Low-voltage LED lighting system integrated with solar power cell and monitoring of the LEDs

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Abstract—**An article puts forward the concept of and actualizes a new LED system of interior lighting for administrative buildings. The main advantage of given lighting system, which is also its scientific novelty, is its use of safe low-voltage power supply (24V) for LED lamps, absence of transformers and integration with solar power cells, which allows to significantly bring down the energy consumption of lighting.**

I. INTRODUCTION

In accordance with the Paris Agreement on Climate 2016, Kazakhstan committed itself to reducing greenhouse gas emissions by 15% by 2030 compared to 1990 [1].This means either to save electricity or to switch to alternative energy sources. At the same time there is an industrial development of Kazakhstan, which provides for an increase in electricity consumption. The electricity consumption for lighting is about 12% of total consumption [2]. Therefore, the solution of the diametrical tasks stated above is partially possible with the use of energy-efficient LED lighting systems.

In this paper, we are considering the creation of an energy-efficient low-voltage LED lighting system with serviceability monitoring of LEDs and integration with solar power cells.

Currently, lighting systems are used with high-voltage power - 220V in all countries of the world. The development of new technologies in the field of alternative energy and the production of high-performance, reliable LED crystals of increased power makes it possible to change the approach to organizing the lighting of the building. Fundamentally new element is the coincidence of the power of LED lighting elements and alternative energy sources (solar panels) to 24V, which allows the development of a new architecture of lighting systems with battery life.

The idea of the research is to replace hazardous high voltage 220V in lighting systems for safe lighting 24V, which coincides with the power of energy-efficient LED lamps and the voltage generated by solar cells. This will allow the transition to a fundamentally new architecture of lighting systems. Changing the power supply system will significantly reduce energy consumption due to the use of LED lighting without voltage converters, increase the reliability and durability of the lighting system, and significantly improve the safety of working with the lighting system. A constant current with a voltage of 24V does not pose a danger to human life.

Increasing the safety of the lighting system will completely eliminate injuries from electric current when lighting is used. In turn, this will reduce the cost of health care and the number of deaths of the population.

The classical scheme of switching on the LED in the lighting device is shown in Fig. 1.

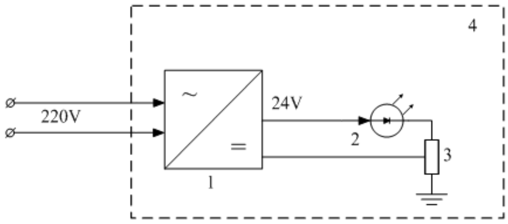


Figure 1. The classical scheme of the LED lighting device

Power supply 1 (converter from AC to DC) is one of the elements of the lighting device. Loss of energy when lighting a room by LED lamp connected to a network with alternating voltage of 220V is wasted with voltage conversion.

Wide introduction of alternative energy sources, such as solar cells or solar cells for the use of typical lighting devices leads to the need to convert the DC current received from them to AC 220V. Usually, when using alternative energy sources, lighting devices are used that are schematically represented as a circuit 4 (Fig. 1). To provide AC voltage 220V converter is installed 24-220V. In this case, the general scheme for implementing the connection of LED lighting systems is shown in Fig. 2.

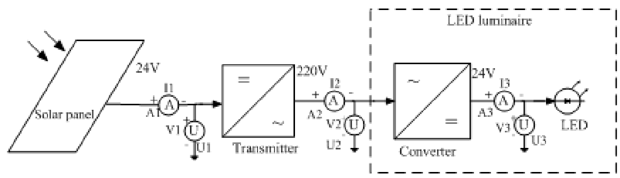


Figure 2. General scheme for system research

Despite the low efficiency of solar panels, their introduction is promising due to the use of renewable energy. However, in the scheme under consideration there are two transducers - positions 2 and 3, which introduce losses and leakages into the lighting system. The first transmitter 2 converts the DC current generated by the solar battery 24V into the working voltage of the AC 220 V network, and the second transmitter 3 converts the AC into a constant current from 220V to a voltage of 24V.

II. Experimental research and results

The use of low-voltage lighting system will save energy lost by double conversion of current [3,4]. Design has been collected consisting of a solar panel, a transmitter, a converter, an LED instrument, a voltmeter, an ammeter for studying the energy losses was collected (Fig. 2).

