Simplified Method of Visualization of Light Distribution at the Initial Stage of Design of Symmetrical LED Luminaires

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Abstract

The article offers a simplified method of visualization of light distribution of LED luminaires, with due consideration of specifics of LED as illuminant: namely, its dime size that allows to consider it a point source, and broad installation opportunities – combination with different shapes and surfaces. The efficacy of the proposed method is confirmed by calculation and visualization of light distribution of symmetrical LED luminaires. Among them there are three rotationally symmetrical luminaires that demonstrate which way the shape of shade influences luminous distribution. Main results of the research have been obtained owing to the elaboration and use demonstration of a simplified methodology of calculation and visualization of light distribution of symmetrical LED luminaires grounding on the combination of graphical-analytical method and computing methods with the use of free software, namely IESGen, LDT Editor, IESviewer.

Keywords: symmetrical LED luminaires, visualization of light distribution, initial stage of design.

Problem formulation. The most widely spread record format of photometric quantities related to light distribution of luminaires is IES format which has become standard in some countries [1]. It is accepted by almost all the software featuring 3D-modelling, and its main convenience is that it has the form of a text that is up to editing and correcting. However, this format secures allocation of all the necessary photometric quantities of a luminaire, without providing any graphic image of the present light distribution. Thus, further construction of diagrams and visualization of light distribution of a luminaire requires the use of additional software products.

Analysis of recent research and publications. The vast majority of special computer programs elaborated for designing optical and luminous systems are commercial. Some global producers of LED products create special free software [2], that assist designers in choosing the most relevant LEDs for the designed illumination device by means of matching by several set-up parameters, i.e. directed luminous flux and specific value of efficiency rate of secondary optics and power source. Such applications are an important informative supplement for general design of a luminaire but are not related to prediction and visualization of its luminous intensity distribution. Thus, aiming at passing all the stages of

visualization of luminous intensity distribution by means of free software and at creating a file, which is applicable for further calculations of illuminance of certain objects, a combination of several program applications has been employed in the process of elaboration, namely IESGen [3], LDT Editor [4], IESviewer [5].

The purpose of the article. So, the aim of the present paper is the creation and demonstration of the use of simplified method of visualization of light Distribution in symmetrical LED luminaires, employing computer methods based on the combination of software tools from several free applications.

Results. The procedure of calculation and isocandela curves construction included the following steps. Initially, calculations were performed according to the data of LED illumination and basing on structural layout of luminaires. Afterwards, an IES file was created by means of IESGen software, and later, in the program LDT Editor by DIAL GmbH all calculations on every luminaire were input and corresponding diagram of luminous intensity distribution were obtained. While saving the corrected file, LDT Editor converts it into its own format with .ldt extension. However, this does not make a problem since this format was created for editing luminaire files using free programs for calculation of lighting designed by DIAL GmbH, and it easily integrates into them, allowing both to perform preliminary rough calculations of lighting by means of DIALux Light program, and to create spatial visualizations of luminous intensity distribution of a luminaire as well as to simulate conditional borders of its photometric body in full version of DIALux program. Besides, .ldt format is friendly for IESviewer program which enabled to create graphic visualizations of preliminary constructed diagram of luminous intensity distribution not schematically – in the form of diagrams, but realistically – as a photo of luminous intensity distribution of a luminaire.

Taking into account that a LED can be considered a point source of light with definite luminous intensity distribution [6, p. 47-77], it is worth mentioning that the majority of modern frameless powerful LEDs (without primary and secondary optics) have type D diagram, i.e. cosine one (according to the classification which is wide-spread in Ukraine), or BZ₅ (according to British zonal classification), or circular (according to the typology, singled out on the basis of these catalogues) [7]. Considering that luminous intensity distribution with such a curve is believed to be appropriate for general lighting of accommodations and public

spaces, the design of this method was elaborated with the use of LED luminaires made of frameless LEDs.

The elaborated method is based on the hypothesis of unified value of luminous intensity of a separate LED $I = 1$ cd in calculations for illumination devices containing LEDs with the same luminous intensity distribution, and of unified value of a separate LED $\Phi = 1$ lm in calculations for complicated illumination devices which contain LEDs with different luminous intensity distribution.

