the rest of them. The use of energy efficient lamps must be emphasized and regarded as a requirement for this type of projects.

1 INTRODUCTION

Photovoltaic (pv) or solar cells, as they are often called, are semiconductor devices that convert sunlight into direct current (dc) electricity. Groups of pv cells are electrically configured into modules and arrays, that can be used to charge batteries, operate motors and power some electrical loads (appliances). With the appropriate power conversion equipment, pv systems can produce alternating current (ac) compatible with any conventional appliances, and operate in parallel with and interconnected to the utility grid.

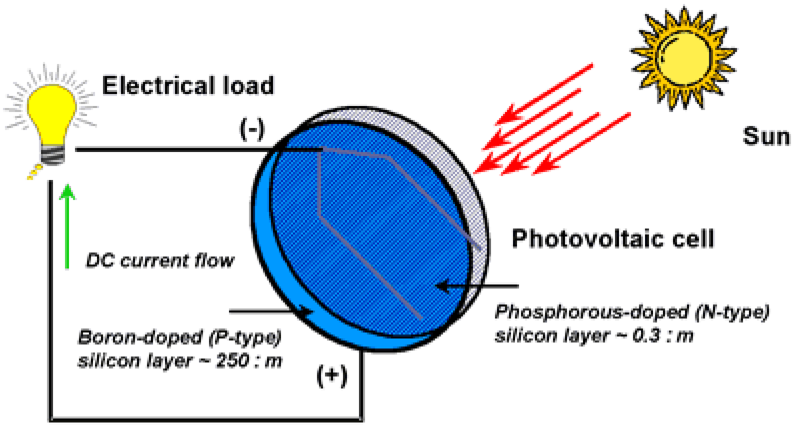

Figure 1 Diagram of photovoltaic cell [4]

Solar energy is a renewable resource that is environmentally friendly. Unlike fossil fuels, solar energy is available just about everywhere on earth. Furthermore, this source of energy is free and immune to rising energy prices. Solar energy can be used in many ways, to provide heat, lighting, mechanical power and electricity.

2 GENERAL INFORMATION

Simply put, pv systems are like any other electrical power generating systems the only difference being that the equipment used is different than that used for conventional electromechanical generating systems. However, the principles of operation and interfacing with other electrical systems remain the same and are guided by a well-established body of electrical codes and standards.

Although a pv array produces power when exposed to sunlight, a number of other components are required to properly conduct, control, convert, distribute and store the energy produced by the array.

Depending on the functional and operational requirements of the system, the specific components are required and may include major components such as a dc-ac power inverter, battery bank, system and battery controller, auxiliary energy sources and sometimes the specified electrical load (appliances). In addition, an assortment of balance of system (bos) hardware, including wiring, over current, surge protection and disconnect devices, and other power processing equipment. Figure 2 shows a basic diagram of a photovoltaic system and the relationship of individual components.

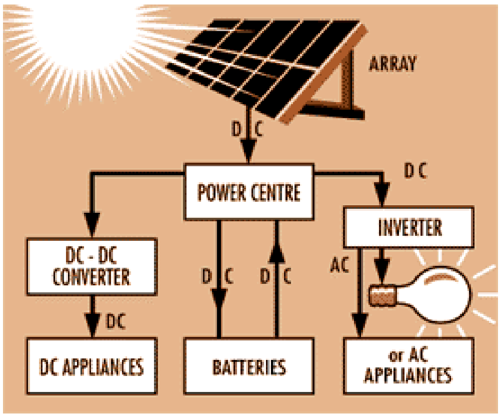

Figure 2 Major photovoltaic system components.

Batteries are often used in PV systems for the purpose of storing energy produced by the pv array during the day, and to supply it to electrical loads as needed (during the night and periods of cloudy weather). Other reasons to use batteries in pv systems are to operate the pv array near its maximum power point, to power electrical loads at stable voltages and to supply surge currents to electrical loads and inverters. In most cases, a battery charge controller is used to protect the battery from overcharge and over discharge.

Using pv generated electricity for architectural lighting raises new challenges. The luminaires should fulfil both the architectural meaning and should be energy efficient. LED is generally the recommended solution for such an installation, but the cost increases significantly up to now. A combination of fluorescent lamps and metal halide lamps was chosen as the best technical-economical fit.

3 DESIGNING THE INSTALLATION

Before starting the PV dimensioning we had to decide together with the architect on the type and array of the architectural lighting. The system should be both functional and aesthetic. The possibility of mounting the PV panels on the façade (Figure 3) or on the main front roof was excluded from the very beginning. Being a very old building and also considered a patrimony monument, we decided to involve in this project a team of specialist from a world famous luminaire producing company. Following several proposals we reached a common point of view regarding the design.

Figure 3 Planning phase

The first step in designing a lighting PV system is to determine the light source and the energy consumption. The key to a successful design is to use the lowest wattage light source that will meet the project requirements. Some of the best installations of this type use light-emitting diode (LED) or compact fluorescent lamps. Also might be considered low-wattage high-intensity discharge lamps, but issues as warm-up time and restrict limit control options should be taken into account. Among the few practical integrated PV luminaires on the market, typical lamp choices are lower than 50 W, most common being with 26 W and 32 W compact fluorescent.

Due to aesthetics and architectural reasons, a combination of discharge lamps (HIT-CE 70W) and compact fluorescent lamps was used (Figure 4). The total installed power was 1800 W.

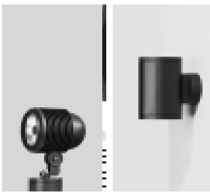

Figure 4 Luminaires used in the project

PV modules produce electricity only when sunlight shines on them. When sizing a stand-alone PV system, the energy output of the PV panels and the storage capacity of the batteries should be high enough to operate devices at night and on cloudy days when little sunlight is available. The geographical zone must also be taken into account (Figure 5).

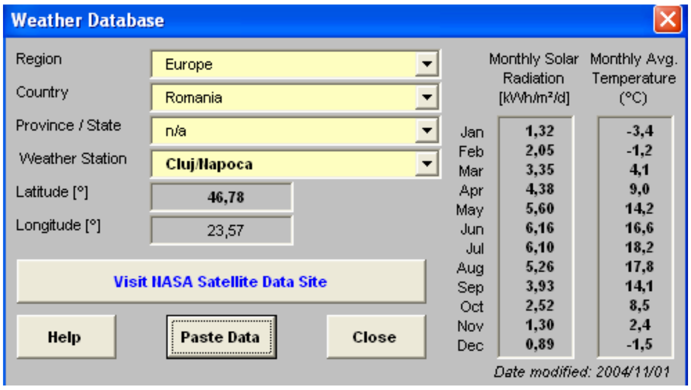

Figure 5 Radiation throughout the year

But this kind of stand-alone system resulted in incredible high prices. Consequently we decided to adopt a by-pass strategy, meaning that when there is not enough power from the sun the standard power supply can be used. Deeper in our research we found out that almost all inverters provide this kind of function. Having our own installed power supply, the second step in designing the system was the dimensioning of the inverter. Theoretically we needed an 1800 W inverter, but that would limit the extension of the system in the future. Because the price difference was insignificant we chose a 2500 W inverter (Figure 6).

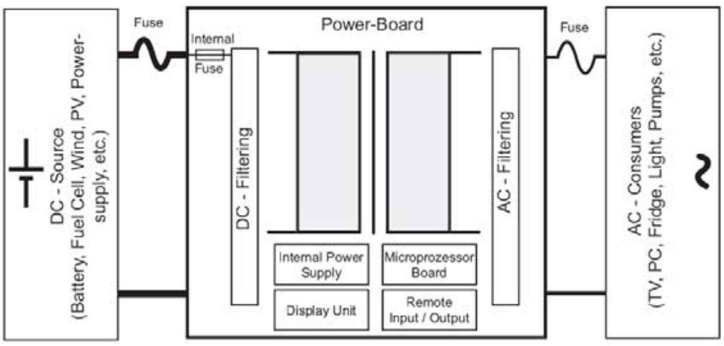

Figure 6 Block diagram of inverter

All that remained now was the dimensioning of the solar panels and batteries. The main challenge was to decide the optimal storage capacity of the batteries corroborated with the correct sizing of the panel surface. The assumption we based on our calculation was that there is an average of 12 hours of daylight/night each day per year. So we had to store enough energy for 12 hours of lighting.

$$P_b = h \cdot P_i \tag{1}$$

where: P_b - total consumed power
h- number of hours with daylight
P_i- installed power of luminaires

So equation number 1 becomes:

$$P_b = 12\ h \cdot 1{,}8\ kW = 21{,}6\ kWh \tag{2}$$

Considering the section of the copper conductors we decided to use a 24 VDC system instead of 12 VDC, connecting the PV panels in series. Therefore:

$$T_{pb} = \frac{P_b}{U_{dc}} \tag{3}$$

where T_{pb} – total power of batteries
U_{dc}- voltage of PV system

$$T_{pb} = \frac{21600\ Wh}{24\ V} = 900\ Ah \tag{4}$$

We chose 4 batteries with a capacity of 250 Ah and a battery charging regulator, in order to prevent the damage of the battery system.

