Efficient Monitoring and Control of Solar Energy Consumption by LED Lighting Devices with Embedded Microcontroller

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Abstract—**The paper deals with the effective monitoring and control of solar energy consumption by LED lighting devices with embedded microcontroller. The low-voltage power supply system and the operation method of the control system for LEDs serviceability in LED matrices were developed.**

Theoretical information revealing the basics of LED lighting system control were considered in this article.

The block diagram of the control system and described the principle of its operation are presented. The program algorithm presented in the form of a flowchart.

Keywords— energy saving, solar panel, energy consumption, alternative energy sources, microcontroller, control system

I. INTRODUCTION

One of the most important global problems of the 21st century is the modernization of the planet energy complex aimed at reducing the greenhouse gas emissions, reducing and even abandoning the use of all type of fossil fuels, slowing the global warming. The world community has clearly decided that without the transition to renewable energy sources (RES), the most scientists' pessimistic forecasts can become a reality. In our modern world and particularly in Kazakhstan, great importance is given to improving the energy efficiency of power supply systems allowing the release of a significant amount of energy, which in turn will reduce greenhouse gas emissions or use the released energy in new industrial projects. Improving the energy efficiency of the economy is important for business and society as a whole.

A. Political Energy Efficiency Efforts

In Paris, in December 2015, a climate agreement was worked out in the form of a commitment signed by the countries to decarbonize energy by replacing the use of fossil fuels with RES. This agreement has been approved by 195 countries that allowed to call it a historic one. It replaced the then-current Kyoto Protocol of 1997 that set greenhouse gas emission quotas for only a few of developed countries. Start between 2050 and 2100 to limit the emission of greenhouse gases from human industrial activity to levels that trees, soil and the oceans can naturally process. Review the contribution of each individual country to reduce harmful emissions to the atmosphere every five years. Developed countries should allocate funds to a special climate Fund to help poorer countries deal with the effects of climate change – such as natural disasters or rising ocean levels – and the transition to renewable energy.

The Agreement purpose is to prevent the temperature on the planet from increasing by more than 2 degrees Celsius. Increasing the RES share in the global energy system will affect both exporters and importers of fuel. For fossil fuel importers the transition to a higher share of RES will have potentially beneficial effects by shifting the positive factors from trade to the economy. Also, such a transition will mean higher energy security that is ensured by greater use of local resources. [1]

B. Energy Saving Technologies

Energy saving is the efficient use of energy resources through the use of innovative solutions that are technically feasible, economically justified, acceptable from environmental and social points of view and do not change the usual life way. This definition has been formulated at the UN International energy conference (IEC). [2]

The main aim is the energy saving in all areas by reducing useless energy losses. Analysis of losses in the field of production, distribution and consumption of electricity shows that most of the losses – up to 90% – are in the energy consumption field, while losses in the electricity transmission are only 9-10%.

Therefore the main efforts on energy saving are concentrated in the electricity consumption sphere. The main role in increasing the efficiency of energy use belongs to modern energy-saving technologies. Energy-saving technology – a new or improved technological process characterized by a higher efficiency of fuel and energy resources (FER). Introduction of energy saving technologies into the economic activity as businesses and individuals at the household level is an important step in solving many environmental problems – climate change, pollution (e.g., emissions from HES), exhaustion of fossil resources, etc.

The people used to live their modern lifestyle by using an amount of electronic and electrical devices. However, the increase in the use of electronic and electrical appliances has

negatively affected the unprecedented increase in energy consumption. Subsequently, due to the gap between supply and demand, the fees paid by the end user increase annually. As a result, there is a serious need to optimize the energy consumption and to develop more energy-efficient technologies and electronic systems. This need has LED to the development of new fundamental and applied research in the field of energy conservation. [2, 3]

C. *The Alternative Energy Sources*

Energy saving mode is especially relevant for mechanisms that work in a part of the time with a reduced load, for example, conveyors, pumps, fans, etc. There are many devices, which could reduce losses during the operation of electrical equipment, the main of them are capacitor banks and variable frequency drives. Variable frequency drives with built-in power optimization functions flexibly change the speed depending on the actual load, which allows to save up to 30 50% of the electricity consumed. At the same time, it is often not necessary to replace the standard electric motor, which is especially important by modernizing production. Such energy-saving electric drives and automation tools can be implemented in most industrial enterprises and in the field of housing and communal services: from elevators and ventilation systems to enterprise automation. [4]

II. DEVELOPMENT AND DESIGN OF AUTOMATED LED LIGHTING CONTROL SYSTEM

During the development and design of the automated LED lighting control system with LED serviceability control, the following tasks were completed:

- the structure of LED lighting system with LEDs serviceability control was substantiated;
- the system features were defined;
- the block diagram of the control system was designed;
- the block diagram of the algorithm was developed.

