MODE CONTROL OF LIGHTING SYSTEM BASED ON THE SMART-LIGHT CONCEPT

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Abstract
Modern urban lighting systems are complex teretorially distributed systems, which in turn are part of higher-level systems - electric power systems or their various subsystem levels. They have common elements with them (supply and distribution networks of high and medium voltage), as well as power supplies and means of regulation and control. This makes it necessary to apply methods and technical means of control in urban lighting systems, adapted to the modes of urban electric networks, and basically oriented towards structural and parametric integration into control systems of urban electric networks. To control the modes of electrical networks, so far, methods and technical means based on discrete, mainly manual control are used. However, more and more nowadays, man-machine automated systems are used, which, when controlling, take into account, in addition to technical parameters of networks, the parameters of the human body and the environment.

Keywords: lighting system, smart-light, smart-grid, mode control.

INTRODUCTION

Modern city lighting systems are complex geographically distributed systems, which in turn are part of higher-level systems - electric power systems or their various subsystem levels. They have common elements with them (supply and distribution networks of high and medium voltage), as well as power supplies and means of regulation and control. This makes the processes in them interdependent, and the parameters interdependent. This applies to the influence of lighting systems on the formation of the maximum power consumption of cities on a daily interval, which is due to the massive switching on of lighting electrical appliances in the evening, pollution of urban power grids with higher harmonics and a decrease in the power factor of the networks, due to the nonlinearity of the characteristics of light sources and the discreteness of the driver parameters, etc. On the other hand, the electrical networks of power systems themselves affect the parameters and networks of lighting systems. This concerns the influence of network voltage modes on the parameters and modes of lighting electrical receivers, the state of the environment, the social and environmental consequences of such a state. This requires the use of methods and technical means of control in urban lighting systems, adapted to the parameters and modes of urban electrical networks, and basically focused on structural and parametric integration into control systems for electrical networks of power systems. At its core, the management of the modes of urban electrical networks, while mainly methods and technical means based on discrete, mainly manual control are used. However, more and more nowadays, man-machine automated systems are used, which, when controlling, take into account, in addition to the technical parameters of networks, the parameters of the human body and the environment.

EXPOSITION

As a basis for building such systems, we can consider multi-level hierarchical distributed structures, the effectiveness of which has been confirmed by practice. In such structures, the functions of higher coordination and organizational management, in general, are performed by the upper level of the hierarchy. In the systems of electricity consumption and lighting of cities, this is an operational information and control complex, which is part of the automated control system of an energy association.

A feature of city lighting systems is their significant impact on the socio-economic conditions of people living. City lighting systems are focused mainly on creating a comfortable light environment in the places where the population lives. Therefore, to control their modes, it is necessary to apply new principles, criteria and control parameters. In addition, the large territorial distribution of power supply and lighting systems in cities, in combination with a large number of modes of operation, make it necessary to use distributed flow control systems. As an element of power supply and lighting systems of cities, together with other consumers connected to the power center of the CPU, form it and the resulting load graph of the GN, as well as the laws of voltage regulation and reactive power compensation. Therefore, optimization of operating modes of city lighting systems requires coordinated management of network modes using a combination of local and global criteria. At the same time, on the basis of local criteria, optimal conditions for the operation of individual local objects are provided, and through global ones - the conditions for the operation of the system as a whole. In this case, in the event of a conflict situation, priority is given to the global criterion.

The foregoing requires the use of a unified management system built on a hierarchical principle. In general, the presence of these features necessitates the use of a systemic control of the modes of lighting systems in cities of multilevel multicriteria control systems built on a multi-circuit hierarchical principle. Decision-making processes in such systems have a wide range - from very short management actions to planning processes for a long period. For these reasons, in the systems under consideration, there are differences in the duration of cycles, criteria and control parameters at different territorial and hourly levels. This makes it problematic to control the modes of city lighting systems within the existing concept. For this reason, the modern theory and practice of managing complex systems modes is increasingly inclined towards empirical and suboptimal solutions with the distribution of the problem into separate tasks and the subsequent application of special procedures, their integration and coordination. Therefore, the fundamental concept for solving the complex problem of managing the modes of city lighting systems is the use of a multilayer structure distributed in time and space, taking into account the factors of social and environmental adequacy.

