POSSIBLE TECHNICAL SOLUTIONS IDENTIFICATION IN INDOOR LIGHTING SYSTEMS DESIGN

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Abstract - The paper presents the appropriate way to be followed for a systematic assistance of indoor lighting systems design that means the choice of optimal economical solution from the whole acceptable technical solutions, for a given electrical equipment offer. After the complete specifications of solutions in offer (SO) significances and their quantitative determination, it reiterates the theoretical basis of the solutions predetermination phase. Until now, the included conditions in the electrical equipment predetermination phase are the followings:
- luminaires choice according to the room destination and its environment;
- accurate color rendering by including in SO only those luminaires of which lamps respect color rendering index or color temperature;
- illumination uniformity by fulfilling the luminaires plane placement conditions;
- minimum average illumination;
- limitation of glare phenomenon by considering the maximum suspension height.
The developed program is presented, witch the first part is represented by indoor lighting database, followed by the calculation part, with the scope to select those of SO who fulfill a exposed minimum lighting conditions.
It is considered the fact, shown in the general designing chart, that the possible technical solutions, to be further subject of a complete lighting and economical analysis, using professional design programs.

Keywords: luminaires, general designing chart, solutions in offer, possible technical solutions.

1. INTRODUCTION

Computer aided design programs dedicated to indoor lighting installations, in general made by the companies producing the electrical lighting equipment, invite the designers to choose the types of luminaires, with the equipment recommended when more variants are possible. Even the programs (Dialux) commanded by an association of European concerns start from the same point, having only the advantage that present a more developed a database. In this situation, any lighting systems designer, regardless of his professional experience, will be content to find some acceptable technical solutions, from which will choose a solution that satisfies the priority criteria.

Given the complexity of a lighting system, with many involved factors, it is unlikely that an unsystematically approach could led to the economically optimal solution. For this reason, opening an initial as large perspective on the SO and shaping a selecting methodology for the optimal solution, from the economical point of view, represent the essential requirement of the actual indoor lighting design.

Developing the relative databases to the luminaires of their equipment the flexibility to the technological improvements are always current desiderates for a performance work design. On the other side, should take of the fact that the manipulation of the extensive databases and to identifying the SO becomes the extremely laborious.

A consequence, it was considered useful and necessary to carry out a program to facilitate the identification a minimum number of solutions that satisfy some of the lighting conditions, fulfilling the goals of the offer analysis phases for determining the possible technical solutions.

2. METODOLOGICAL BASIS

2.1. The economical optimization phases

The correct approach to an indoor lighting project, by using the available computer programs and compliance with the conditions that the proposed solution satisfying the completely lighting, and economically to represent the optimum desired by the customer, requiring the following phases according to the diagram shown in Figure 1.

The initial phase of the *application defines*, requires a detailed description of there, identify the appropriate values for photometric sizes and restrictions explanation on the placement on vertical or in plane luminaires.

The *offer analysis* is the generic name for the second phase, which selects the types of the luminaires after the recommended destination by the manufacturer and types the lamps after the fitting set of luminaires and color rendering index R_a (or color temperature).

The *electrical equipment predetermination* can be based on the analytical methods which take into account a few lighting characteristics to fulfill by the lighting installation: illumination uniformity by fulfilling the luminaires plane placement conditions; minimum average illumination; limitation of glare phenomenon by considering the maximum suspension height. In the paper uses the utilization factor method, in original form, matrix.

The fourth and the fifth phases are solving with the computer assistance, supposing that it has a program that can cover the calculation requirements for the both aspects.

