Intelligent street lighting technologies for transport operation

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Abstract. The paper discusses a modern concept of smart street lighting that for illuminating city streets implies the use of special street lamps controlled via intelligent platforms. These platforms can regulate the intensity of lighting according to environmental conditions. At daybreak or when there is no people around, lamps’ brightness automatically decreases (or the lights entirely go down), which helps save electrical energy. As the result, expenditures from public funds on street lighting are reduced and the impact of electric power stations on the environment decreases. Street lighting is an essential part of the city infrastructure, since it performs several functions at ones. Firstly, it provides a sufficient level of illumination for traffic networks and pedestrian areas at night time, which not only enables reducing the number of traffic collisions and injuries, but also makes life of car drivers more convenient. Moreover, properly designed street lighting including street lamps on avenues, boulevards and in yards reduces the level of urban crime. Street lightning in Russia annually consumes approximately 7 billion kW/h of electric power, which is equivalent to 16 billion rubles. While producing such an amount of electric energy, millions of tons of various exhausts pollute the atmosphere. Smart street lighting systems help reduce the demand in electrical energy for outdoor illumination. The most important indicator of a civilized city is a well-lit roadway for transport – motorways. For transport on roads, various street lighting fixtures are used, but the most popular are energy-saving gas-discharge lamps, which effectively achieve full compliance with the standards and requirements for road lighting.

1. Introduction

Analysis of scientific publications and technical solutions referring to this area showed that several approaches to the improvement of energy efficiency of the electrical engineering system of street lighting (EES SL) are currently used: replacing light sources with more efficient ones; optimization of parameters of lighting networks; development of energy-efficient control algorithms for EES SL. [1-4].

In the existing scientific researches, the methods for optimizing the parameters of elements of a street lighting network were implemented without formalizing boundary conditions reflecting the requirements of documents regulating electric power industry [5-8]. At the same time, the algorithms of energy-efficient control were implemented using deterministic methods, which does not provide a high level of energy efficiency of street lighting systems under changeable outdoor conditions (weather, daylight) and uncertain initial data (traffic intensity) [9].

The authors propose a smart solar street lighting system, that is to be used on all highways, pedestrian and other outdoor areas including squares, parks, public gardens, warehouses, parking lots, seaports, building lights, etc. It is designed to replace inefficient, environmentally hazardous gas street lamps and
reduce energy consumption by more than two times [10, 11]. The term “smart” is an equivalent of the word “intelligent”, in regard to systems. The proposed smart system of Solar Street Lighting perceives the environment and acts in accordance with a changing situation. The components of this system are a solar panel (or wind turbine), a street lamp, a battery, a smart controller, a sensor, LED lights, a light post, a mounting basement, etc. [12, 13].

The analysis of research works and technical solutions that refer to advancing EES SLs’ energy efficiency has proved that the most promising and least scrutinized ways to increase the energy efficiency of EES SLs are the following: to create methods for optimizing the parameters of elements of a lighting network and its topology; to develop control algorithms for EES SLs using artificial neural networks [14-16].

2. Materials and Methods

Intelligent street lighting control systems include the following components:

- Smart LED-lamps capable of dynamically changing the intensity of luminous flux. Such lamps are provided with motion detectors, photoelectric sensors, specialized sensors, controllers and data transmission units.
- Data transmission network that connects city street lights with a central server and with each other. Experts in this industry believe that wireless communication lines made on the basis of GPRS/3G/4G networks are the most progressive for smart street lighting systems.
- IoT-platform-based monitoring center. Such centers enable centrally-managed control of street lighting, which facilitates the work of operational and technical services. Operational services get the ability to regulate brightness of street lamps remotely proceeding from weather conditions (rain, snowstorm, fog, bright moonlight, etc.), and to set a schedule for automatically turning on/off the lighting in certain city districts. Technical services can promptly detect electrical equipment that has gone wrong by assessing lamppost sensor’s readings and send repair team to detected areas.

3. Results

Today, mercury, metal halide and sodium gas-discharge lamps, as well as incandescent light bulbs are used for illumination of city streets. Halogen, fluorescent and LED lamps are also popular. The value of luminous power radiated by streetlights depends on a type of lamps and their amount. Since high-quality lighting of a night city requires a tremendous amount of electrical energy, each design project of street lighting should be focused on the implementation of new developments in the field of energy saving.

Therefore, today the latest energy-saving LED streetlights are actively used, which are characterized by incredible high durability and large values of luminous efficacy outdoing the capabilities of other types of lamps. LED street lighting allows optimizing expenditures for maintaining the whole lighting system, as the need to replace light sources disappears and energy consumption reduces.

Recent innovations have contributed to advancing an optical part of streetlights that is made of high-strength polycarbonate material, which has made their light smoother and safer for street illumination. A light fixture illuminates only necessary areas focusing a light flux on them, so that excess power is not consumed for lighting unnecessary objects.