An analysis of the functional tasks of urban power supply systems indicates the possibility of integrating urban lighting systems into such systems. However, as evidenced by the results of the analysis, a simple transfer of the ideology of building control systems at higher levels to systems of a lower level here cannot be applied from the operational, technological and socio-ecological features of urban lighting systems. The main problems of controlling the regimes of the city lighting systems can be summarized as follows:

- control of network modes requires the transmission of a significant amount of information to a large number of objects with minimal delays (circular control mode), which causes an increase in the cost of the system;
- the presence of information flows of various sizes, intensity and priorities makes it difficult to apply a well-developed classical ideology.

The problems of controlling the modes of city lighting systems include the additional lack of a sufficient number of control channels. As a rule, this is a small number of telephone communication channels with especially important objects of power supply systems of cities: individual RP, TP or IP, focused on performing simple functions of discrete control. In some cases, VHF or GSM communication is used in a limited frequency range. It should also be noted that there are no continuous control systems for 0.4-10 kV facilities. At the same time, these objects have a predominant impact on the technical and economic indicators of the entire system of electricity consumption and lighting in cities.

The conducted studies have shown that in urban conditions the most acceptable environment for systems of the upper levels (110 kV networks and above) are telephone lines GSM and VHF channels, and for the lower ones - power lines and GSM channels. This largely determines the hierarchical structure of urban lighting control systems, which to a certain extent repeats the structure of urban networks. In this case, the radial-node structure of control systems is used as a typical technology for the technology that uses telephone lines as a medium for transmitting information. In this case, power station are located in the nodes of lighting loads, at the TP, RP or ASU of consumers. And the characteristics of the network are largely determined by the ability of the information facilities of the dispatching points to control the flows of information. [1,2,5]

The tree structure of EM control systems is typical for control systems that use a radio environment. high-speed channels are usually used to transmit information (usually radio relay). In this case, the main control points can act as repeaters or information storage devices. The intermediate points in these conditions can act as data concentrators. The location of the main and intermediate points, as well as the allocation of independent parts of control systems, are determined by the topology of distribution networks and the organization of control channels.

A mixed configuration of a network control system is typical for control systems that combine a VHF environment, an environment of telephone communication lines and power lines of PM 0.4-10 kV. Moreover, each point in the network can be either a switch or a data concentrator. An essential condition for the operation of such a network is the availability of a highly efficient algorithm required for high-speed switching and signal distribution.

The presence of restrictions in terms of the number of communication channels and their bandwidth necessitates a combination of organic channels organized in all three environments, and makes it expedient to use a mixed structure of control systems. (Fig. 1) In these conditions, the main problem that arises in the management of urban lighting systems is the reduction in the volume of transmitted information. One of the ways to solve it is to reduce the redundancy of information, which can be carried out in the following main directions:

- increasing the intelligence of local control systems by providing them with a part of the functions that control, and reducing information communication with higher and adjacent systems;
- "compression" of information by its previous probable processing;
- improvement of structural and algorithmic solutions;
- coordination of the use of local network resources;
- ensuring the possibility of integrating the control system into the existing automated control system of energy associations.

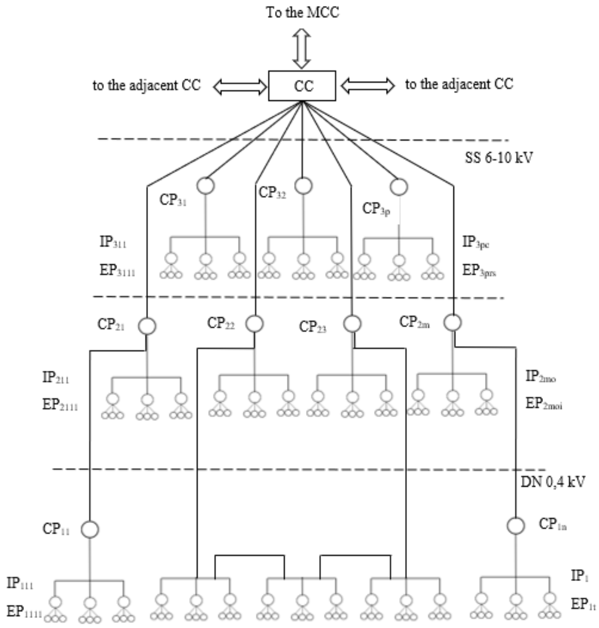


Fig. 1. *Topology of the lighting control system*

The use of the considered basic approaches in combination with the standardization of the elements of the control system allows the use of a hierarchical integrated principle of building a control system for city lighting systems, which provides the possibility of unifying elements and modifying its software. At the same time, the use of microprocessor and computer technology allows automating not only technological processes, but also the processes of processing and storing information.