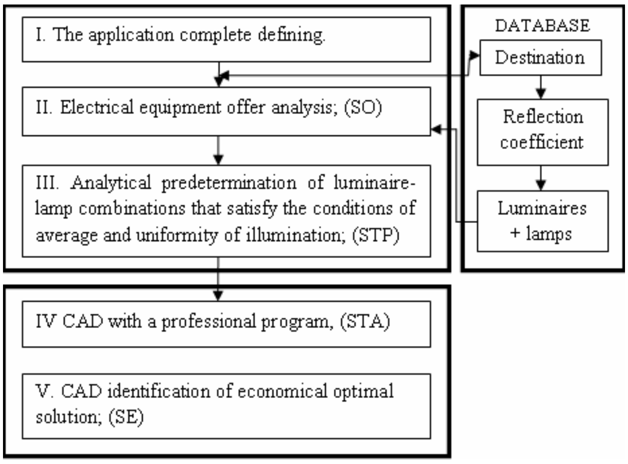

Fig. 1 - The program structure and position of the design methodology for economical efficiency of indoor lighting installations.

The solutions pyramid proposed in [2] accompanying the phases presented in the chart, which including the following solutions levels:

- solutions in offer (SO), representing the part of the offer which corresponding the application and also the solutions base of the pyramid;
- possible technical solutions (STP), selected after following the predetermination phase of the electrical equipment;
- acceptable technical solutions (STA) is the result to pass through the STP solutions verification phase on the computer, of which are selected only those which fulfill the lighting conditions;
- economical solution (SE), in fact the optimum economic of the STA.

2.2. Analytical bases

Concerning the luminaires of SO, we need to consider the accurate color rendering by including in SO only those luminaires of which lamps respect color rendering index or color temperature. Also, for the hanging height, the domain defined by the minimum and the maximum hanging heights will be considered.

The minimum hanging height is determined in terms of the limitation of glare phenomenon, defined form the accepted correlations between the mounting height by the eyes H_o and room dimensions (L_1, L_2), in the horizontal plane, according to the luminance of luminaires.

For the luminaires of luminance L_c < 5000 nt, to determine the minimum hanging height requirements H_{min} in the form:

$$h_{\min 1} = \frac{L_1}{6} + h_{om} - h_u \qquad (1)$$

$$h_{\min 2} = \frac{L_2}{4} + h_{om} - h_u \qquad (2)$$

and the minimum height, h_{min}=max(h_{min1}, h_{min2}), where h_{om}-the average human height, up to eye level, h_u-the height useful plan.

The maximum hanging height resulting from the condition of the minimum length of the pendulum h_{cmin}, representing the distance between the ceiling and the optical center of the luminaire when this would be mounted directly on the ceiling:

$$h_{Max} = H - h_u - h_{c\min} \qquad (3)$$

and H is the height of the room.

If choose the incremental step Δh (eg. 5÷20 cm), which cover the range (h_{Max}-h_{min}), then it can calculate the number of options N_{sh} that multiply the solutions on offer, due to changes the hanging height above the utilization plane:

$$N_{sh} = \frac{h_{Max} - h_{\min}}{\Delta h} + 1 \qquad (4)$$

The luminaires plane placement is solved based on the relative distance between two luminaires d*, [3] of which the recommended maximum values should be concordantly with the illumination uniformity conditions. It considers only relations on the linear sources placement, which are the types selected in the offer. So, for the number N_1 of the luminaires number on a row is used the double inequality:

$$\frac{L_1}{h \cdot d_{1*M}} + (1 - 2k_{p1}) \le N_1 < \frac{\mathrm{L}_1}{\mathrm{L}_\mathrm{c}} - 2k_{p1} \qquad (5)$$

where h represents hanging height, d_{1*M}=0.7 is the maximum value recommended for the relative distance on the luminaires within the same row [3], L_c - the luminaire length equipped with the linear source, $k_{p1} \in (0,25...0,5)$ the coefficient taking into account the luminaires distance from the wall and the utility given of the wall space.

The number of rows, denoted by N_2 is limited inferior, according to the relation:

$$N_2 \ge \frac{L_2}{h \cdot d_{2*M}} + (1 - 2k_{p2}) \qquad (6)$$

where d_{2*M}=0.6 is the maximum value recommended for the relative distance between two side by side rows, k_{p2}-the coefficient similar to k_{p1}, but corresponding the distances from the wall as L_2 dimension.