Regarding the solar panels (Figure 7) we decided to start with a number of 8, each having a capacity of 150 W (the number of panels and batteries is extensible up to 2500W).

Figure 7 Solar panel used

4 COMMISSIONING

The main task in mounting the equipment was to find a professional team, able to mount such a system. This was almost impossible at that time, so we decided to involve the producer of the equipments for the support.

We also had to install the panels in such a place that do not affect the architecture of the building. We decided to use the roof of the deposits, where the panels are invisible from any part of the street and do not affect the aesthetics (Figure 8). We had also the advantage of not having other tall buildings in front.

Figure 8 Mounting the panels

We also had to adapt the support of the panels in order to be able to change their angle for increasing the efficiency during the year. Giving the fact that an auto tracking system would increase our costs significantly, we decided to mount an adjustable support with the following exposure angles: 37 Degree for summer and 80 Degree for winter.

6 CONCLUSION

Photovoltaic systems have a number of merits and unique advantages over conventional power-generating technologies. PV systems can be designed for a variety of applications and operational requirements, and can be used for either centralized or distributed power generation. PV systems have no moving parts, are modular, easily expandable and even transportable in some cases. Energy independence and environmental compatibility are two attractive features of PV systems. The fuel (sunlight) is free, and no noise or pollution is created from operating PV systems. In general, PV systems that are well designed and properly installed require minimal maintenance and have long service lifetimes.

Nowadays, the high cost of PV modules and equipment (as compared to conventional energy sources) is the primary limiting factor for the technology. Consequently, the economic value of PV systems is realized over many years. In some cases, the surface area requirements for PV arrays may be a limiting factor. Due to the diffuse nature of sunlight and the existing sunlight to electrical energy conversion efficiencies of photovoltaic devices, surface area requirements for PV array installations are on the order of 8 to 12 m^2 per kilowatt of installed peak array capacity.

Like most PV systems, there almost never is a direct payback from solar lighting. Night electric rates are especially low, and there are no major rebates or subsidies to reduce the pay-back time. Solar lighting is only cost effective where power is miles away and the costs of installing wiring are prohibitive; otherwise, it is at best only a sustainable gesture.

As for professional use, solar lighting runs the risk of being “off” when needed because of battery depletion or need for battery replacement. Perhaps the greatest concern is that practical solar systems employ only low-wattage lamps. To achieve IES recommended light levels, it may take more luminaires with higher wattage lamps, and some lighting requirements may not be able to be achieved.

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PROBLEMS AND PROPOSALS FOR SUSTAINABLE LIGHTING SOLUTION FOR SPECIAL AREAS OF HISTORICAL MONUMENTS, ACCORDING TO EU DIRECTIVES TO REDUCE ENERGY CONSUMPTION

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SC PIEME SRL

ABSTRACT

In historic monument buildings, with special interior spaces: arched, murals, with vintage decorative elements, which are proposed for restoration with a new destination, to follow lighting prescriptions and technical implementation of high energy efficiency solutions raises specific problems. This paper presents few proposed solutions, some of them being realized.

1 INTRODUCTION

An important chapter, in restoration work of historical monuments, is to establish the lighting solution, which in the same time must provide the level of lighting prescribed by normative and also to integrate into the harmony of space, through form and color, sizes and mounting height, optimum achievement of desired effects.

The development rhythm, in particular the development of light source and lighting devices, offers the possibility to realize increasingly high performing lighting systems, more efficient, with lower energy consumption, but those systems have the disadvantage of high cost, the return of investment being made in a reasonable period of time.

The implementation of modern lighting systems in historical monuments is a tolerated compromise. But without this compromise the restored buildings can not answer of contemporary needs.

The imposed limitations of this compromise does not allow, in all cases, to find the optimum lighting systems, under the lighting and efficiency aspects, particularly in spaces with the mural paintings on the wall and ceilings, the vaulted ones, or other types of vantage decorative elements.

This paper presents solutions for special areas, some of them are just at design level (those are supported by lighting simulation and modeling in a program) and some of them are after the implementation of proposal solutions.

2 LIGHTING SOLUTIONS IN SPACES WITH DESTINATION OF CHURCH

The design of rehabilitation of the electric installation in churches, witch are historical monuments, include the following lighting systems in concordance with the destination of areas: liturgical and architectural lighting in the ship and the choir, the general and / or architectural lighting in garret and tower, access lighting, emergency lighting.

The electrical design starts, in all cases, by studying the existing lighting solutions or the solution from ancient period.

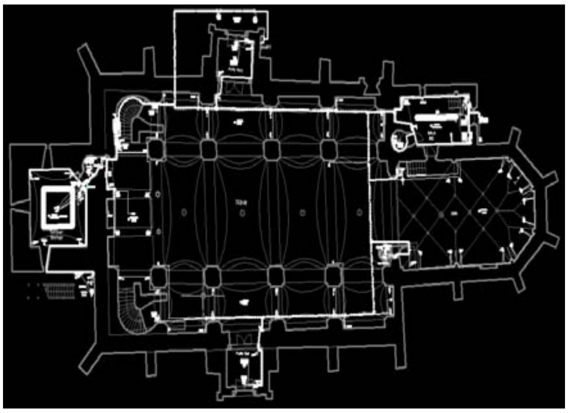
An example of this type of work is Reformed Church of Aiud.

The existing lighting solution isn’t corresponding, because the level of light is very low, the existing lighting devices are producing blindness effect, the choir and the garret are without any lights, and it doesn’t mach from esthetical point of view: simple black reflectors, located in places with maximum visibility. Also, lighting sources with linear halogen are not energy efficient.

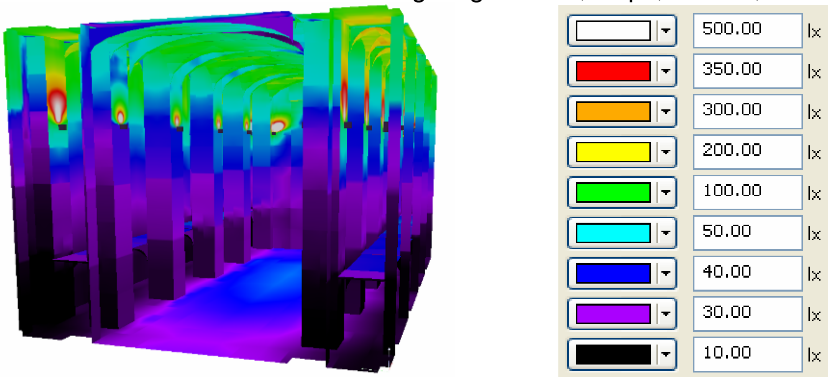
We proposed the follow sollutions:

- for the choir it was suggested a lighting source using reflectors with metal halides of 35 W with color rendition index over 90, placed in the floor, limiting in this matter, the duration of illumination of the walls with murals of sec. XV-XVIII, for their protection.
- for the ships sides and ground floor, indirect lighting, with wall-washer reflectors, and metal halides source, mounted on the columns, above their decorative elements. Lighting devices will be partially

masked, by position and color. Solution will achieve a general lighting and also, an architectural lighting.

