THE ROLE OF SMART GRID TECHNOLOGIES IN IMPROVING ENERGY EFFICIENCY OF ELECTRICAL NETWORKS

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Abstract. The increasing demand for electricity and the growing number of electrical consumers require the introduction of modern technologies for efficient management of power systems. Traditional electrical networks often experience technical losses, equipment overloads, insufficient monitoring, and delays in detecting faults. Smart Grid technologies provide new opportunities to improve the efficiency, reliability, and controllability of electrical networks through digital monitoring, automated control, and real-time data analysis. This article examines the role of Smart Grid technologies in improving energy efficiency in electrical distribution networks. Particular attention is paid to smart meters, automated monitoring systems, Internet of Things technologies, SCADA systems, and intelligent control mechanisms.

Keywords: Smart Grid, energy efficiency, electrical networks, electricity losses, smart meter, digitalization, SCADA, IoT, power supply, intelligent control.

The continuous growth of electricity consumption has become one of the important challenges facing modern energy systems. The development of industry, agriculture, construction, transport, and residential infrastructure leads to an increase in the number of electricity consumers and the load on existing electrical networks. At the same time, a considerable part of electrical distribution infrastructure in many regions has been operated for several decades. Aging equipment, insufficient monitoring, overloads, and inefficient operating modes can result in significant energy losses and reduced reliability of electricity supply.

Smart Grid as a modern approach to energy management. A Smart Grid can be considered an intelligent electrical network capable of monitoring its own operating condition and supporting automated decision-making. Unlike conventional electrical networks, which mainly operate according to predetermined control principles, Smart Grid systems use real-time information to respond to changes in electricity demand and network conditions.

The basic elements of a Smart Grid include:

- *intelligent electricity meters;*
- *IoT sensors;*
- *communication networks;*
- *SCADA systems;*

- *automated control devices;*
- *data processing systems;*
- *analytical and decision-support software.*

The integration of these components allows electricity network operators to obtain information about voltage, current, power consumption, equipment condition, and other important parameters.

Reduction of electricity losses. One of the main objectives of Smart Grid implementation is the reduction of electricity losses. Losses may occur because of the technical characteristics of transmission and distribution equipment, overloaded transformers, inappropriate operating modes, and outdated infrastructure.

Real-time monitoring allows operators to identify sections of the network where abnormal energy consumption or increased losses occur. Smart meters can provide detailed information about electricity consumption, while IoT sensors can monitor technical parameters of equipment. The collected data can then be analyzed to identify inefficient operating conditions. Based on this information, network operating modes can be adjusted, loads can be redistributed, and appropriate technical measures can be implemented.

Smart meters and energy efficiency. Smart meters represent one of the most accessible elements of Smart Grid implementation. Traditional meters mainly record electricity consumption, whereas smart meters can transmit information automatically to a central monitoring system.

This creates several advantages. First, electricity consumption can be monitored remotely. Second, abnormal consumption can be detected more quickly. Third, detailed consumption data can be used to analyze load patterns.

For consumers, the availability of accurate consumption information can also encourage more rational electricity use. For electricity suppliers and network operators, smart meters provide a valuable source of data for planning and operational management.

The modernization of electrical networks in developing settlements requires consideration of existing infrastructure, available financial resources, and local energy consumption patterns. In such conditions, complete replacement of the existing network may be economically difficult. A more practical approach is the gradual introduction of digital technologies. For example, the modernization process can begin with the installation of smart meters and IoT sensors at strategically important network facilities. The next stage can involve integration with SCADA and the creation of a centralized monitoring system. Finally, intelligent analytical and control functions can be introduced.

Conclusion. Smart Grid technologies provide significant opportunities for improving the energy efficiency and reliability of electrical networks. The combination of smart meters, IoT sensors, SCADA systems, communication technologies, and intelligent control enables continuous monitoring and more effective management of electricity networks. The use of real-time information makes it possible to identify energy losses, detect abnormal operating conditions, optimize network modes, and improve equipment

management. For settlements with aging electrical infrastructure, digital modernization can represent a practical approach to improving the quality and reliability of electricity supply. Therefore, the implementation of Smart Grid technologies should be considered not only as a technological modernization process but also as an important mechanism for achieving long-term energy efficiency and resource savings.

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