Calculate the efficiency of this scheme. The values of the measured currents and voltages are given in Table 1.

TABLE I
EXPERIMENTAL VALUES OF CURRENTS AND VOLTAGES

I_1,A	U_1,B	P_1,W	I_2,A	U_2,B	P_2,W	I_3,A	U_3,B	P_3,W
3,5	24	85	0.35	220	77	2.7	24	64

The current and voltage are measured before and after the converters. These data calculate the power before and after the converters and the efficiency of both converters and the total efficiency of the system. The results of calculations based on the experimental values obtained are shown in Table 2.

The obtained results showed ineffective application of double voltage conversion with loss of energy by 30%.

TABLE II
ESTIMATED VALUES OF ENERGY EFFICIENCY

P_1,W	P_2,W	P_3,W	η_1 %	η_2 %	$\Sigma\eta$ %
85	77	64	90	80	72

In the absence of converters, the question arises of stabilizing the current. If we use 20 "Amstrong" luminaries on the floor of an office building, we need to provide a current of the order of 20A at a voltage of 24V. In the event of failure of one lamp with parallel switching, there will be redistribution of currents on the LEDs. The current on the remaining lamps will increase, which will lead to gradual degradation of the LEDs.

We suggest using a source with voltage stabilization for low-voltage power supply of LED lighting. In this case, if the LED lamp fails, the current will also be redistributed along the lamps, but the current in the lamps will decrease. This will reduce the illumination on the floor.

For research the operation of LED lighting systems, we have developed two schemes - classical, using drivers with current stabilization (Fig. 3) and a circuit with voltage stabilization, including the control of LED failure (Fig. 4).