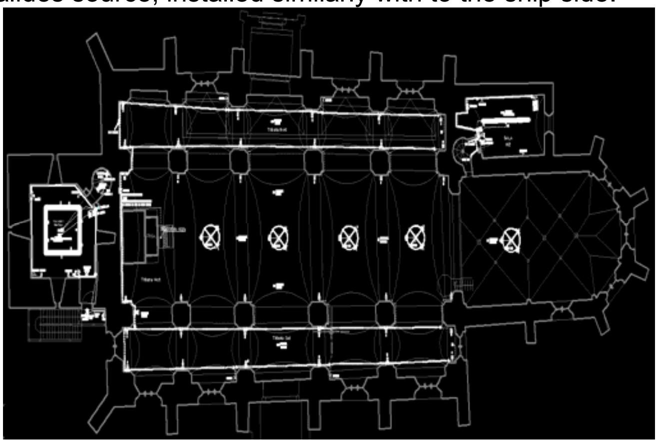


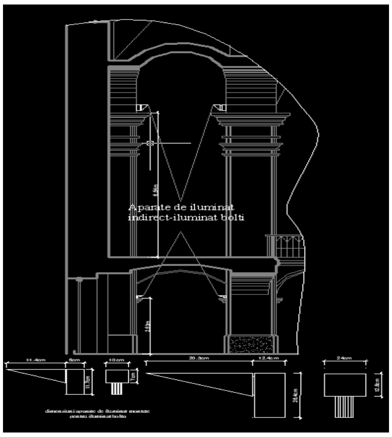
AIUD REFORMED CHURCH
EXISTING SITUATION AND EXTRAS FROM ELECTRICAL DESIGN:
lighting of choir, ships, access, vestry



PARTIAL SIMULATION – VAULT LIGHTING OF AIUD REFORMED CHURCH

- in the ship, in accordance with the design theme, we maintain partial the current lighting system: reflectors with linear halogen source fixed on the heating radiation system recently installed, the rest of the lighting devices are eliminated . General lighting will be completed with reflectors with metal halides source, installed similarly with to the ship side.





AIUD REFORMED CHURCH
EXTRAS FROM ELECTRICAL DESIGN AND INSTALATION DETAILS
SHIPS AND FARST FLOOR GALLERIES LIGHTING LIGHTING DEVICES

-in tower, having destination area of expositions, are proposed reflectors with halogen PAR source, on tracks, controlled by human presence detector to reduce the energy consumption. Lighting inside the tower can also serve as outdoor lighting and it is controlled, in this purpose, by a schedule programmer.

- in the garret, with valuable mural paintings on the walls, it was proposed direct lighting, with reflectors using metal halides source, with timer operation between 1s-1h.

The proposed solutions are following, on one hand, the integration of modern lighting devices in historical monument spaces, positioning them in locations less visible, but accessible for maintenance, ensuring appropriate levels of lighting in accordance with destinations and on the other hand the economy of electrical energy.

3 LIGHTING SOLUTIONS IN SPACES WITH DESTINATION OF LIBRARY

The lighting level prescribed being 500 lx, it is often impossible to achieve by placement the lighting devices on the ceiling.

Examples for such situations:

KÁROLYI CASTLE FROM CAREI AIUD“BETHLEN GABOR” NATIONAL COLLEGE
EXISTING SITUATION

AIUD “BETHLEN GABOR” NATIONAL COLLEGE - EXISTING SITUATION

The proposed lighting solution consists of a general semi-indirect lighting with suspended lighting devices, at 3 m from the floor, along vault line. Lighting sources are T5 fluorescent tubes of 28 W.

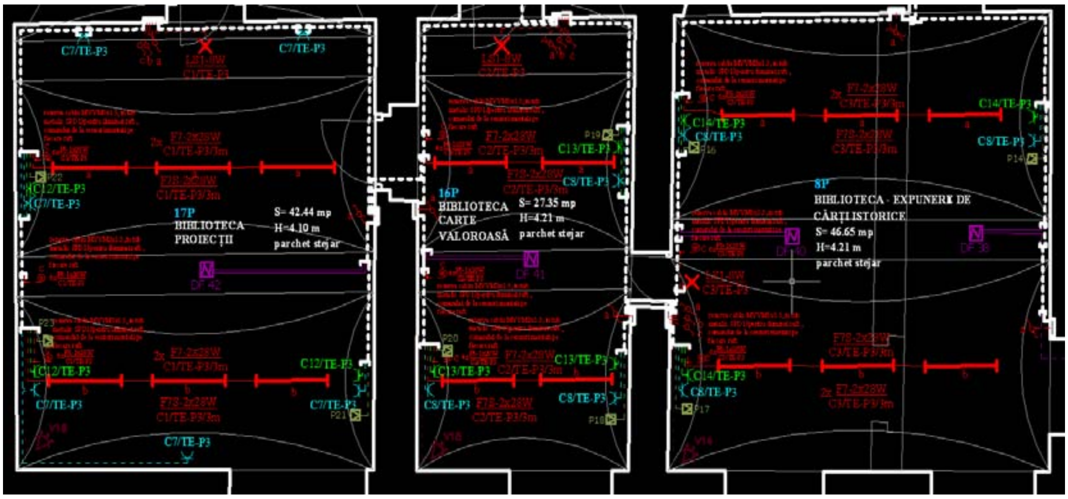
In addition, it was foreseen the lighting of books shelves, with dedicated lighting devices; the light source is also T5 fluorescent tubes of 28 W, which are controlled by sensors, mounted between the shelves.

All lighting devices are proposed with electronic ballast.

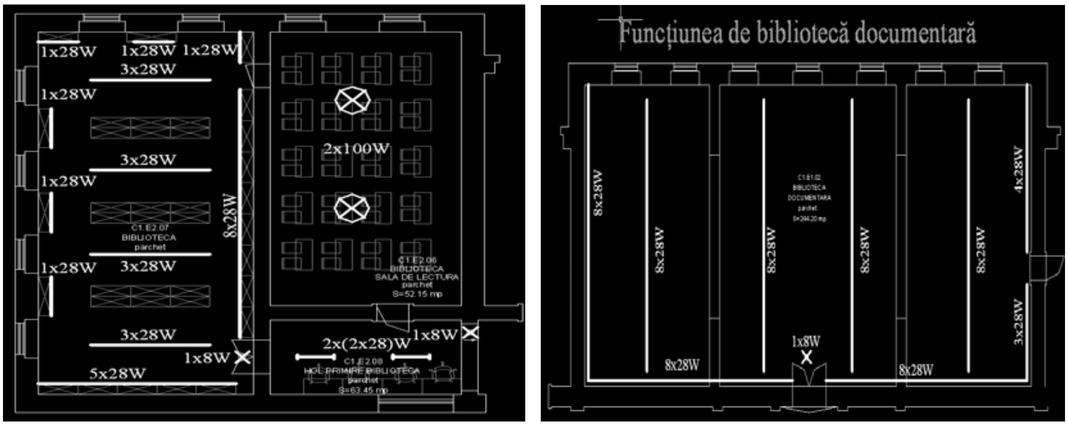
Where the ceiling isn’t allowing, by esthetical reason, the installation of lighting devices with T5 fluorescent tubes, we have proposed the lighting devices as a pendulum with circular compact fluorescent sources.

Foreseeing the control of light by presence detectors between library shelves, beside the efficient consumption, it contributes by reducing the exposure time of valuable books and old wooden furniture from the degradation effect of light.

It can be noticed that the proposed solutions are expensive, but those solutions respect the imposed conditions by photometric aspect, by restoration of historical monuments, and by energy efficiency.



EXTRAS FROM ELECTRICAL DESIGN OF CAREI KÁROLYI CASTLE RESTAURATION



EXTRAS FROM ELECTRICAL DESIGN – DALI PHASE
AIUD NATIONAL COLLEGE "BETHLEN GABOR"

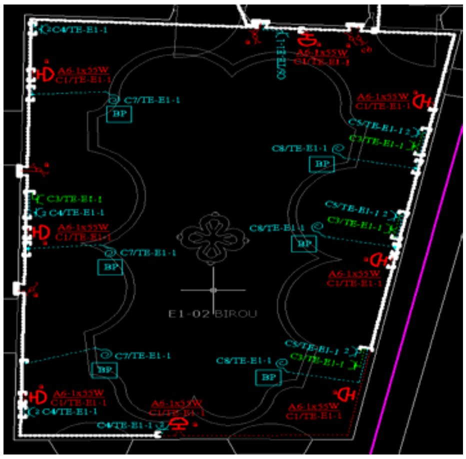
The proposed solution will be returning the investment before the duration of expiry time of the electrical installation.

