Lighting Control System for Premises with Display Screen Equipment

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Abstract. The use of Display Screen Equipment (DSE) at enterprises allows one to increase the productivity and safety of production, minimize the number of personnel and leads to the simplification of the work of specialists, but on the other side, changes usual working conditions. If the personnel works with displays, visual fatigue develops more quickly which contributes to the emergence of nervous tension, stress and possible erroneous actions. Low interest of the lighting control system developers towards the rooms with displays is dictated by special requirements for coverage by sanitary and hygienic standards (limiting excess workplace illumination). We decided to create a combined lighting system which works considering daylight illumination and artificial light sources. The brightness adjustment of the LED lamps is carried out according to the DALI protocol, adjustment of the natural illumination by means of smart glasses. The technical requirements for a lighting control system, the structural-functional scheme and the algorithm for controlling the operation of the system have been developed. The elements of control units, sensors and actuators have been selected.

1. Introduction
Development and improvement of lighting control systems (topology, communication lines, ways of transferring information, etc.), and element base (lighting sources, control devices, sensors, etc.) are conducted by many russian and foreign scientists, engineers, designers [1-7], however, quite often these results are not applicable to lighting control systems for premises with DSE. In this paper, the automation of the lighting system of a workplace equipped with DSE is being considered. The choice of this area of research in a large variety of automated lighting control systems, is due to the least study and a small number of projects implemented. The low interest in the premises with DSE from the developers is also dictated by special requirements from the sanitary and hygienic norms for lighting in such places. The lighting systems are outdated, this is recognized at the state level and is confirmed by the state program of the Russian Federation "Energy Saving and Increasing Efficiency for the Period to 2020", which provides for energy saving measures in various sectors of the country's economy.

The creation of lighting systems should be based on two main points: energy efficiency and safety for the organs of vision. A promising approach that allows to significantly increase the efficiency of lighting is the function of a smooth control of the power of light sources, which allows changing the luminous flux depending on the level of natural illumination. LED lighting fixtures with adjustable
brightness are widely used, this is justified, since the creation of redundant levels of illumination is not beneficial both from an economic standpoint and from the point of view of hygienic effects.

The availability of PCs and automated process control systems at the enterprise allows to increase production productivity and safety, as well as to minimize the number of operating and operational personnel. Thus, the introduction of modern technologies in the operation of enterprises leads, on the one hand, to simplification of the work of specialists, on the other hand, to a change in the usual working conditions.

Long-term work of personnel associated with the constant monitoring of the current state of technological processes on displays requires increased concentration, which leads to increased stress on the human eye. As a result, the staff develops visual fatigue, which contributes to the emergence of nervous tension, stress, possible erroneous actions. The causes of visual fatigue are, on the one hand, unsatisfactory parameters of the light environment, and on the other, the absence of clear requirements for the parameters of display terminals.

The questions of normalizing the light environment for operators conducting a significant part of the working time after recognizing graphic schemes and numerical values on the screens have not been fully studied at the moment and therefore require in-depth studies together with the creators of displays and lighting system designers.

2. Standards for premises with Display Screen Equipment

The system of hygienic assessment of the parameters of the light environment of rooms with displays, which has developed since the introduction of a special assessment of working conditions, does not control the safety of lighting installations; in addition, samples of energy-efficient light sources on the market often do not provide confirmation of the declared characteristics (including Quality of lighting).

Requirements for the parameters of the light environment of workplaces equipped with display terminals are specific [8-11], they can be called more stringent. In the normalization of most types of visual work, only the minimum value of illumination is limited, while large levels of illumination are considered acceptable. But when working with displays, the excess of illumination leads to a decrease in the contrast of the screen image, making it difficult to recognize it, therefore, it is necessary to limit not only the minimum, but also the maximum permissible value of illumination. The most stringent requirements are for the quality of lighting of such jobs, namely the pulsation of the light flux. If for the main types of visual work is permissible is a 20-percent flicker, while using displays, only 5%.

Despite this, the current regulatory documents [12-14] do not contain requirements for the output voltage pulses when the LEDs. These special requirements (inadmissibility of excessive lighting and flicker limitation) must be taken into account when designing lighting workplaces with DSE.

Previously clarified [15], that inertial properties of view can be considered presenting inertia block in a linear model of single outbreaks:

\[
S(t) = \frac{1}{v} \int_{-\infty}^{t} L(\tau) \cdot A(t - \tau) d\tau
\]

(1)

where \( S(t) \) – lightness; \( L(\tau) \) – brightness; \( A(t) \) – damping function; \( v \) – constant factor.

or:

\[
S(t) = \frac{k}{v} \int_{-\infty}^{t} L(\tau) \cdot e^{\frac{\tau-t}{v}} d\tau
\]

(2)

The mathematical transformations shown in [15] found that as the pulsation frequency increases, the lightness decreases monotonically to zero, but at what values of the flicker frequency becomes indistinguishable and harmless to the organs of vision, it is impossible to say. Different researchers [16-17] call as a harmless threshold the values of the frequency of 25, 70, 300 and 5400 Hz. Probably,
such a difference in estimates is due to the lack of a unified approach to evaluating the shape and the duty cycle of the signal. An analytical study of the inertial properties of vision shows that a significant factor in the formation of visual sensations in the pulsation of light is the frequency of pulsation. At present, work is underway to create an adaptive dialogue system for artificial lighting based on LED light sources, taking into account the above features.

