

OPTIMIZATION OF TECHNICAL MAINTENANCE OF STREET LIGHTING SYSTEMS BASED ON REAL-TIME MONITORING

Baymatova N T

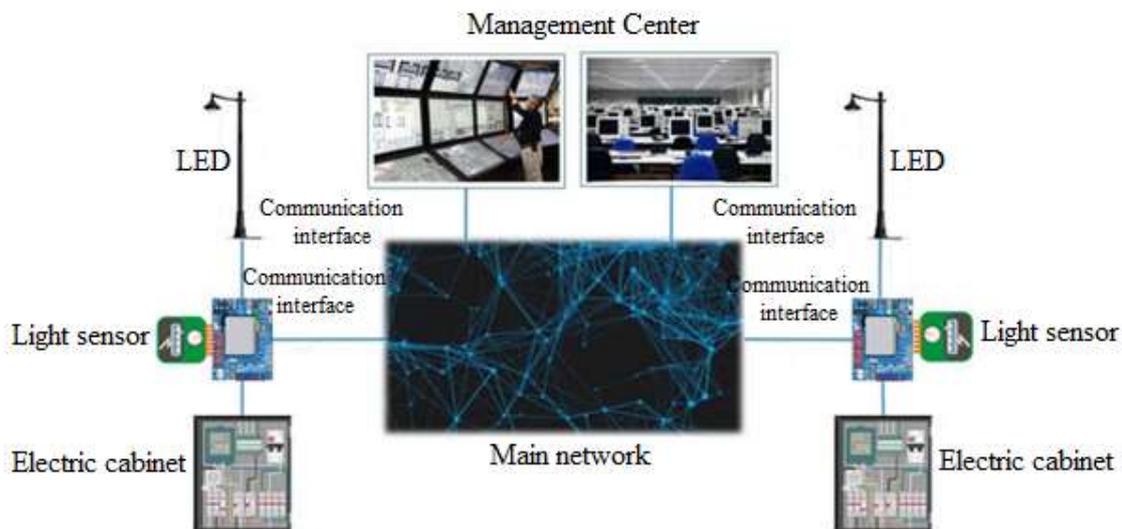
Khvan A A

*Tashkent State Technical University, Tashkent,
Republic of Uzbekistan email: baymatova@gmail.com*

Annotation: *This article will consider the real-time monitoring capabilities of street lighting systems and the optimization of maintenance on their basis. Partial fault detection, forecasting and reduction in operating costs are highlighted.*

Keywords: *monitoring, maintenance, forecasting, street lighting, optimization.*

The most general architecture of smart street lighting infrastructure is shown in the figure below, which clearly shows all the main components of this system. The architecture in question is usually made up of three main components: a “Control Center”, a “communication network”, and a “light controller” (i.e., a street lighting system). The Control Center is considered the heart of the entire system and performs the tasks of collecting, processing and making decisions on their basis in real time. In this center, special software will be installed, which will be able to optimize energy consumption, control the life of lamps and take quick action in case of emergency. The communication network, on the other hand, ensures the continuous exchange of information between the Control Center and the lighting devices. This network can be organized through various technologies – for example, wireless communication standards such as “Wi-Fi, ZigBee, LoRaWAN or 5G”. The communication system sends information coming from sensors in the lighting columns to the center, and vice versa, conveys commands coming from the center to the lighting devices. The communication network, on the other hand, ensures the continuous exchange of information between the Control Center and the lighting devices. This network can be organized through various technologies – for example, wireless communication standards such as “Wi-Fi, ZigBee, LoRaWAN or 5G”. The communication system sends information coming from sensors in the lighting columns to the center, and vice versa, conveys commands coming from the center to the lighting devices. The lighting controller, on the other hand, directly regulates the operation of street lighting lights. It performs tasks based on information that comes through sensors, such as “turning off lights during the day, activating them to some extent at night, automatically increasing the level of light when moving vehicles or pedestrians approach.” Control devices also play an important role in ensuring energy efficiency [1-3]. In this way, smart street lighting infrastructure not only reduces energy consumption, but also increases City Safety, reduces service costs and serves to ensure environmental sustainability.