One of the most important parameters of the LED lighting system – that needs to monitor – is the LEDs serviceability. The most modern systems offer a light level control and an automatic on/off switching function for LEDs. The LED health control system proposed by us consists of the following parts (Figure 3): power supply; current sensor; relay; LED matrix; microcontroller; personal computer.

A. *The Principle of the System Operation*

The LED matrix consists of 4 LED strips, each of them includes 8 LEDs connected in series. Power to the LED matrix can be supplied from the power supply or from the solar panel. Since each LED strip located in the matrix is rated at 24V, so we have the ability to use a solar panel as a power source, which saves from the electricity consumption.

In order to calculate the required power for our solar panel it is necessary to know the monthly electricity consumption. To determine the required amount of electricity consumed in kilowatts in hours, you can look at the electric meter. So, if the monthly used energy was, for example, 200 kWh, the solar battery should produce about 7 kWh of electricity per day.

The calculation should take into consideration that solar panels generate electricity only in the daytime, and their performance depends on the angle of the Sun above the horizon, and also on the weather conditions. On average, up to 70% of the total amount of energy is generated from 9 am to 16 PM and in the presence of even a small cloud or haze, the power of the panels falls by up to 2-3 times. If the sky is covered with continuous clouds, then at the best can be get 5-7% of the maximum capabilities of the solar system. (Figure 1)

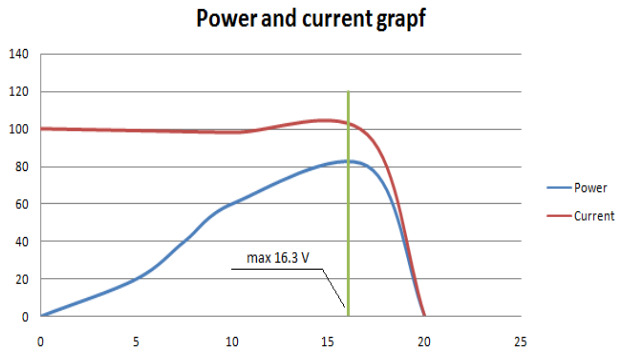

Fig. 1. .The graphics of the power and current of the sunlight at 80W in the inclining fire

B. *Calculation of the Power Supply System's Features*

Given all of the above, it can be calculated that to obtain 7 kWh of energy under ideal conditions, you will need an array of panels with a capacity of at least 1 kW. If we take into account the decrease in performance associated with changes in the angle of incidence of rays, weather factors, as well as losses in batteries and energy converters, this figure should be increased by at least 50-70 percent. If we take into account the upper figure, then for this example we will need a solar panel with a capacity of 1.7 kW.

Further calculation depends on which photocells will be used. To dial an array of solar cells with an output voltage of 12 V and a current equal to 1 700 W / 12 V = 141 A you will need to connect 24 elements in a row (serial connection allows you to summarize the voltage) and use 141 A/ 3 A = 47 such rows (1 128 plates).

The area of the battery with the most dense laying will be 1 128 x 0.0046 = 5.2 sq. m. for the accumulation of electricity, batteries with a voltage of 12 V, 24 V or 48 V are used, and their capacity should be enough to store the 7 kWh of energy. (Figure 2)

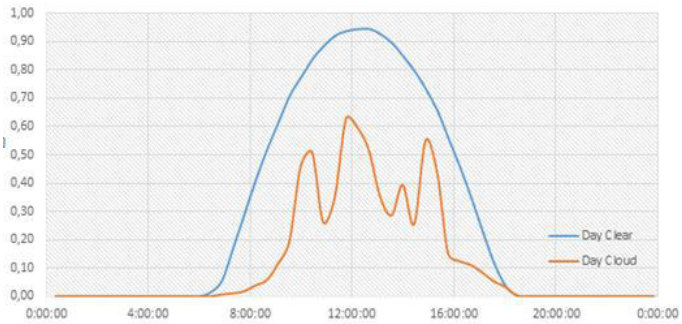

Fig. 2. .Graphics of fireworks of solar energy.

C. *Design of the Control System*

A sensor connected to the power supply block to detect the current level of energy consumption of the LED matrix panel. The measured value of the current level is sent to the microcontroller. After that, the microcontroller compares the received data with the set value (a certain constant).