To reach the design parameters, the worker must respect very strictly the defining characteristics of the lighting devices specified by designer: light source, shape, size, color, mounting heights, color rendition index, type of ballast and housing.

4 LIGHTING SOLUTIONS IN SPACES WITH DESTINATION OF OFFICES

The aim is to ensure a bright environment that respects all prescribed aspects from point of view quantitative and qualitative, but without damaging the historic value of the monument. We present a recent work of this kind:

It was proposed a general lighting with the devices installed on the wall. To complement the level of lighting, we have created the possibility for each office to plug a local lighting device, using multi-plugs blocks.

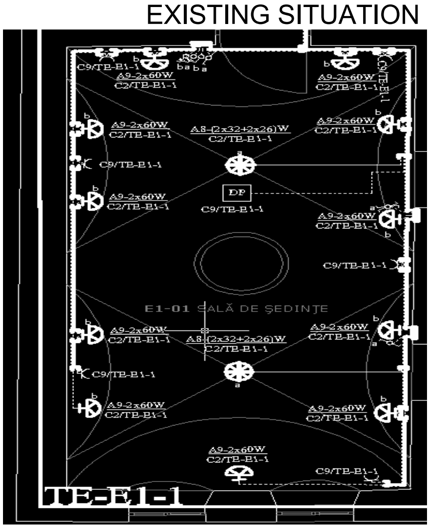


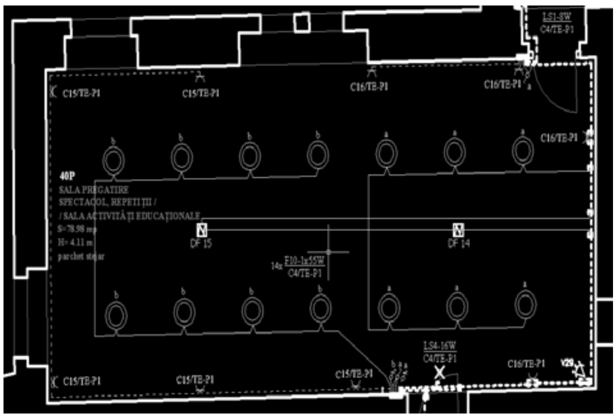
"PIAȚA MICA" BUILDING FROM SIBIU
EXISTING SITUATION AND EXTRAS FROM ELECTRICAL DESIGN

5. LIGHTING SOLUTIONS IN SPACES WITH DESTINATION CONFERENCE ROOMS AND MEETINGS

In those cases the problems are similar like in the case of offices, complemented by the requirement for adjustment of luminous intensity for each sequence of light proposed. Examples of recent works:

EXISTING SITUATION IN "PIAȚA MICĂ" BUILDING FROM SIBIU





EXTRAS FROM ELECTRICAL DESIGN OF RESTAURATIONS
"PIAȚA MICĂ" BUILDING FROM SIBIU AND KÁROLYI CASTLE FROM CAREI

In the first case, the proposed location for the lighting devices is in the two middles of vault for general lighting, and on the side walls to complement it. Lighting devices are proposed with compact fluorescent sources, respectively halogen sources. The system is composed of dimmable elements for controlling the light sequentially.

In the second case, the ceiling is plan, so the lighting devices are proposed with circular fluorescent source, and dimmable in the two sequences proposed.

6 LIGHTING SOLUTIONS IN SPACES WITH DESTINATION AREAS OF CIRCULATIONS

In most historical monuments, the ceilings above the circulations areas are with vaults.

Possible placements for lighting devices are: suspended from the vault, placed on the walls or in the floor.

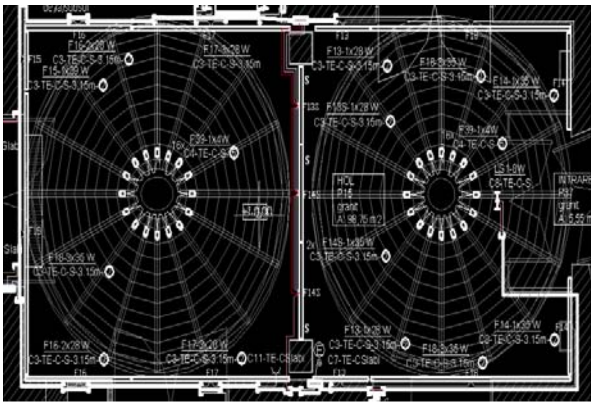
ALBA IULIA MAJLATH GUSZTAV HIGHSCOOL SEMINARY AND CLUJ-NAPOCA BRASSAI HIGHSCOOL
EXECUTED ELECTRICAL WORKS

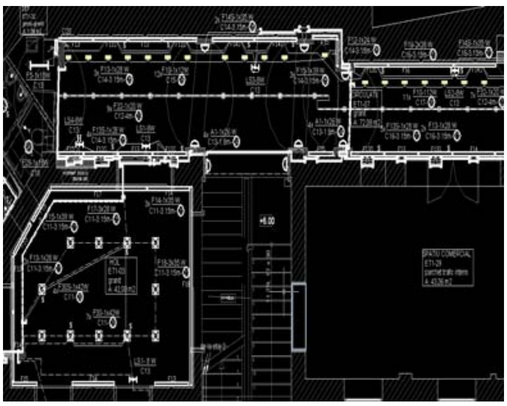
Also in these cases the proposed solutions where compact fluorescent tubes of 26W in order to increase efficiency.

The Continental Hotel from Cluj-Napoca, transformed in NEW YORK galleries, has a restoration project that is handed to the owner; the restoration work will start after finding a new investor. In this building, the control of lighting in common areas such first, second, third and attic floor, will be made with programming and command EASY blocks installed in the electrical connections boxes from common levels.

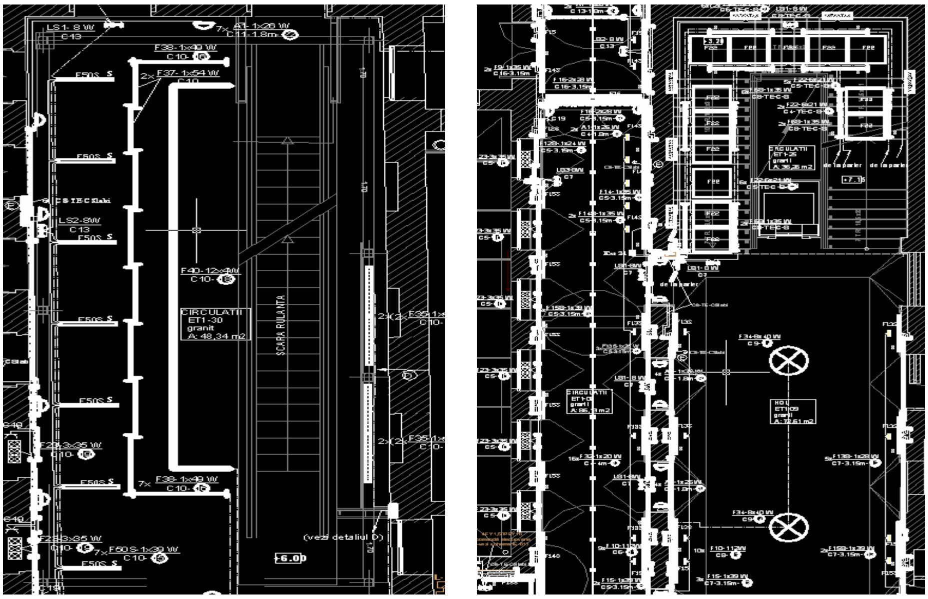
The command outputs have in parallel auto-maintaining buttons, on the electrical connections boxes doors, which allow manual control of the sequences whose function is indicated by lamps installed next to the buttons. The lighting devices are with fluorescent and fluorescent compact sources, LED-s and in the areas of showcases it's used halogen PAR source. In lighting solutions assessments, collaborations where made with dr. eng. Dorin BEU.