Smart lighting infrastructure architecture

The Control Center is the infrastructure management office: it commands/adjusts each street light (e.g., activating, turning off, dimming) and monitors infrastructure operating conditions for maintenance purposes. The command/information exchange between the Control Center and each street light is carried out through a communication network, which should adequately cover the entire area where the lighting fixtures are installed. Finally, the street lighting system is intelligent components of street lights that execute commands received by the Control Center and send back the necessary information. From a smart city point of view, street lighting systems may be equipped with IoT sensors (e.g., vehicle traffic ocular lighting system, or for air quality monitoring), whose ocular lighting systems are transmitted to dedicated control centers. Inally, the street lighting system is intelligent components of street lights that es:

1. Energy efficiency is the saving of electricity and reducing overhead by automatically activating, turning off or dimming the lights.
2. Optimal light level control is to adjust the lighting level according to the time of day, weather conditions and traffic flow.
3. Remote monitoring and control – centralized control of all lights, monitoring their performance and quick detection of malfunctions.
4. Support additional IoT services – integrate various sensors for air quality, temperature, traffic or security monitoring.

Such an approach, in addition to “improving the reliability” of the lighting system, also makes maintenance processes significantly more effective. For example, a partial malfunction of street lights – the failure of only part of the LED chips – may not be detected immediately by the human eye, but an intelligent monitoring system records this process in real time and reports it to the Control Center. Through this, the service personnel will be able to detect the malfunction at the exact location and with the exact cause [4].

Partial failure states are usually caused by "voltage fluctuations or surge shocks in the power supply". In particular, the strong electromagnetic impulses generated during thunderstorms generate wave voltages in the lighting networks. If the system does not have sufficient "voltage protection elements" (filters, stabilizers, protective diodes, etc.), such vibrations will cause some chips inside the LED backlight to fail. As a result, even if the entire luminaire does not turn off, its efficiency decreases and excessive energy consumption occurs. Thus, one of the important advantages of smart lighting infrastructure is the "possibility of detecting and eliminating partial failures". This will not only save electricity, but also extend the service life of the system and reduce operating costs.

The importance of monitoring electrical parameters:

Street lighting systems can act not only as a light control, but also as a "distributed analyzer" that allows monitoring and analysis of electricity consumption. Traditionally, only active and reactive power consumption was measured, but modern intelligent systems allow real-time monitoring of the following parameters as well:

Voltage (U) – records fluctuations in the electrical network and sharp drops/rises. Flow (I) - allows you to determine the level of consumption and the risk of overload. Power factor ($\cos \varphi$) – indicates the level of energy efficiency. Average consumption-allows you to analyze energy consumption in hourly, daily, weekly, monthly and annual cross-sections. Voltage (U) – records fluctuations in the electrical network and sharp drops/rises. Flow (I) - allows you to determine the level of consumption and the risk of overload. Power factor ($\cos \varphi$) – indicates the level of energy efficiency. Average consumption-allows you to analyze energy consumption in hourly, daily, weekly, monthly and annual cross-sections.

As a result of the high resolution and real-time recording of these parameters, the technical capabilities of the system expand:

1. Fault detection and forecasting – voltage fluctuations, overload or a decrease in the power factor can be the starting signs of hardware failures. By early detection of such situations, costly emergency repairs can be avoided and scheduled maintenance performed.

2. Optimization of maintenance-using the data obtained, it is possible to give a forecast of the life of the luminaires, the degree of degradation of LED chips and the reliability of electrical components. This makes it possible to plan service work more accurately.

3. Further information about the city's electricity grid – street lighting infrastructure becomes auxiliary monitoring points for network operators. As a result, valuable information is collected about the load, voltage quality and energy efficiency of the city's electricity grid.

4. High time accuracy-instead of providing only averages, real-time tracking significantly improves infrastructure management. This makes it possible to make operational management decisions.

Therefore, in terms of technical requirements, monitoring many parameters in real time “requires high technological performance”, but, as a result, serves to increase the reliability and efficiency of the infrastructure.