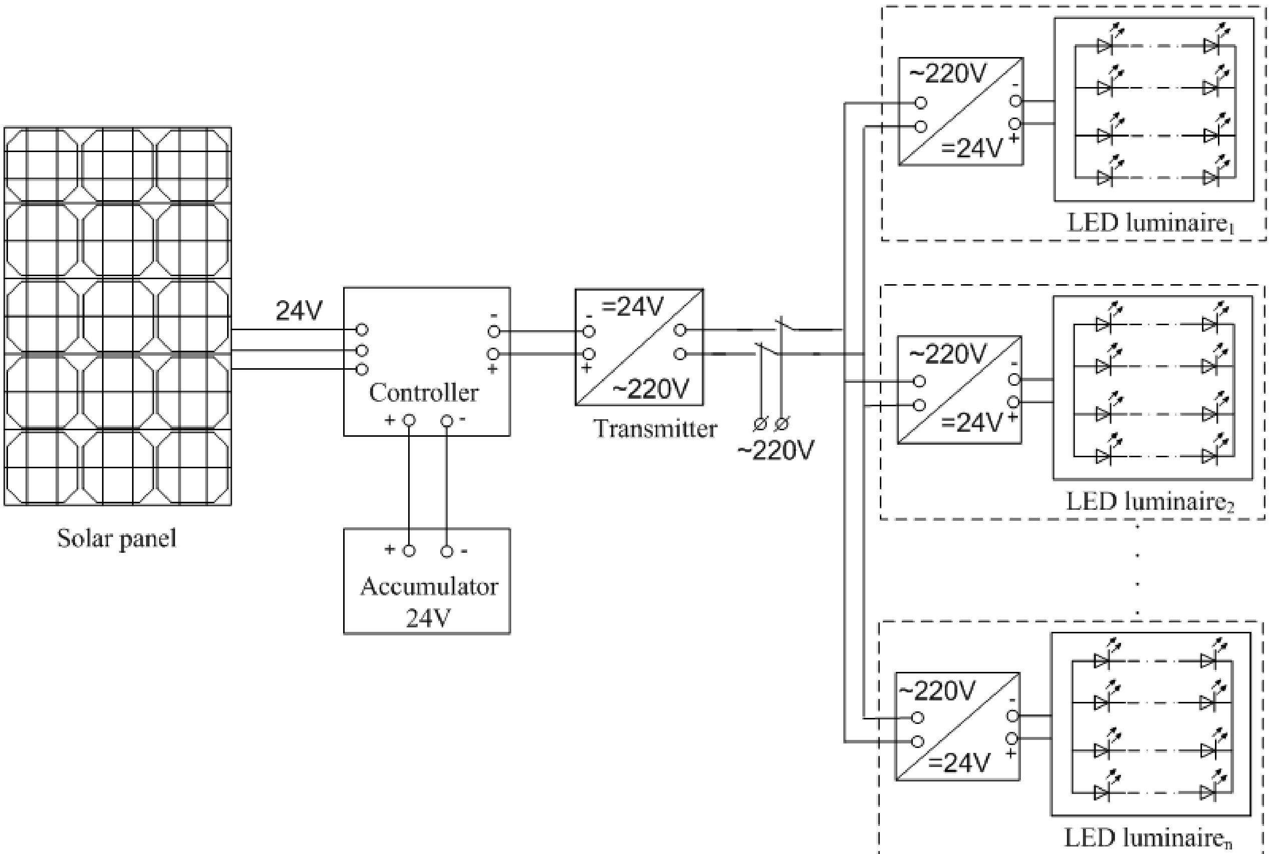


Figure 3. Classical scheme of LED lighting with current stabilization

The classic connection of LED lighting fixtures uses voltage converters. This scheme was implemented on the floor of the educational building of the East Kazakhstan State Technical University [5].

For power supply, two flexible solar panels with a capacity of 450W were used (the total maximum power of two panels 900W). The corridor was illuminated by 20 luminaries 32W (the total power consumption 640W). Four batteries with a capacity of 650A·h with a voltage of 12V were used in the lighting system. Two batteries were connected in series with total voltage of 24V.

The controller for the operating mode of the batteries and the matching of the external circuit to the solar panel was standard (PWM controller 40A). The 24/220 voltage converter was taken from a standard uninterruptible power supply. The scheme provides for switching to the internal system of power supply 220V when the solar battery fails.

Fig. 4 shows applying of the LED lighting system in accordance with the described scheme.

Figure 4. LED lighting of the floor educational building

The developed control and monitoring system [6] provided data on the energy efficiency of LED lighting using drivers with current stabilization and a solar cell. This lighting system allows you to save electricity almost 10-12 times compared to lighting based on energy-saving fluorescent lamps installed on other floors of the university building.

Integration of the solar power source into the LED lighting system allows to exclude the process of voltage conversion and to provide an operating voltage of 24V.

We are invited to monitor the operation of each lamp in real time to maintain the operating mode of the low-voltage lighting system. The ammeter is used as a sensor to detect a failure. With this control, the circuit of a low-voltage LED lighting system integrated with solar cells is shown in Fig. 5.

Consider the operation of the proposed circuit using the example of a single lamp. The LED matrix consists of 4 LED strips, each of which includes 8 series-connected LEDs. Power to the LED matrix can be fed from a power supply or solar panel. Since the LED strip located in the matrix is designed for 24V, we have the opportunity to use the solar panel as a power source, which saves energy.