We are presenting details from electrical lighting design of circulation spaces, mentioning also that the emergency lights are monitored by zones:



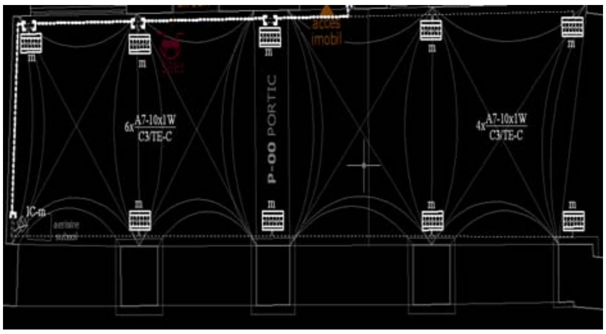


FROM ELECTRICAL DESIGN OF RESTAURATIONS
NEW YORK GALLERIES FROM CLUJ-NAPOCA



FROM ELECTRICAL DESIGN OF RESTAURATIONS
NEW YORK GALLERIES FROM CLUJ-NAPOCA

EXISTING SITUATION - ACCESS,
Asymmetric and chaotic lighting, with
LED reflectors



EXTRAS FROM ELECTRICAL DESIGN - ACCESS,
Symmetric lighting with LED reflectors
proposed by vault born

”PIAȚA MICĂ” BUILDING FROM SIBIU

6 ENERGY EFFICIENCY AND RETURN OF INVESTMENT VERSUS MINIMAL COST

The impediments on implementation of an energy efficient lighting system in historical monuments are the same as in residential, economic and educational environment.

The cost of lighting devices with electronic ballast and with elements that control the light intensity is superior compared to those with electromagnetic ballast, without light intensity control. In the case of insufficient funding cheaper solution is chosen.

Of course, in making decisions there’s another important factor: the education one. The user does not have in all cases the training in the spirit of energy saving, often neither of the visual comfort, he will try to achieve the minimum investment cost.

As a consequence, under the aspect of lighting and energy efficiency we will meet in historical monuments successful investments and bad investments which immediately after completing may be subject to modernization.

We think that efforts, to inform users about the possibilities to save energy, with all its advantages, and about the relation between visual comfort and the efficiency of activity, are beneficial and we are proposing the enhancement of them.

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APPROACH ON MODELLING OF HORIZONTAL DAYLIGHT TRANSFER BY LIGHT-PIPES AND ANIDOLIC CEILINGS

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ABSTRACT

In a world newly concerned about carbon emissions, global warming, and sustainable design, the planned use of natural light in interiors of buildings has become an important strategy to improve energy efficiency by minimizing lighting, heating, and cooling loads. The introduction of innovative, advanced daylighting strategies and systems can considerably reduce a building's electricity consumption and also significantly improve the quality of light in an indoor environment. This paper intends to compare two daylighting techniques based on daylight collection at the façade of buildings and its horizontal guiding to interiors through mirrored ducts: light-pipes and anidolic ceilings, which should increase daylight level in the depth of side-lighted rooms. The comparison is made by the use of Desktop Radiance light modelling software and in situ measurements of daylight transfer through one horizontal SunPipe system installed in our Lighting Laboratory of the Faculty of Civil Engineering.

1 INTRODUCTION

In a world newly concerned about carbon emissions, global warming, and sustainable design, the planned use of natural light in interiors of buildings has become an important strategy to improve energy efficiency by minimizing lighting, heating, and cooling loads. The introduction of innovative, advanced daylighting strategies and systems can considerably reduce a building's electricity consumption and also significantly improve the quality of light in an indoor environment. Advanced daylight systems are window and skylight designs that intentionally modulate and shape the intensity and distribution of daylight in a space to meet the task requirements without glare. In most cases, daylight performs an ambient lighting function.

An advanced design scheme delivers this ambient daylight uniformly across electric lighting control zones that automatically switch or dim in response to the daylight level. At other times the daylight will serve a specific task or accent function and may be designed with a distinct gradient across the space to highlight or emphasize a particular area. In either case, the goal of the advanced daylighting scheme is to create a comfortable, attractive, low glare lighting environment resulting in improved energy efficiency.

Advanced daylighting design combines multiple daylighting and electric lighting strategies to optimize the distribution of light inside the building. It considers whole building energy impacts, minimizing the building's overall energy usage and integrating the design of the daylight apertures with the electric lighting design and controls. Advanced design takes advantage of finely tuned shading strategies and high performance glazing technologies to modulate the intensity and spectral distribution of the daylight admitted to the space, minimizing heat gain during the cooling season and heat loss during the heating season.

Side-lighting schemes have the advantage that they can also provide a view to the exterior, can provide daylight for all floors of multi-storey buildings, and do not have to penetrate the roof membrane. The downside is that it's more difficult to control glare and to provide uniform lighting since the penetration of daylight is limited to a perimeter band whose width is about two times the height of the windows. Side-lighting schemes provide daylight levels that are high near the perimeter and fall off rapidly away from the window. As a rough rule of thumb, usable daylight is available at a room depth of 1,5 to 2,5 times the window head height, depending on the design [5]. This dictates relatively high ceiling heights and narrow building sections to fully daylight a building from side-lighting. One technique that allows an elevated window head height without increasing the floor-to-floor height is to slope the ceiling at the perimeter of the space. In effect, the sloping ceiling steals some of the plenum space and leaves less room for HVAC ducts, luminaires and other equipment. But with coordinated design, a full-height plenum can be maintained in the centre of the building to adequately serve these purposes.

Because of the asymmetrical distribution of daylight from a side-lighting scheme, an advanced daylight design combines daylight from different directions to balance light levels across the space, either through opposite lateral apertures, or from a central zone with daylight supply (atria) [1]. Other solutions may be advanced directing (as light-shelves and anidolic ceilings) and transport systems (using light-pipes).

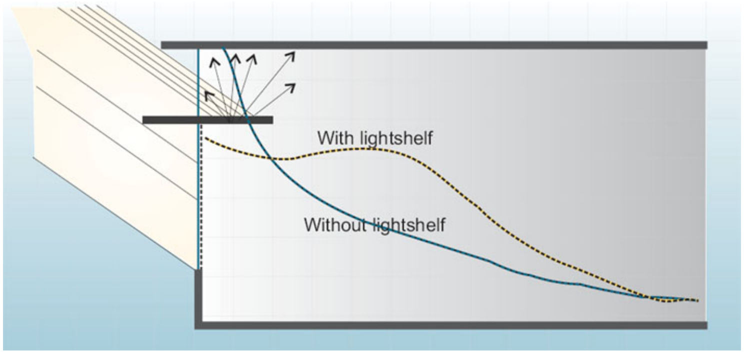

Figure 1 Example of daylight directing element (light-shelf) and its daylight distribution.

In case that the building scheme doesn't allow these solutions and when these solutions alone cannot provide visual comfort conditions, than the permanent supplementary electric lighting must be used. It should maintain the necessary level of illuminance in the absence of daylight, but its main goal is to balance luminance within the visual field. It has been shown that luminance balance is obtained when the level of supplementary lighting is in direct proportion to the available daylight in the room [2, 7], even it may appear to be a paradox. But generally, the greater the amount of available daylight, the higher must be the contribution of the supplementary lighting.

This situation may be avoided, or at least it may represent a limit of ability, if buildings are equipped with advanced daylighting systems or using automatic control systems able to diminish if necessary the contribution of daylight and thus reducing energy consumption, of course without negative influences on occupants' visual comfort.

2 DAYLIGHT GUIDING THROUGH LIGHT-PIPES

The light-pipe is a secondary light source that transmits light from the primary (natural or artificial) source within interior spaces, to a specific target or on specific reflecting or transmitting surfaces [1]. Light-pipes transmit light radiation through total internal reflection.

As solution for a simple and efficient daylight transport towards interior space, solar tubes are specific light-pipe systems for roof applications. A modern system is known as the Super Silver SunPipe, which consists in a 0.5 mm thick high purity silver coated mirror finish aluminium tube, with 98% reflectance. This system maximizes the concept of renewable energy by reflecting and intensifying sunlight and even normal daylight, down through a highly reflective silver base mirror-finish aluminium tube.