Undoubtedly, the most important task of street lighting systems is to reduce light, create economy according to some criteria. Over the years, the main control systems have evolved into very advanced systems that provide enhanced capabilities to adapt the light intensity to the actual working environment. Unlike the simplest and older style street lighting systems, which allow you to set the intensity of light only on a predetermined schedule, modern control systems allow you to adjust the lumen output to the current traffic flow, the amount of which is controlled under special control. sensors, in some cases even taking into account meteorological conditions, are used in the ocular lighting system, together with the brightness of the adjacent road surface. Such advanced features are designed according to specific rules that allow you to dynamically reduce the light intensity when certain conditions are met. In particular, according to the lighting standard, each track is assigned a certain light class, which largely depends on the expected traffic flow. Referring to motorized transport routes, it defines six classes from M1 to M6, each corresponding to a specific average light requirement. However, the standard allows the class of light to be dynamically adapted to the actual conditions assessed using real-time measurements.

For example, in Italy, the CEN/TR 13201-2 standard is implemented through the norm of UNI 11248, which standardizes adapted lighting strategies and thus allows the design of systems that regulate lighting conditions according to factors that may change over time, such as congestion. flow, light or weather conditions. or example, in Italy, the CEN/TR 13201-2 standard is implemented through the norm of UNI 11248, which standardizes adapted lighting strategies and thus allows the design of systems that regulate lighting conditions according to factors that may change over time, such as congestion. flow, light or weather conditions. In particular, two different modes of operation can be applied: (a) TAI (Traffic Adaptive Installation), where only the volume of traffic is used in the lighting system; (b) FAI (Fully Adaptive Installation), where even meteorological conditions and road surface brightness are taken into account.

When TAI is installed, the light class can be reduced to one level if the Okocha lighting system's average traffic is below 50% of the face value, while the traffic can be lowered to the 2nd Light class if it is below 75% of the face value. hen TAI is installed, the light class can be reduced to one level if the Okocha lighting system's average traffic is below 50% of the face value, while the traffic can be lowered to the 2nd Light class if it is below 75% of the face value. In TAI systems, traffic volume is allowed to dim at a certain time interval (usually in the 10th minute), such as the ocular lighting system, and if two successive samples are below the limit.

Obviously, separate approaches (pre-installed dimming, TAI or FAI) lead to accurate savings, require different technologies and systems of different complexity. If

to achieve the most savings, a low-latency communication network is required. Obviously, separate approaches (pre-installed dimming, TAI or FAI) lead to accurate savings, require different technologies and systems of different complexity. If to achieve the most savings, a low-latency communication network is required. In fact, when TAI or (for more reason) FAI is adopted, street lights belonging to the same TAI/FAI segment constantly exchange information, and they must react to different conditions (accepting other dimming levels) at the same time to avoid confusion. Drivers with different illuminated parts of the road. An additional feature associated with safety and energy conservation is constant light output (CLO). In this regard, it should be noted that the light flow of LED lighting, like other light sources, decreases over time with the age of the diode and the accumulation of dirt. Usually, when there is no possibility of dimming, street lights are excessively modified in such a way that they significantly exceed the required light intensity from the first day, therefore, a decrease in the efficiency of the lighting over time does not violate the minimum required lighting rules.

This excess margin depends on the supply factor (TF), which determines the percentage of total light output at the beginning of the installation period, resulting in the output falling. MF is calculated taking into account the coefficient of light flux (i.e., the wear of light flux over time due to the aging of the light source), as well as other factors, i.e. survival factors, luminance storage coefficient and surface storage coefficient. This excess margin depends on the supply factor (TF), which determines the percentage of total light output at the beginning of the installation period, resulting in the output falling [5]. MF is calculated taking into account the coefficient of light flux (i.e., the wear of light flux over time due to the aging of the light source), as well as other factors, i.e. survival factors, luminance storage coefficient and surface storage coefficient. It must be said that this policy leads to a useless waste of energy.

The LED is initially powered at a certain percentage of the light capability (100%) and then continuously dimmed until the last 100% current supply, so that the required light level remains constant until the end of service life. Obviously, this dim programming protects the LED chip and saves electricity costs during the entire life of the lighting.