To build such systems, it is necessary to solve three main tasks:

- the choice of a rational structure of a flexible system that ensures the performance of the necessary functions with specified quality indicators;

- selection of the structure of the control system, which ensures the optimization of the number of connections and the number of control points;

- development of an algorithm for the functioning of the control system, which ensures the achievement of the specified numerical characteristics.

The concept under consideration, the construction of a control system for the modes of city lighting systems, is based on a hierarchical multi-level aggregation structure. At the lower levels, the control system is represented by a certain number of local systems, which are characterized by relative independence of functioning, adapted for use in load nodes of networks. For them, the most effective is the stabilization of the parameters of the technological process. The structure of such control systems is distributed in nature (Fig. 2). Its active elements, which correct the mode parameters, are as close as possible to the control objects. Ideally, active elements are installed directly at the load nodes of the networks.

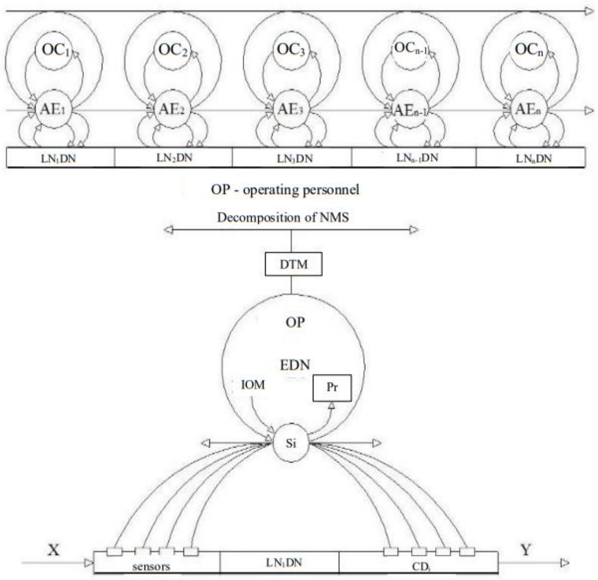
In this work, the construction of the control system is carried out on the assumption that its main goal is to implement the "control" task, which determines the belonging of the control system to the system S, represented by the pair X, Y, provided that Y is a solution to the optimization problem carried out for a specific combination control parameters. In this case, the solution to the problem is represented as a set of X and Y:

$$S \subseteq X \times Y \ldots \qquad (1)$$

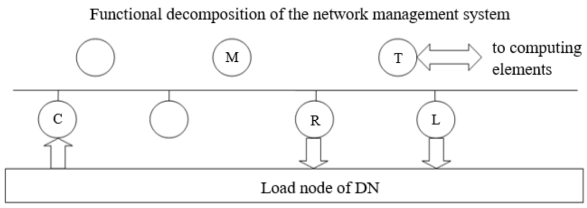
Given the purposeful functional nature of the system, we can talk about the network management system as a reflection of equation 2. Where X and Y are the reflected huge number of inputs and outputs.

$$S : X \to Y, \qquad (2)$$

where X and Y are the reflected huge number of x∈ X inputs and y∈ Y outputs.



a)



b)

Fig. 2. *Decomposition of the network management system: a) structural; b) functional; C - collection and processing of information; R - regulation; L - logical control; M - manual input and display of information; T - transmission of information; Pr- processor; IOM - input-output module; OC - object controller; DTM - data transmission multiplexer*

Taking into account the internal state of the system, formed by the history of the functioning of the system, the input signals of the control system participate in the formation of the output signals. The latter is due to the presence of information in the elements that are memorized. As a result, the control system can be considered as a display of the Cartesian transformation of input signals X and a set of internal states Z, a set of output signals Y:

$$S : X \times Z \to Y \ldots \qquad (3)$$

In the considered control system, a number of sequential decision-making levels are distinguished, at each of which information is processed, which comes from the elements of the lower level. Their goal is to develop coordinating actions for the elements of this level. The point of allocation of decision-making levels is made in accordance with the vertical decomposition of the control system. Based on the results of modeling the modes and in accordance with [3,4], the following control levels have been identified in the power supply and lighting systems of cities: lighting control point, TP, RP, SS 35-110 kV and the city lighting system as a whole. Each of them has its own duration, criteria and control parameters. Allocation of functional tasks, the solution of which is not related to other tasks of this level, the horizontal decomposition of the control system is responsible. The horizontal decomposition of the lower levels of the control system corresponds to the allocation of local control systems, which can be controlled in an autonomous mode. The number of local control systems is determined by the structure of networks, technical content and territorial location of its elements. The functioning of local systems is determined by the control algorithm, which characterizes the sequence of operations and the transformation of an input signal into an output signal. At the same time, information transformation operations can be considered as algorithmic functions, which are a kind of modules from which a control algorithm can be added. First of all, this applies to standard elements that perform certain algorithmic functions. The signs of the typification of the control system of its elements can be their orientation, information power, target orientation, and so on. In the work, for the typification of control systems and its elements, an objectively oriented feature was adopted, which provides the possibility of statistical analysis and forecasting of the development of the RM control system, the management of individual objects, as well as the most accurate state of the list of necessary algorithmic functions, to assess the composition of the control system parameters, to formulate the basic requirements for technical means. Under these conditions, the concept of a typical control system is reduced to a typical functional structure of a control system, which can be represented by the display:

$$F : X \times \bar{f} \rightarrow У \ , \qquad (4)$$

where F is a set of algorithmic functions.

The general regularities of the functioning of control systems considered determine the basic requirements for the algorithms for the functioning of local control systems. Further detailing of the operation algorithm of the control system can be performed using their contour decomposition, which is based on the presence in the local control system of several nodes for collecting and processing information, connected in a certain way by active elements. At the same time, decision-making in the developed control system is based on a multilayer principle, according to which a complex control problem is divided into a family of sequentially connected more substantive problems. In decision making, each previous layer forms the basis for decision making in the next layer. Solving a problem, in general, is a consistent solution to its constituent problems. This corresponds to the time distribution of the operation for controlling the parameters of the network mode. At the same time, the information nodes, carrying out a cyclical exchange of information between the load nodes and the active elements, in each cycle use additional information that is obtained over longer time intervals. As such, signals from active elements, various kinds of static data, and so on are used.

Analysis of typical structures of a control system using its contour decomposition allows us to identify a subset of algorithmic functions, the use of which ensures the solution of problems of control of technological processes of transmission and conversion of electricity in urban lighting systems. Such as:

- regulation: collection, processing of data, formation and issuance of commands that control, in order to stabilize individual parameters of the technological process or change them according to a given law;

- information transfer: data preparation and implementation of exchange protocols with adjacent and higher-level systems;

-logical control: control of discrete and continuous executive bodies according to a given or reconfigurable program, depending on the state of the technological process;

- display of technological information:

indication, data logging, manual input of instructions, commands and data.

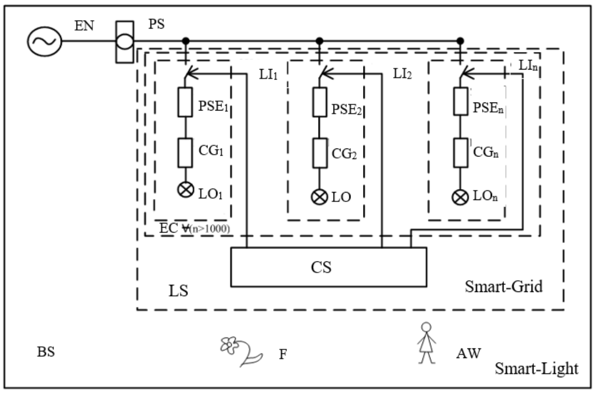


Fig. 3. *Biotechnical lighting system.*

* *EN - electrical network, PS - power source, PSE - protective and switching equipment, control gear ~ starting and control equipment, LO - light sources, LI - lighting installations, EC - electrical complex, CS - control system. LS - lighting system, F - flora, AW - animal world, BS - biotechnical system.*

CONCLUSION

Thus, the proposed concept of controlling the modes of lighting systems allows us to take into account their features associated with taking into account the color-light effect of lighting on the animal and plant world, as well as adjacent systems of a higher level - electric power systems and networks. In such conditions, the presence of the noted features makes it necessary to separate the lighting systems of cities into an independent Smart-Light system of a higher level, combining the Smart-Grid system and the city's life support system as a whole. The structure of such a system is shown in Figure 3. It includes an energy system, a power supply system, representing a set of lighting installations with a control system, built on the basis of the Smart-Grid concept, as well as an electric lighting system as an integral part of the city's life support system.

The application of the considered basic provisions allows us to return to the main goal of creating technical systems - to meet the human demand for a comfortable living environment as a means of human life support.

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