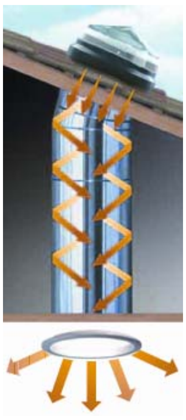

Figure 2 How the SunPipe works.

This system developed by the British manufacturer Monodraught Ltd. is a revolutionary new way to pipe natural daylight from the rooftop into the building to brighten areas from dawn to dusk where daylight from windows cannot reach, even on overcast days [4].

The diamond dome specially designed to maximise the capture of sunlight collects both direct sunlight and diffused daylight. The faceted top surface catches sunlight from any angle and the vertical prisms at the base of the diamond dome capture low level light, i.e. early in the morning and late in the afternoon. Global daylight is piped into the desired room by means of silver-coated aluminium pipes with a mirrored surface internally. At ceiling level, the diffuser has the ability to distribute the light in every direction, giving an even spread of light throughout the interior space (see Figure 2).

Nevertheless, the performance of a light-pipe is remarkable and typically, the 300 mm diameter SunPipe can light up an area of 10 square metres to a normal daylight level that is without the need for electric lighting during normal daylight hours [6]. Larger light-pipes, of 450 mm and 530 mm diameter, are used in larger offices and buildings with higher ceilings.

For the purpose of this paper, one horizontal 300 mm diameter SunPipe has been used in order to collect daylight on the façade at the top level of the window and to pipe daylight at 3 m away from the window wall inside the room. Two 45 degrees elbows have been used for simulating a descent of the SunPipe at a false ceiling, as it can be seen in Figures 3 and 4.

Figure 3 Daylight dome collector of the horizontal SunPipe installed on the façade.

Figure 4 Horizontal SunPipe ending with two 45 degrees elbows above imaginary false ceiling.

3 DAYLIGHT TRANSFER BY ANIDOLIC CEILINGS

Anidolic ceiling systems use the optical properties of compound parabolic concentrators to collect diffuse daylight from the sky; the concentrator is coupled to a specular light duct above the ceiling plane, which transports the light to the back of a room [3].

The primary objective is to provide adequate daylight to rooms under predominantly overcast sky conditions. An anidolic ceiling consists of daylight-collecting optics coupled to a light duct in a suspended ceiling. The system is designed for side-lighting of non residential buildings. Anidolic (non-imaging) optical elements are placed on both ends of the light duct.

On the outside of the building, an anidolic optical concentrator captures and concentrates diffuse light from the upper area of the sky vault, which is typically the brightest area in overcast skies, and efficiently introduces the rays into the duct. At the duct's exit aperture in the back of the room, a parabolic reflector distributes the light downward, avoiding any back reflection. The daylight is transported deeper into the room by multiple specular reflectors lining the light duct, which occupies most of the area above the ceiling. On sunny days, direct penetration of sunlight is controlled by a blind that can be deployed over the entrance glazing. The entire anidolic ceiling system is shown in schematic form in Figure 5.

Reflectors in the anidolic elements consist of anodized aluminium surfaces (reflectance 0.9) attached to shaped frames to produce the desired optical control. An anidolic ceiling system is designed to be located on a vertical facade above a view window. Because the external anidolic device collects diffuse light rays with high optical efficiency, the anidolic ceiling is suitable for lighting rooms with diffuse daylight during overcast conditions.

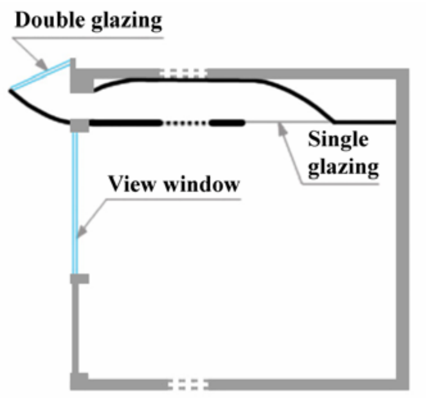

Figure 5 Vertical section of an anidolic ceiling [3].

The system is designed to collect diffuse light from the sky vault, so it can be used in any latitude if solar blinds are installed to protect against glare and overheating from direct sunlight. In its present application, the primary objective of the system is to provide adequate daylight under overcast sky conditions [3]. In order to collect sufficient luminous flux, the anidolic collector must typically span the full width of the room facade, and the light duct must completely occupy the void above the suspended ceiling in the room. No other building systems or structural elements should be placed in this space. If they are, the luminous performance will decrease. In addition, because the use of anidolic ceilings directly affects many other building components, the use of this system requires additional coordination in planning and construction.

4 VALIDATION OF THE MODELLING SOFTWARE

Before comparing the horizontal daylight-guiding techniques, the validation of the modelling software was required. For this purpose, the room was modelled and the simulated daylight factor was compared to the measured values.

Although the outside scenario was not overcast sky conditions, the daylight factor term was extended to express the ratio between the horizontal illuminance measured at a certain internal point and the horizontal external illuminance. Therefore, the term “daylight factor” used within this paragraph has an extended meaning. The modelled room has the dimensions 3 m x 5 m x 3 m and the window is 3 m x 1.7 m large, which can be seen in Figure 6.

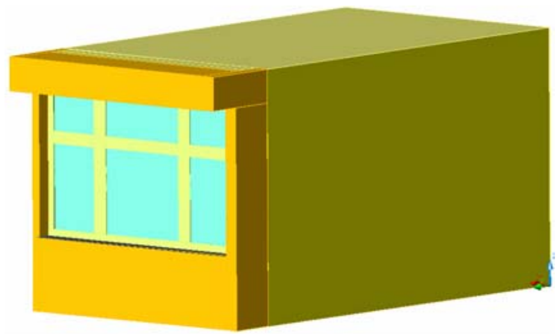

Figure 6 The room modelled by the use of Desktop Radiance 2.0.

The simulation was undertaken for CIE intermediate sky condition in the city of Braşov. The window wall is east oriented and the working plane was located at the usual height of 0.8 m. The results of the simulation can be seen in Figure 7, which shows the variation of the extended daylight factor with the depth of the room.

Figure 8 below shows the measured values of the extended daylight transfer using the same reference grid as the one used in the modelling software.

Figure 9 shows the comparison between the measured values and the simulated values of the extended daylight transfer, showing the acceptable precision of the Desktop Radiance 2.0 light simulation software. For better assessment of the difference between these values, Table 1 below shows in detail the difference of the extended daylight factor values for both cases.

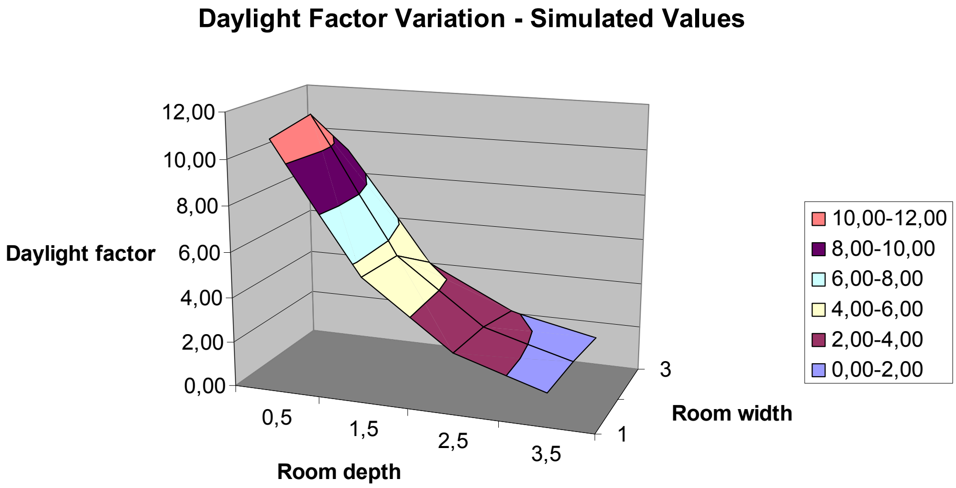

Figure 7 Simulated values of extended daylight transfer through windows.