From an economical perspective, is better to start the calculations with the minimum number of luminaires:

$$N_{c\min} = N_{1\min} \cdot N_{2\min} \qquad (7)$$

following that the number of luminaires incrementing be done of nearby, until the exhaustion of all possible technical solutions, limited to the minimum flux lamps

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for each type of luminaire.

If considered N_{nc} the number of all variants of numbers of luminaires, ranging from the minimum number calculated with (7) and the maximum number defined above, then the number of initial variants is:

$$N_{VI} = N_{Oc} \cdot N_{sh} \cdot N_{nc} \quad (8)$$

where N_{Oc} is the number of luminaires types identified in the offer.

Detailed the design phases and highlighting how to shape the corresponding solution is done in the following.

2.3. Predetermination of electrical equipment

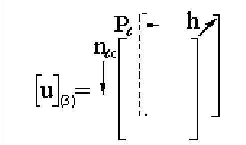
The electrical equipment predetermination phase, solved by the utilization factor method is laborious, imposing its realization by a computer program.

The photometric value on which to sort the solutions on offer to get the STP, is represented by the luminaires lamps flux.

After determining the range of values for the hanging height, first the room index is calculated for each of the values set of the hanging height:

$$i = \frac{L_1 L_2}{h(L_1 + L_2)} \quad (9)$$

Knowing the way of luminous flux distribution for each luminaire type selected, the reflection factors of ceiling and walls and the room index, can be determined the utilization factor u, corrected by the real value of luminaires efficiency. Because the luminaire efficiency depends on the power P_l and the number of lamps from a luminaire n_{lc}, the utilization factors corresponding to a luminaire type can be organized in a three-dimensional matrix form:



(10)

the third variable is represented by the hanging height h.

Becomes STP those lighting systems, characterization by the combination of luminaire-lamps, hanging height and number of luminaires, that fulfill the double inequality written in condensed form, matrix:

$$\frac{E_{med} \cdot A}{k_{Mt} \cdot N_c}\left[u^{-1}\right]_{(2)} \leq \left[\Phi_{lc}\right]_{(2)} < \frac{E_{medM} \cdot A}{k_{Mt} \cdot N_c}\left[u^{-1}\right]_{(2)} \quad (11)$$

where $A=L_1L_2$ is the room area, E_{medM} - the upper limit of average illumination, set according to the following value E_{med} of the illuminations scale, k_{Mt} –the total maintenance factor, by the lighting installation, $N_c=N_1 \cdot N_2$ – the number of luminaires and Φ_{lc} – the luminaire lamps flux.

Writing the matrix relation is conventional and index (2) shows that two-dimensional matrix is treated having organized rows and columns, as variables n_{lc} and P_l.

3. THE PREDETERMINATION PROGRAM FOR STP

3.1. Databases

The evolution of methods and techniques of data organization was determined by the necessity to have as quickly and easily the access to a volume of increasingly more information. A programming environment that allows the creation, the database management and construction the applications is Visual FoxPro with other programming languages such as: MySQL, ORACLE, SQL SERVER etc.

In Visual FoxPro a database is assigned a special file (.DBC) where is stored data relating as a whole database, such as: the components tables, the permanent relations between tables, etc.

It creates a database that contains more tables:

- the destination room (libraries, offices, schools, textile industry, machine building industry, metallurgy and steel, food, electricity plants, printing, etc..) of the types rooms that will be illuminated. These rooms are characterized by the overall evaluation glare index (UGR), maintained illumination (E_m), color rendering index (R_a), color temperature (T_c), height useful plan (h_u);
- luminaires, characterized by the type of luminaire, luminaire dimensions, lamp type, lamp power, the number of lamps from a luminaire, the flux lamps of luminaire, the lamp color temperature, color rendering index, the lifetime of the lamps, the luminaire hanging height, the safety degree, socket type, applications of the luminaire;
- reflection coefficients for different categories of materials: painting, building materials, metal surfaces, textiles and paper;
- the utilization factors for luminaires with fluorescent lamps, characterized by the ceiling reflection index, the wall reflection index, the room index which is calculated according to room dimensions;
- offer solutions, possible technical solutions that contain information about the solutions obtained from the offer solutions browsing, and selecting those that correspond our application, the characteristics listed in the luminaires plus the number of luminaires, the number of luminaires in a row, the number of rows, the room index, total flux of the luminaire and height which is mounted the luminaire above useful plan.