Economic analysis - we will discuss the economic benefits that can be achieved by converting traditional lighting infrastructure into smart lighting. In the form of absolute money, costs and possible savings vary from one country to another. However, in our experience, the relative contribution of each cost item (e.g. electricity, maintenance) to the overall cost figure is approximately the same worldwide, so possible savings can be achieved by introducing smart features. Therefore, below we represent such savings as the annual operating costs of a conventional non-LED fixture, including maintenance, as a percentage. This cost can be distributed as follows: 70% of the cost of electricity, calculated taking into account 4200 hours of light per year for each street lighting and 130W conventional lamps. 30% for maintenance

operations calculated taking into account labor (50%), the use of specialized vehicles (30%) and materials (20%).

Remote control of lights: additional savings can be achieved by real-time monitoring of the operation of the lights (lamp status and electrical parameters) and the introduction of a street lighting system capable of transmitting the collected data along with the polar ID to the Control Center, which can detect or predict failure situations in time. This allows for failure prevention (e.g. when an incorrect power supply causes a flash in a state of stress) and allows for the optimization of fault recovery operations. It is difficult to calculate the amount of savings provided by improved maintenance practices, since it depends on how the maintenance is managed locally. However, this is expected to be a few percentage points per year for street lights. The expected energy saving making the street lighting system capable of dimming LED lights leads to two more advantages. On the one hand, this feature allows the illuminator to observe changes in daylight, i.e., to compensate for changes in natural light at sunset and sunrise, the intensity of light can be "adjusted" by subtle time granulation, which prevents light-induced energy expenditure. simple activate / deactivate policy. On the other hand, the dimming profile can be easily adjusted over the years to compensate for the inevitable disruption of the light flow due to the aging of the luminaire. This allows variable light sources such as LEDs to realize their cost-effective function, which ensures further energy conservation.

The economic benefit of dimming light depends on many factors, such as lighting capacity, adopted dimming mode, and daylight duration. Nevertheless, several tests have shown that reducing energy consumption by 40% -45% is a real goal, leading to a 15% -17% annual savings for each armature. We discussed future services and integration with 5G networks - the savings that can be achieved by converting traditional public lighting infrastructure into smart infrastructure. However, the advantages of such technology are not limited to economic aspects: if the lighting infrastructure is far-sighted, the presence of a capillary wireless network that reaches every place where smart street lights are available is an important result. This allows data collection from nearby sensors and the provision of new services, such as:

- smart parking: real-time monitoring of parking spaces (empty / occupied);
 - waste management: determining the amount of garbage in containers to optimize garbage collection routes and schedule;
 - air quality: monitoring air pollution levels;
 - structural health: monitoring vibrations and material conditions in buildings, bridges and historic sites
- smart parking: real-time monitoring of parking spaces (empty / occupied);
- waste management: determining igns.

Smart street lighting systems are important not only in improving energy efficiency, but also in ensuring infrastructure reliability and optimizing maintenance. Real-time monitoring and the ability to monitor various parameters serve to

effectively control the performance of the luminaires, detect partial failures in advance and reduce costs. In addition, through the integration of IoT sensors, security systems, 5G communications and other intelligent technologies, street lighting systems are being formed as a central element of modern urban infrastructure. Therefore, the introduction of such systems is one of the main directions for the construction of “energy-efficient”, safe and innovative cities.

REFERENCES:

1. P. P. F. Dheena, G. S. Raj, and Gopika Dutt, “IoT based smart street light management system”, *Int. J. Adv. Res. Eng. Sci. Technol.*, vol. 1, pp. 20-30, 2018.
2. D. A. Devi, and A. Kumar, “Design and Implementation of CPLD based Solar Power Saving System for Street Lights and Automatic Traffic Controller,” *Int. J. Sci. and Res. Pub.*, vol. 8, pp. 58-62, 2019.
3. H. Satyaseel, G. Sahu, M. Agarwal, and J. Priya, “Light intensity monitoring & automation of street light control by Iot,” *Int. J. Innovations Adv. Comput. Sci.*, vol. 6, no. 10, pp. 34-40, 2017.
4. J. Ashish, A. Bababe, and I. Ranjan, “Smart Street Light Management System using LoRa Technology,” *Int. J. Sci. Res.*, vol. 4, pp. 2319- 7064, 2018.
5. O. Rudrawar, S. Daga, J. R. Chadha and P. "Smart Street lighting system with light intensity control using power electronics," 2018 Technologies for Smart-City Energy Security and Power (ICSESP), Bhubaneswar, India, 2018, pp. 1-5