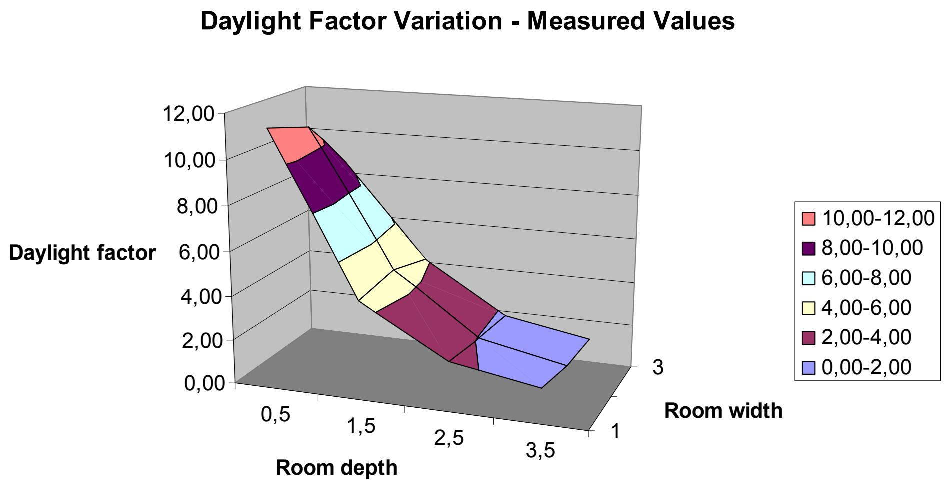

Figure 8 Measured values of extended daylight transfer through windows.

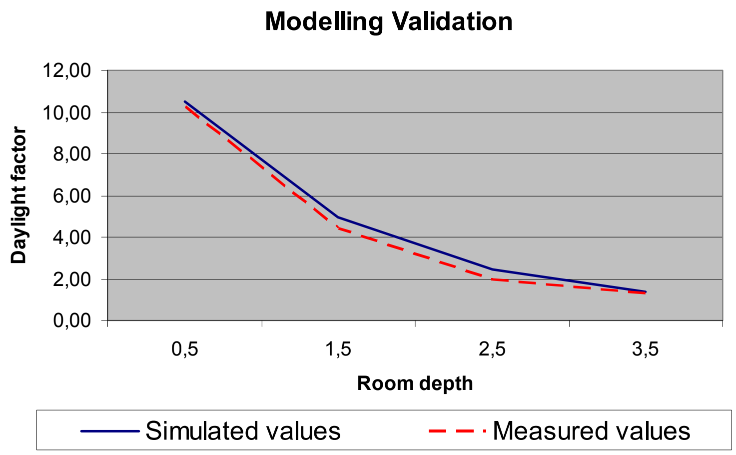

Figure 9 Comparison of the simulated and the measured values for the extended daylight factor.

Table 1 Difference (%) between calculated and measured values of the extended daylight factor.

Coordinates	y1	y2	y3
x1	-4,20	4,37	5,97
x2	19,83	12,72	-2,26
x3	17,45	22,73	15,79
x4	-7,25	18,80	11,14

Given the above mentioned values, it can be stated that the precision of the modelling software is in an acceptable range and therefore this software has been also used for modelling the anidolic ceiling. The same software was used for simulating the room side-lighted by windows and the illuminance values calculated for these both scenarios were compared to the values of the illuminance measured in situ in the room equipped with the horizontal SunPipe at the same points of the reference grid. The three scenarios mentioned above were analyzed for CIE overcast sky conditions.

5 MODELLING OF THE ANIDOLIC CEILING

The same room was modelled by the use of Desktop Radiance 2.0 software and the model room is shown in Figures 10 and 11 below.

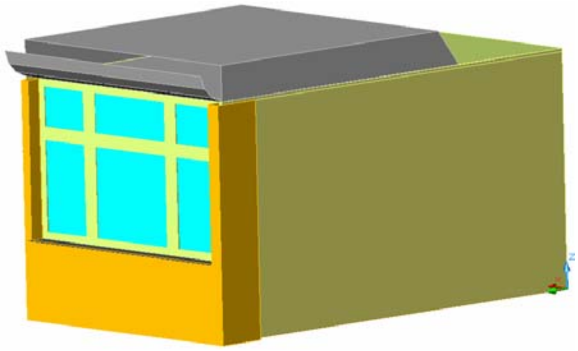

Figure 10. View of the simulated room equipped with anidolic ceiling.

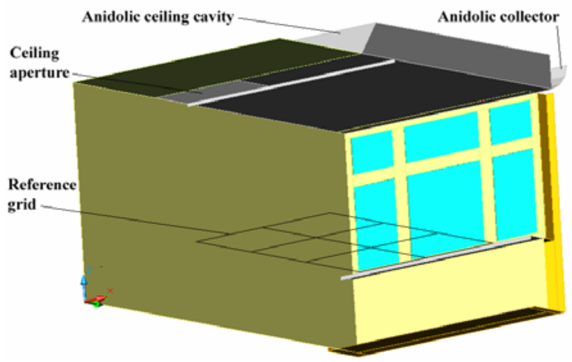

Figure 11. Section of the simulated room equipped with anidolic ceiling.

Table 2 below shows the values of the daylight factor calculated at the points of the reference grid indicated in Figure 11.

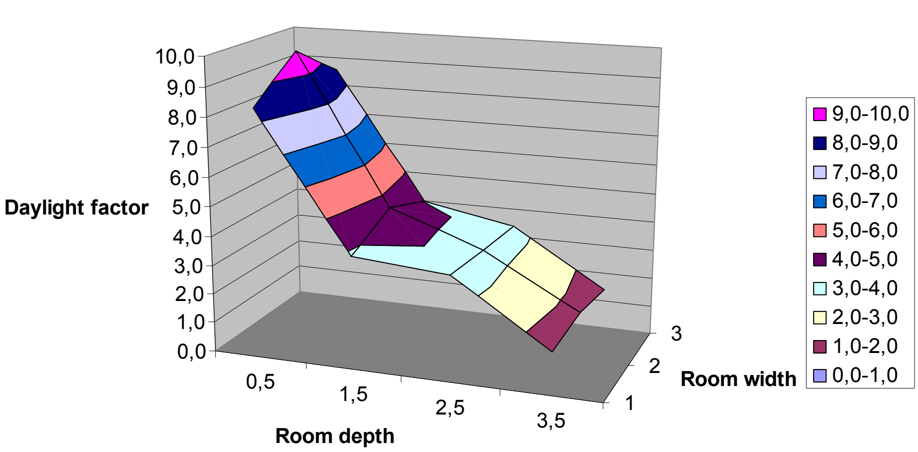

Figure 12 Daylight factor variation in the working plane of the room equipped with anidolic ceiling.

It can be seen that the 60 cm large and 3 m wide aperture in the anidolic ceiling maintains the illuminance at a relatively constant level (see values for coordinates x2 and x3).

Table 2 Daylight factor calculated for the simulated room with anidolic ceiling.

Coordinates	y1	y2	y3
x1	8,4	9,7	8,5
x2	3,8	4,6	4,0
x3	3,6	3,5	3,4
x4	1,5	1,6	1,4

The variation of the daylight factor for the side-lighted room equipped with a supplementary anidolic ceiling can be seen in Figure 12.

6 MODELLING OF THE SIMPLE ROOM

The simple room without anidolic ceiling and without the horizontal light-pipe was modelled under overcast sky conditions in order to compare it with the anidolic ceiling solution.

The values of the daylight factor are written in Table 3 and the variation of the daylight factor can be seen in Figure 13 below.

Table 3 Daylight factor calculated for the simulated simple room.