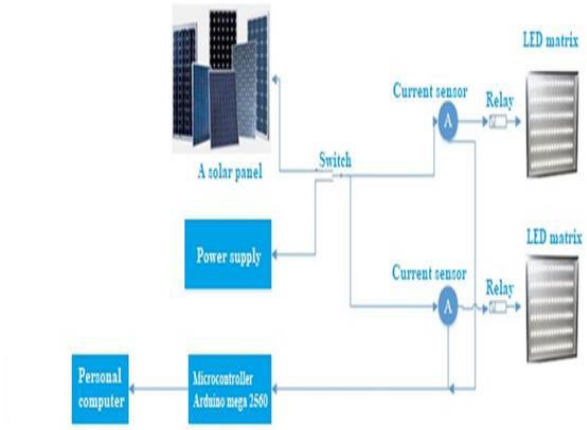

Fig. 3. A block diagram of the LEDs serviceability control system

(a solar panel, a switch, current sensor, relay, LED matrix, power supply, personal computer, microcontroller)

If the data obtained is less than this value, the personal computer will display information about the failure of the number of LED strips in the corresponding matrix.

There may be another case – if the value of the obtained value is greater than the specified value. This means that there has been a short circuit in the system. In this case, first of all, the power supply will burn, if it does not have short circuit protection, all LED matrices will also go out, in addition, there is a high probability of fire. Therefore we suggest installing a solid state relay on the LED matrix and connecting it to the microcontroller.

The microcontroller will control the LED matrix via relay. This will allow us to de-energize the LED matrix in the event of a short circuit, which ensures the safety of the system. System features – for LED power supply, low voltage 24V power supply will be used. In ordinary office buildings, 4×18W fluorescent lamps are used, their light output is 4000K.

LED matrices with such light output will have a power twice less than 32 W. In this regard, for lighting the corridor of the University, we can save half as much power. Using a low-voltage lighting system allows to include alternative energy sources (in our example, solar energy) in the lighting system. The possibility of using such solar energy will increase the energy efficiency of the system.

D. *The Program of Control System*

The block diagram of the program's algorithm illustrated on the Figure 4.

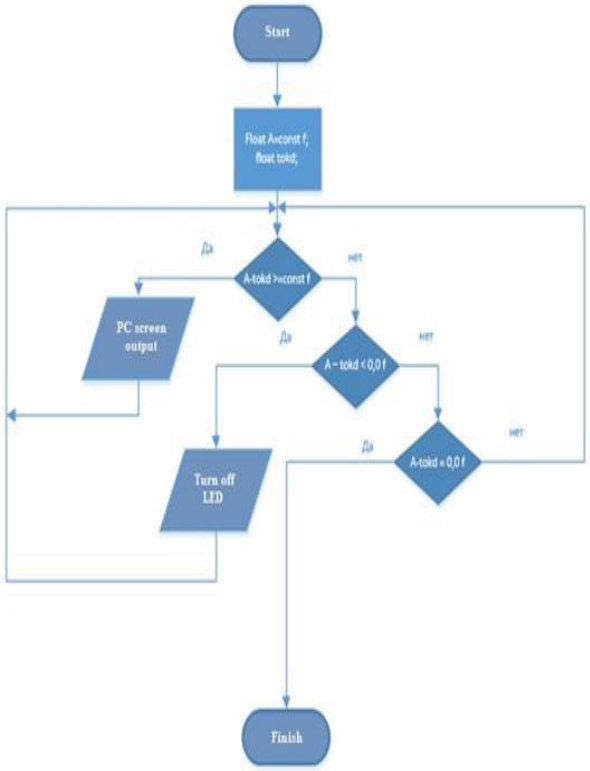

Fig. 4. . Block diagram of the program algorithm

Start of the program. Set a value A, which will be a constant necessary for further work. Declare a *tokd* variable. This *tokd* value will show the value received from the current sensor. After that, we subtract the value obtained from the current sensor from the constant. Then the first condition is checked:

$$A\text{-}tokd >= const\, f \qquad (1)$$

If this condition is met, then the PC screen will display the information that the LED strip of the corresponding LED matrix "burned out" and the cycle repeats again until we eliminate the LED malfunction.

Next, if the condition A-tokd>=const f is not satisfied, the following condition is checked:

$$A - tokd < 0{,}0\, f \qquad (2)$$

If the condition is satisfied, then a short circuit has occurred, in which case the LED matrix is switched off and the comparison is performed again. After the condition A – tokd <0,0 f is not met, the last condition is checked

$$A - tokd = 0{,}0\, f \qquad (3)$$

If the condition is met, then all LED strips are serviceable. If the specified condition is not satisfied, the cycle will return to the first comparison and will repeat until the system problems are resolved.

CONCLUSION

The proposed control system of LEDs serviceability provides a unique opportunity to save energy in the safe operation of the entire system.

At this stage, we have given theoretical information that reveals the basics of LED lighting system control. The block diagram of the control system and the principle of its operation have been presented and described. We have developed a program algorithm, which is presented in the form of a flowchart. His description has been given.

In the future, it is planned to develop the program code in the C language, the Arduino MEGA 2560 microcontroller will be used for control, and a PC application will be developed in the Visual studio 2015 software environment.

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