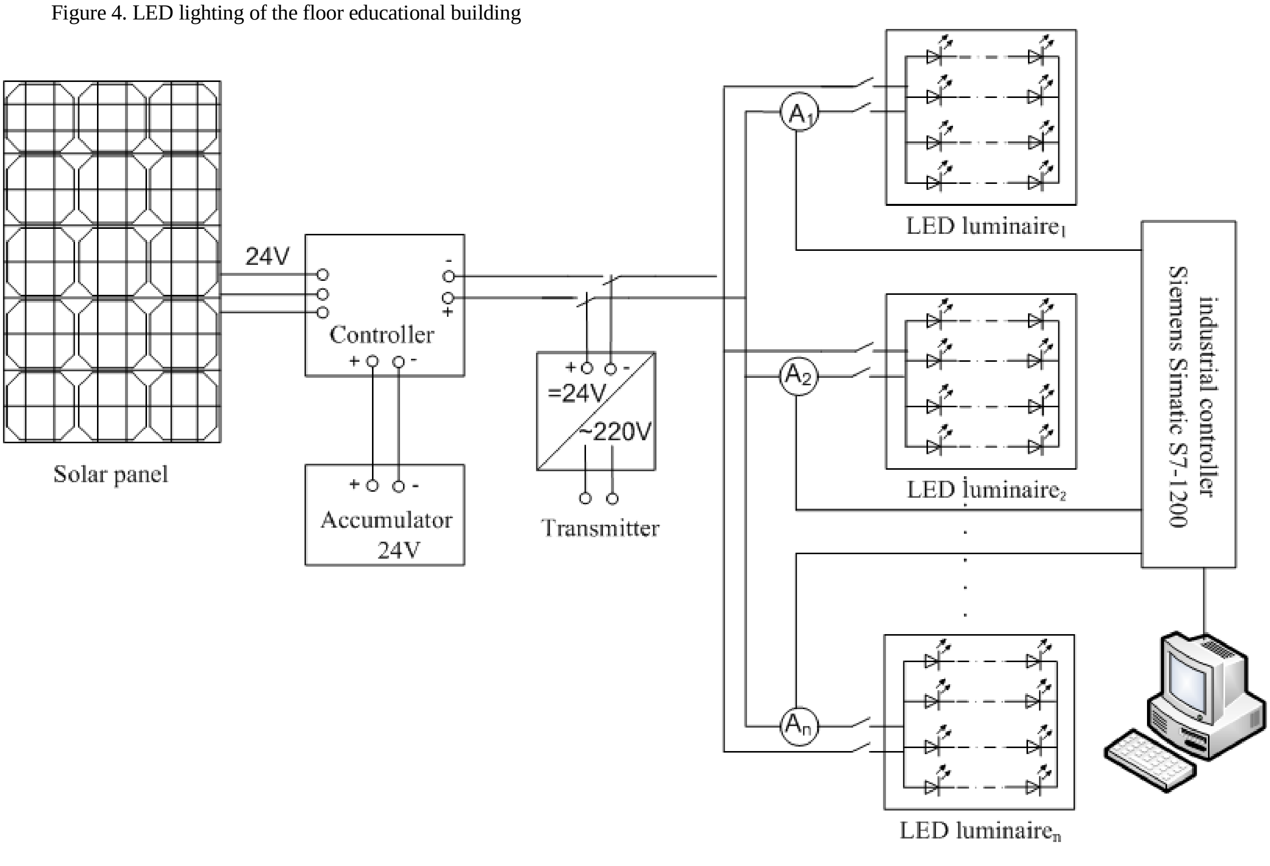


Figure 5. Classical scheme of LED lighting with current stabilization

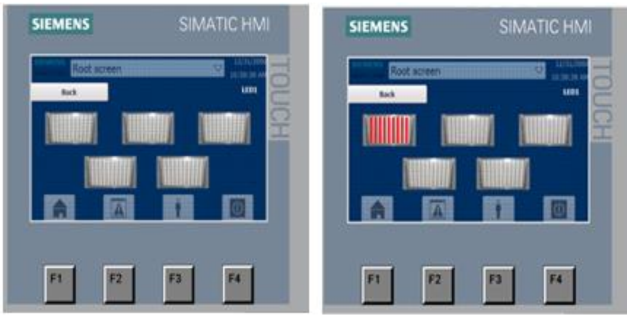
A sensor connected to the power supply unit measures the level of current that the LED matrix consumes. Next, the measured current level value is sent to the Siemens Simatic S7-1200 controller (Fig. 6).

After that, the controller compares the received data with the set value (a certain constant set for each system individually).

Visualization of the modes of operation of the LED lighting system is shown in Fig. 7.

If the received data is less than set value, the information on the failure of the number of LED ribbons in the corresponding matrix is displayed on the personal computer and on the touch screen of the controller Siemens (Fig. 7,b).

Figure 6. The appearance of the industrial controller unit



a b

Figure 7. Operational information on work and fault of the LED lighting system: a - all LED lamps work normally; b - the lamp of module 1 failed

If the value of the received value is greater than the set value, it means that a short circuit has occurred in the system. This can damage the power supply if it does not have short-circuit protection and all LED matrixes go out. In addition, there is a high probability of a fire. Therefore, we propose to install a solid state relay on the LED matrix and connect it to the controller. The controller will control the LED matrix via a relay. This will disconnect the LED matrix in the event of a short circuit, which ensures the safety of the system.