Coordinates	y1	y2	y3
x1	8,5	9,8	8,6
x2	3,7	4,4	3,8
x3	1,7	1,9	1,8
x4	0,9	1,0	1,0

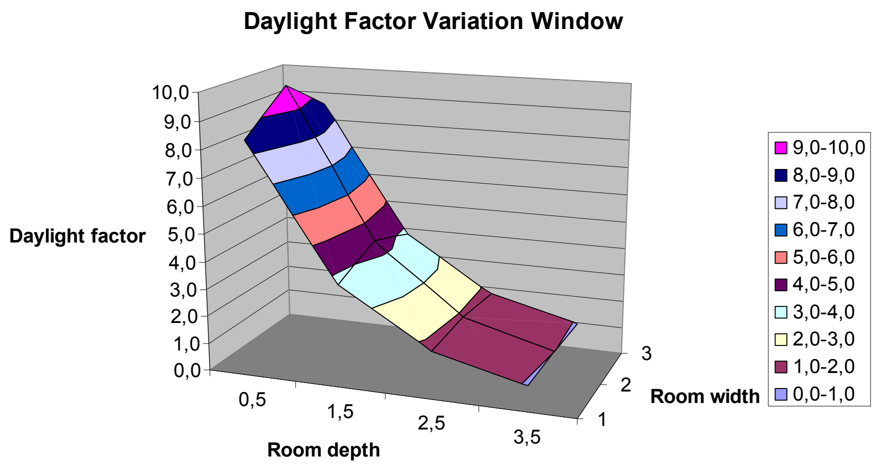

Figure 13 Daylight factor variation in the working plane of the simple room.

7 MEASUREMENT OF THE ROOM EQUIPPED WITH HORIZONTAL SUNPIPE

The real room equipped with the horizontal SunPipe was the subject of illuminance measurement at the points located at the same positions as the points of the reference grid. The measurements were undertaken under overcast sky conditions and the horizontal external illuminance had a value of 5000 lx (on February 9th, 12.30 pm, thick layer of clouds). The values of the daylight factor for this case are mentioned in table 4 and its variation can be seen in Figure 14 below.

The most important fact about the light transfer performance of the SunPipe can be deducted from the fact that given the horizontal external illuminance of 5000 lx, the horizontal illuminance at the level of the SunPipe ceiling diffuser (right below it) was 1400 lx. Despite the façade daylight collection (which is less efficient than roof daylight collection), the length of 3 m and the presence of two 45 degrees elbows, the illuminance measured at the end of the SunPipe was as high as 28% of the external illuminance.

Table 4 Daylight factor measured for the room with horizontal SunPipe.

Coordinates	y1	y2	y3
x1	10,0	10,6	10,4
x2	5,2	5,4	6,0
x3	2,6	3,6	4,0
x4	2,0	1,9	2,0

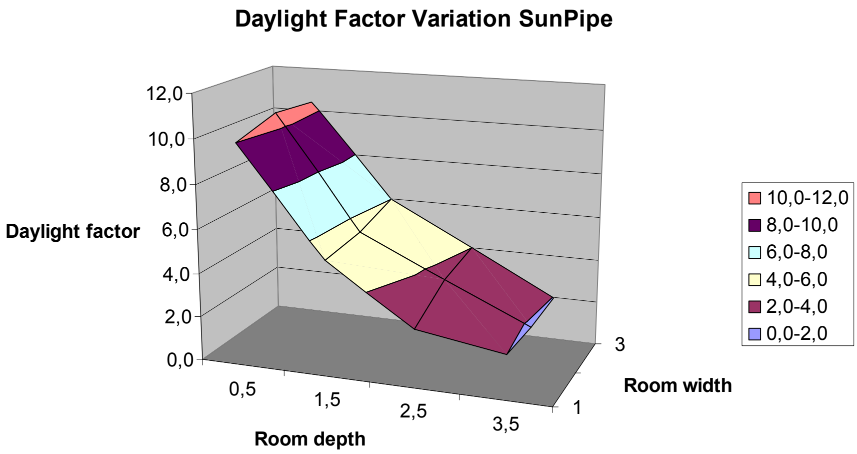

Figure 14 Daylight factor variation in the working plane of the room with horizontal SunPipe.

Other measurements showed that for external horizontal illuminance of 12,200 lx, the vertical illuminance within the axis of the horizontal SunPipe at 3 m from the dome daylight collector was 6000 lx (which is almost half of the horizontal illuminance available at the same time), while the horizontal illuminance within the axis of the vertical segment of the SunPipe after the 90 degrees elbow was as high as 4600 lx. These values show indeed the high performance of the SunPipe in terms of daylight collection and transfer by internal reflection. The end of the SunPipe system with the sections where the illuminance was measured can be seen in Figure 15 below.

Figure 15 Internal end of the horizontal SunPipe.

For the measurements of the illuminance one Chauvin Arnoux LM 76 digital luxmeter with ± 3% accuracy and incidence correction and one Konica Minolta CL-200 digital colorimeter with ± 2% accuracy have been used. By the use of the colorimeter the colour temperature of the external daylight and the daylight reaching the end of the horizontal SunPipe has been measured. Thus it has been noticed that the SunPipe introduces a “warming” effect to the transferred light, given the values of 5900 K for the daylight available at the outside and of 4300 K for the daylight transferred at the internal end of the horizontal SunPipe.

8 GLOBAL ANALYSIS AND CONCLUSIONS

Finally the three scenarios: simple room, room equipped with anidolic ceiling and room equipped with horizontal SunPipe have been analyzed together. Figure 16 below shows the variation of the daylight factor with the depth of the room for these three cases.

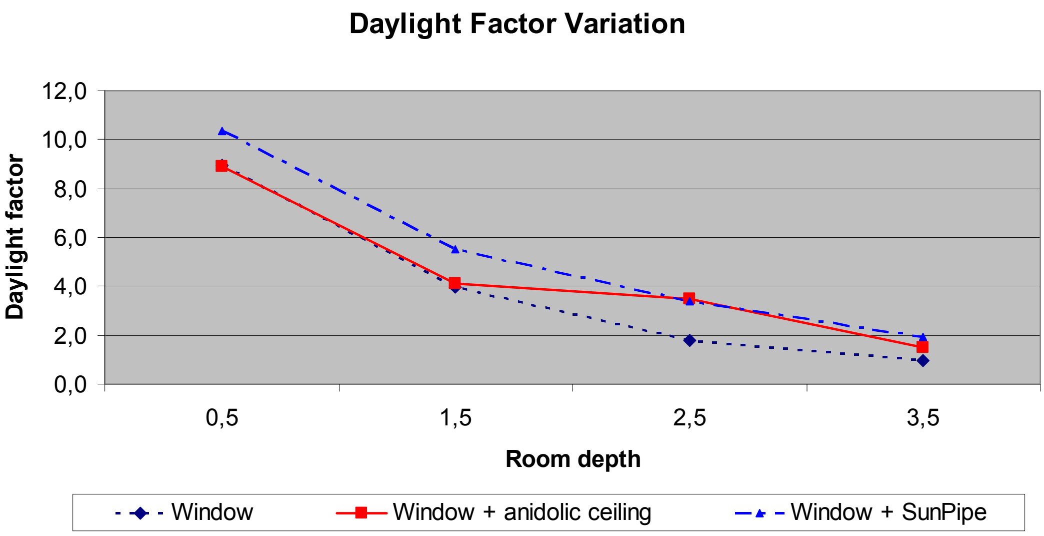

Figure 16 Comparison of the daylight factor values for the three scenarios.

It can be seen from this diagram that for the simulated cases there is an obvious contribution of the anidolic ceiling aperture, which maintains approximately constant the illuminance level between sections 2 and 3 on the reference grid.

The measured daylight factor seemed to be higher the one calculated with the simulation software and therefore the daylight factor for the third scenario, where the windows are supplemented with the horizontal SunPipe, seems to be higher that the one calculated for the simple room. However, it can be seen the slight increase of daylight factor in section 3 of the reference grid, where the SunPipe descends at the imaginary false ceiling.

Although the increase of daylight contribution by the use of the horizontal SunPipe is not so evident, it has to be emphasized that the 300 mm SunPipe is placed only in a single position. The anidolic ceiling is however 600 mm large and 3 m wide, which gives indeed the possibility of extracting more light from the mirrored ceiling cavity. Nevertheless, the performance of the SunPipe can be seen through the reading of Tables 2 and 4, where the daylight factor for coordinates x3 and y3 shows that indeed the higher illuminance below the SunPipe than below the anidolic ceiling aperture.

Under these circumstances, it can be stated that the SunPipe might represent a more efficient and definitely a much easier to be installed daylight-guiding technique, but for specific applications anidolic ceilings might be a good solution if the coordination of specialists during planning and construction succeeds.

Future work will assess the performance of daylight transfer through horizontal SunPipe as parts of a branched light-pipes system, supposed to act like a complex daylight-supplying network of ducts able to transport daylight on longer distances inside various types of buildings.

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