A casing of a street light fixture is usually made of durable material: it is performed in a shape of full-metal aluminum frame, which is closed by a plastic lid, serving as an element of decor. In double modules of modern LED lamps, independent integrated LED drivers are installed. The shape of a light fixture is approved in accordance with the requirements of industrial design; it should protect the core elements of a lamp from wind loads and impurity (Figure 1).

High durability of streetlights is out of doubt, since their frame is developed according to a specialized scheme based on the experience of creating elements for aircraft turbines, which allows for heat removal at the highest rates. Thus, the design of casing part of a lamp favorably affects the effect of heating on its internal batteries and electronic components. Due to this, street light fixtures can stay operable for 20-25 years.
Besides photoelectric sensors that record the illuminance level on a street, street lamps can be provided with integrated GPS receivers with computing devices. A similar method of street lighting automation is offered by the Korean company Stwol. In this case, street lights control the illuminance level on the basis of the geographic position of a controller which is known from GPS. By correlating data on location with a current date and astronomical time, the computing system is able to accurately determine the time of sunset or sunrise. Then the lights automatically turn on 15 minutes before dusk and turn off 15 minutes after dawn.

The smart street lighting system can be used not only to turn on/off the lights automatically in the morning/evening or to control the light intensity, but also to alert pedestrians and drivers about emergency situations. For example, lights may start flashing, which will signalize about a rescue vehicle or ambulance passing through. Or sensors installed on flashlights can collect data on city traffic, the level of environmental pollution, etc. The probable smart streetlight’s providence with equipment is shown in Figure 2.

![Figure 1. Principle of operation of smart streetlights. Source: https://ganit-star.com.](image-url)
4. Discussion

Analysis of the current state of business activity in the field of recycling in the Russian Capabilities of Smart Lighting system include the following functions:

- Monitoring operable condition of light fixtures. Monitoring operable condition of light fixtures can be automatized regarding the following components: LEDs, solar panels, batteries, etc.

- Monitoring the environment (situation). The running status of environmental monitoring automatically detects daylight level, wind strength, air temperature, the Earth's surface illumination, traffic intensity, etc., and adapts the system to a current situation.

- Recording and archiving history. All components of operable condition of light fixtures and of the environment can be located in a remote information center, professional analysis can help forecast working life of light fixtures and optimize their operable condition.
Smart and remote control. Comparing with the previous simple manual on/off control capabilities, solar LED lamps can be smartly controlled in accordance with the given system status, environment (situation) status, special lighting requests, etc.

Smart city support platform. Smart Lighting can be integrated into a smart urban management platform (cloud service). Smart Lighting is a good demonstration of smart and non-polluting illumination. Smart Lighting system sends an alarm signal about malfunctions to a computer or mobile phone and provides an operability forecast; optimizes the operation of light fixtures, and allows a user remotely accessing technical support.

5. Conclusions
The market for solutions in the field of smart street lighting is now actively developing. According to data provided at the beginning of February 2017 by analytical company WiseGuyReports, by 2026, money invested in smart street lighting will have amounted to $57 billion for LED streetlights and $12.6 billion for intelligent control platforms. Traditional incandescent lamps consume too much energy and produce too much heat. Therefore, today many countries around the world are progressively replacing traditional streetlights with intelligent LEDs. 89% of streetlights are forecasted to be switched over to LEDs by 2026, and 42% will have been interconnected via the Internet on the basis of an IoT platform by that time.

According to WiseGuyReports, Europe is the largest market for smart street lighting solutions. The European Union has estimated that approximately 7.6 billion euros were spent on illumination of city streets in 2015. Meanwhile, introduction of street lighting control systems will allow European city councils to reduce costs by almost 60%. This is the reason, why the European Commission (EC) is now highly concerned with providing all European cities with LED streetlights. When all lampposts are equipped with intelligent LED bulbs and connected to an IoT platform, European city services will be able to control light brightness remotely and carry out repair works in advance, just responding to readings of detectors installed.

High price of such lampposts, that reaches 8,000 euros/pc at times, restrains their widespread distribution. However, at the beginning of March 2017, the web portal EurActiv announced that the EC was looking for ways to support city authorities in the implementation of this expensive, yet economically sound idea of modernizing street lighting systems.

Today, Germany, the UK and the USA are the leaders in the implementation of intelligent street lighting systems. In the last few years, India and China have been actively catching up with the leaders, due to the growth of the number of specialized projects in these countries. The following companies offering their smart street lighting solutions are considered the key players in the market: GE Lighting, Philips Lighting, Acuity Brands, Osram and Honeywell Lighting.

Today, Russia is far from the widespread implementation of smart street lighting systems. More than 50% of streetlights in Russia are obsolete and need to be replaced.

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