CONCLUSION

The use of a low-voltage lighting system allows the integration of solar cells into the lighting system. The possibility of using solar energy makes the system energy efficient (Fig. 8).

Energy efficiency data were obtained experimentally as a result of research of two LED lighting systems (Fig.3,5).

The histogram shows the level of energy consumption in 4 cases:

1 - with the converter from the network 220V;
2 - from the 220V network without a converter;
3 - together with a solar panel with a converter;
4 - only the solar panel 24V.

It is seen that about 30% of the energy goes to the work of the converters.

In this case, using solar energy consumption goes only emergency lighting and maintenance work, and is on average about 50 kW·h.

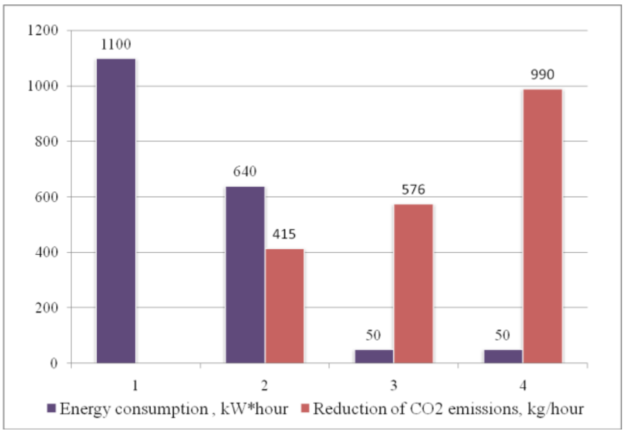


Figure 8. Results of saving electricity of low-voltage lighting system

The use of alternative energy sources in the proposed lighting system will not only save energy, but also reduce consumption of non-renewable energy resources. And as a result, improve the environmental situation associated with increased volumes of hydrocarbon fuel emissions.

If we calculate the energy generated by the solar panels and convert it into an equivalent amount of CO_2 gas ejected into the atmosphere by the power plant [7], we get a reduction in emissions by 990 g/h. When lighting the corridor during the year, an average 4 hours will reduce emissions of the order of one ton of CO_2.

In conclusion, we note that the proposed new system of low-voltage power LED lighting integrated with solar sources of energy is safe, cheaper (due to the lack of converters), more reliable and energy efficient. The results obtained make it possible to draw conclusions about the prospects and possibilities for the practical implementation of the basic principles of low-voltage lighting.

REFERENCES

[1] Kazinform International news agency. Kazakhstan sig ns Paris Climate Agreement: http://www.inform.kz/ru/kazahstan-podpisal-parizhskoe-soglashenie-po-klimatu_a2932653

[2] Babko A., Inyutin S. Energy and light audit in buildings, structures and street lighting: textbook // Astana: Publishing House ..., 2014. – p.174.

[3] Baklanov A., Zhaparova A., Titov D. Improving the Efficiency of Led Lighting by Switching to Low-voltage Technology // International Conference on Industrial Engineering (ICIE-2015), 22-23 October 2015, Chelyabinsk and Novocherkassk, Russia.

[4] Baklanov A., Zhaparova A., Titov D., Gyorok Gy. Study of the Effectiveness of Switching-on LED Illumination Devices and the Use of Low Voltage System in Lighting // Acta Polytechnica Hungarica. – 2015. – Volume 12. – P.71-80.

[5] Grigoryeva S., Baklanov. A., Titov D., Sayun V., Grigoryev Ye. Analysis energy efficiency of automated control system of LED lighting. // IEEE-Euroasian Conference on Future Energy and International Siberian Conference on Control and Communications (SIBCON–2017), June 29-30,2017, Astana, Kazakhstan.

[6] Grigoryeva S.V., Dmitrieva T.S., Titov D.N. Evaluation of energy efficiency of LED lighting systems by the example of an educational building // Vestnik KazNRTU. – 2017. – №5(123). – P. 273-277.

[7] Calculating CO2 emissions from a coal-fired power plant // The Institute for Energy and Environmental Research – 2016. – Volume14 (3). – P.11-15.