3. Lighting control interface

The most common light sources are fluorescent and LED high energy efficiency lighting [18-19]. However, due to [20], building systems of fluorescent lamps is inappropriate and unacceptable, we choose LED lighting. For the current time the most popular lighting control interface is a Digital Addressable Lighting Interface control (DALI), the development of which began with DSI protocol (Digital Signal Interface), developed by the Austrian company Tridonic for use in their own products [21]. DSI is an 8-bit protocol, based on Manchester encoding [22]. Communication carried out at 1200 baud rate. It is a proprietary protocol DSI subsequently served as the basis for a more advanced protocol DALI, which has become the international standard. DALI may function as a standalone system or subsystem within the building automation. The standard allows not only the management, but also to configure and monitor devices on the bus [23-24]. Control devices can provide information on other control devices, such as PLC sends commands to change the light intensity. At the physical layer transmission DALI applied Manchester coding, which allows the receiving party to uniquely identify the beginning and end of the transmitted bits without the aid of a synchronization signal. Protocol distinguishes between individual and group addressing, so that the same device can be addressed both individually and as a group. Furthermore, there is still the type of broadcast messages are received by all devices on the line, regardless of their current addresses [25].

Dimming range is usually from 0.1 to 100%, where the lower limit depends on the particular hardware implementation. The standard provides for the preservation in memory of up to 16 predefined light scenes. As a rule, it is enough to implement all required room lighting conditions [26].

4. Structure of lighting control system and algorithm of work

The system can work in three modes of operation:

1. Manual (adjustment) mode;
2. Automatic mode (simple and scripted).

To limit natural light, smart glass is used, it is a composite of layers of glass and various chemicals, changing its optical properties, the coefficient of light transmission, the heat absorption coefficient, the degree of transparency can be controlled by the applied voltage [27]. This system uses a film that is installed on a standard window glass.

In manual mode of operation, the LED lights and smart glasses are manually controlled through the operator panel or dispatch PC. In manual mode, the required power of each of the available luminaires is requested in the range from 0 to 100% (separately, in groups, all at once), the degree of dimming of the smart glass in the range 0 to 100% (each separately), and the indications of the luminance sensors. It is possible to switch to other modes of operation.

When switching to the automatic control mode, data are requested to enter the required level of illumination in the illumination zones. After entering the data, the system, based on a constant analysis of the indications of the light sensors, regulates the power of each lamp and smart glass. If the reading of the illumination level in any of the zones is higher than the set value, then the power of the closest lamp starts to decrease to the required value, if the set value is not reached when the lamps are completely switched off, then the smart windows of the window openings are darkened to a predetermined level Illumination, otherwise an error message is displayed in the system operation. Scripted automatic mode of the system performs scenario management of the system, including:

- adjusting the power of lamps in accordance with the script;
- adjusting the level of shading of smart glass in accordance with the script;
the script may include: run-time control, lighting control of individual zones and their combination.

Based on the algorithm of the system operation, technical requirements for the system, the structure of the room and data on the position of the sensors and lighting devices, a structural and functional scheme of the system can be developed.

In general, the whole system is divided into 3 parts of the block: control unit, sensor unit, executive unit block.

**Control unit.** The control unit of the system is implemented on the basis of signals from the sensor unit, the operator control panel and the dispatcher PC performs calculations and forms the appropriate control actions on the executive device unit. The most convenient logical device for use in industrial automation systems is an industrial controller capable of directly generating control signals. To build the system, the OVEN MODUS 5684 controller is used - the head controller for building small control systems with analog input modules MODUS 5630, the analog signal output MODUS 5635 and the light signal gateway module DALI – MODUS 5671, the blocks are connected via a special IMBX bus.

The choice of the OVEN production controller is due to the fact that these controllers are simple to master, they have a large number of expansion modules and low cost. Model MODUS 5684 is chosen because of its comparative simplicity, availability of a specialized DALI extension module and availability. Since this head controller is not required input and output terminals, it is necessary to use a module input analog signal (for sensor readings) Modus 5630 in an amount of 3 pieces (number of sensors is equal to 9, the input ports on each module - 4 unused ports can then be used for functional expansion of the system. also, for control of smart windows is necessary to use an analog signal output module MODUS 5635 with 4 output voltage channels. for the formation of the signal in for DALI dimming light sources must be used MODUS 5671. Expansion Module dedicated to the realization of human-machine interface must also use the operator touch panel SP310-P.