The offer of luminaires and lamps can generally be extended much as want the designers and the beneficiaries.

3.2. Description of application

The program is realized in Visual FoxPro 9 this is an environment for working with databases. The application is structured on database "database.dbc" which includes several tables: luminaires.dbc, schools.dbc, offices.dbc, offer_solution.dbc, possible_technical_solution.dbc, utilization_coefficients.dbc, textile_industry.dbc, etc.

The communication between user and the application is made easier with a graphical interface. This interface is made in Visual FoxPro with the forms, form1.scx, Fig.2.

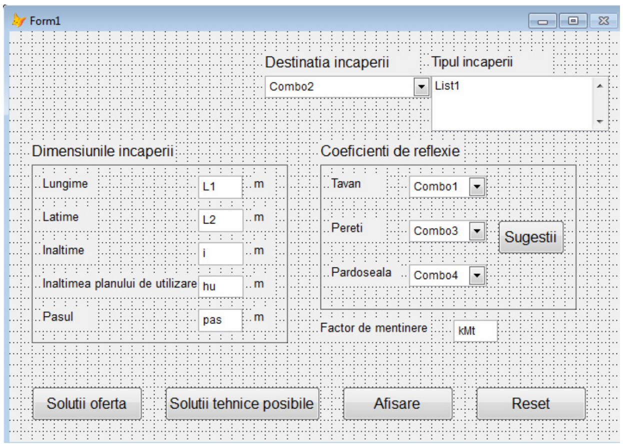


Fig. 2 - Program main form.

From the field *room destination* is choose a general category of the destination which materialize in the aside list, *room type*, then is defined the room where is inserted from the keyboard length, width, height and height of the work plan, the incremental step of hanging height. The reflection coefficients fields for ceiling, wall and floor reflection is selected the refection index of light according to the color of the ceiling, walls and floor. To select the correct coefficient is pressed suggestions, which contains four buttons: painting, building materials, metal surfaces, textiles and paper, which include different materials and appropriate reflection index.

It denotes and maintenance factor value, then press the *solutions offer* (*Soluții ofertă*) stage is selected only luminaires which corresponding the application. For the luminaires selected will be calculated: the minimum hanging height; the maximum hanging height; the minimum respectively maximum luminaires recommended on a row; number of rows and the room index.

Clicking the button *possible technical solutions* (*Soluții tehnice posibile*) will select of the solutions on offer, these luminaires which correspond and terms of luminous flux. The *Reset* button is to start a new application.

The information obtained can be processed by applying them in another program the lighting, the program will continue to run and will display a graphical solution of the luminous flux distribution and location of luminaires in the room.

4. CONCLUSION

A first contribution of this paper is to define more clearly and complete the notion of Solutions in Offer (SO). For the designer who understands and appreciates the proposed methodology, as a sure way to identify the optimal economical solution, it is clear that electrical equipment options are multiplied by the number of hanging heights and number of combinations of the luminaires numbers. The opening of "perspective" initial is essential in order to reach the best solution a view agreed by the designer and should not be necessarily always the criterion of total costs, updated.

For the first design “filter”, it proposes an electrical equipment predetermination, a step which includes: the luminaires choice according to the room destination and its environment; the accurate color rendering by including in SO only those luminaires of which lamps respect color rendering index or color temperature; the minimum average illumination; the illumination uniformity by fulfilling the luminaires plane placement conditions and the limitation of glare phenomenon by considering the maximum hanging height.

The predetermination phase of electrical equipment, solved in the paper in an original form, matrix, of the utilization factor method is quite laborious, which could discourage some designers. Therefore it is considered necessary Computer aided design, conceiving a calculation program, which was included the relative database to luminaires, applications, reflection coefficients, etc.

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