We assume that a LED is a point source. Assuming for the sake of calculation convenience that luminous intensity value of LED $I = 1$ cd, distance from the source to reference surface $r = 1$ m with the spacing between reference points equal to 1° (symmetry of luminous distribution allows to limit values for angle of arrival of a beam from 0° to 90°), we can define illuminance E (lx) using the formula [8, p. 141-144]:

$$E = \frac{I \cos \theta}{r^2}, \quad (1)$$

in which E – illuminance in reference point; θ – angle of arrival of a beam (an angle between a falling beam and a perpendicular line put against the surface in the point of the beam arrival); r – the distance between the source to the surface (the reference point on the surface).

In order to demonstrate the influence of the shape of a shade on luminous intensity distribution, we calculated diagram of luminous intensity distribution for three rotationally symmetrical luminaires with radial symmetry of LED allocation on the mounting surface. Calculations were performed according to formula (1), with the pitch between calculated points of 1° ; balance of luminous intensity distribution allowed to limit the range of values for angle of beam arrival 0° to 90° . The results of the research that represent constructive schemes of luminaires and visualizations of luminous intensity distribution is given in Table 3.

During calculation the following aspects were taken into account:

- Similar frameless LEDs with the same luminous intensity distribution were used as sources, so $I = 1$ cd is admitted as calculated value of luminous intensity for each separate LED.

- In other equal similar conditions illuminance will be proportional to luminous intensity of the source, and two similar sources, allocated nearby, will send in the given direction twice more luminous energy than one source, and such sources can be replaced by one, with bigger luminous intensity. That is why maximum calculated luminous intensity of a luminaire I_{pl} will equate in the calculated plane to the product of luminous intensity of one LED I and the total number of LEDs n in a luminaire. Afterwards it is necessary to determine, which part of the maximum luminous intensity is provided by each LED for calculated plane, depending on the quantity of LEDs that are intersected by a definite calculated plane.

- For performing calculations in case of considerable distances from calculated point of illuminated surface to luminaire, comparing to the size of the luminaire itself, the distance from each separate LED can be considered equal to the average for all the LEDs distance from the provisional central point of the luminaire to calculated point. In this case illuminance of any point on calculated surface will be proportional to that quantity of LEDs that is not cut off by luminaire walls.

- As a provisional central point of a luminaire, we chose the point which lies at the intersection of vertical symmetry axis, which passes through geometrical center of the luminaire, and horizontal axis, which passes through geometrical center of the upwardmost LED (LEDs).

Table 3. Constructive schemes and visualization of luminous intensity distribution of rotationally symmetrical LED luminaires with shades of different shape

№	Constructive schemes of luminaires (scale division 5°)	Visualization of luminous intensity distribution
1
2
3

Then we will analyze the process of construction visualization of light distribution given in Table 3.

Luminaire № 1 in Table 3, as it is obvious from constructive scheme, contains only 15 LEDs that intersect with calculated plane, they are not cut off to calculated angle 60°, from

61° to 65° 6 LEDs are not cut off, from 66° to 70° – 2 LEDs are not cut off, and light does not come to calculated angles starting with 71°.

Luminaire № 2 in Table 3, as it is obvious from its constructive scheme, has only 12 LEDs that are intersected by calculated plane, they are not cut off to calculated angle 35°, from 36° to 40° 4 LEDs are not cut off, from 41° to 45° – 3 LEDs are not cut off, from 46° to 50° – 2 LEDs are not cut off, from 51° to 55° – 1 LED is not cut off and light does not come to calculated angles starting with 56°.

Luminaire № 3 in Table 3, as it is obvious from its constructive scheme, has only 5 LEDs that are intersected by calculated plane, they are not cut off to calculated angle 15°, from 16° to 20° 3 LEDs are not cut off, from 21° to 25° – 2 LEDs are not cut off, and light does not come to calculated angles starting with 26°.

Conclusions. Suggested method of visualization of light distribution of symmetrical LED luminaires does not take into account either light diffusing by the inner surface of luminaire shade (or LED mounting surface), or absorptance and reflectivity of the material which this surface is made of, etc., but this method provides information on the influence of the shape of a designed luminaire shade on luminous intensity distribution, and the visualization of light distribution can become the basis for their further refinement and perfection at later stages of design.

In further studies in this research direction it is reasonable to focus attention on peculiarities of calculation and construction of luminous intensity distribution of LED luminaires in cases when distance from calculated point to a luminaire is insignificant comparing to its size.

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