**Sensor unit.** The sensor unit is the main means of measuring the parameters of the lighting control process, for further analysis in the control unit. Based on the structure of the room and the purpose of the system, to monitor the state of the system, it is necessary to have information about the levels of illumination.

To do this, we use sensors of the level of illumination, in the developed system we will use the room sensor Thermokon.

**Executive unit block.** The executive devices include a set of controlled LED lamps and smart glasses.

LED lamps receive control signals from the control unit (change of power from 0 to 100%) in accordance with the algorithm of the system. For the construction of the system, a Vartton A070 lamp was chosen, which allows for dimming using the DALI protocol. Smart glasses receive control signals from the control unit (changing the light transmittance (darkening) from 0 to 100%) in accordance with the algorithm of the system.

To create a smart glass, the PDLC SmartFilm film is applied, glued to the already installed windows.

5. **Conclusion**

In accordance with the requirements for premises with displays, a lighting control system is developed that can adjust the level of illumination of artificial light sources and limit the excess of natural light. Adjustment of the brightness of the LED lamps is carried out according to the DALI protocol, adjustment of the natural illumination by means of smart glasses.

The technical requirements for lighting control system, the structural-functional scheme and the algorithm for controlling the operation of the system have been developed. The elements of control units, sensors and actuators have been selected.

Using such a system allows not only to achieve maximum energy savings, but also to provide optimal conditions for the visual work of display operators.
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References
[1] Hludenkov V 2010 Lighting Control System - ideal and optimal Solid-State Lighting vol 5 pp 78–80
[2] Peskin A 2011 Intelligent lighting systems Solid-State Lighting vol 2 pp 60–63
[3] Barbasova T A and Vstavskaya E V 2011 Building management systems complex set of external illumination Bulletin of the South Ural State University, Series: Computer technologies, automatic control and radioelectronics vol 23 pp 98–102
[4] Tyukin S V 2012 Experience in the development and application of lighting control systems by Zumtobel Lighting engineering vol 3 pp 42–44
[5] Morgenov A A 2016 Advantages and disadvantages of LED lighting Science, technology and education vol 5 pp 55–59
[6] Vstavskaya E V, Konstantinov V I and Pozjiday M M 2012 Managing a power output of light sources with data transmission over the wires of the mains by latitude manipulation Solid-State Lighting vol 4 pp 60–63
[7] Bogdanov A A 2012 The practice of applying LED lighting control systems Light engineering vol 3 pp 20–28
[8] Hygienic requirements for personal computers and the organization of work. 2.2.2/2.4.1340-03
[9] EN 12464 -1:2011. Light and lighting-Lighting of workplaces
[10] Natural and artificial lighting. 52.13330.2011.
[11] Hygienic requirements for natural, artificial and combined lighting of residential and public buildings 2.2.1/2.1.1.1278-03
[12] IEC 62384:2006. DC or AC supplied electronic control gear for LED modules – Performance requirements
[13] IEC/PAS 62612:2009. Self-ballasted LED–lamps for general lighting services – Performance requirements
[14] 2007 EN 15193. Energy performance of buildings–Energy requirements for lighting. European Committee on Standardisation (Brussels)
[15] Kudryashov A V, Kalinina A S and Yagovkin G N 2016 Lighting regulation considering visual functions 2nd Int. Conf. on Industrial Engineering, Applications and Manufacturing (ICIEAM) pp 1–3
[16] Oshurkov I A, Polyakov V D and Remizevich T V 2013 On the regulatory and hygienic aspects of power LEDs Light and engineering vol 2 pp 12–16
[17] Knoop M 2014 LED lighting quality Light and engineering vol 5 pp 20–22
[18] Zakgeim A L 2012 LED lighting: energy efficiency, visual perception, health safety (Review) Light and engineering vol 6 pp 12–21
[19] Narukawa Y 2010 White light emitting diodes with super-high luminous efficacy Physics vol 43
[20] The Minamata Convention on Mercury Retrieved from http://www.mercuryconvention.org/
[21] Pisaruk T V 2014 Automatic Lighting Control Building Actual problems of energy (Minsk) pp 135–8
[22] Retrieved from http://www.dali-ag.org/
[23] IEC 62386-101. Digital addressable lighting interface
[24] Gvozdev-Karelin S V, Sviridov M S and Dadaev V I 2012 Systems and components of lighting control and energy saving by Osram company Light and engineering vol 3 pp 30–42
[25] Shirokoy Y 2014 Lighting Control Standards Standardization and Certification vol 3 pp 96–103
[26] Overview lighting control protocols Retrieved from http://www.russianelectronics.ru/developer/review/2195/doc/58067/
[27] PDLC SmartSlim Retrieved from http://www.smarttint.com/