

TRANSMISSION OF ELECTRIC POWER THROUGH ELECTRICAL NETWORKS AND OVERHEAD POWER LINES

Sharbiddinov Saydullo

Andijan state technical institute Assistant department of “Alternative Energy Sources”.

Begijonov Axrorbek

Andijan state technical institute 4th year student of the direction of
“Energy Efficiency and Energy Audit”.

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***Abstract.** This article describes the functions of electrical networks, the processes of transmitting electrical energy from generation to consumers, as well as the structural design and operating principles of overhead power transmission lines (OPTL). The reliability of power supply, power quality, classification of consumers, and the main technical elements used in transmission lines are analyzed. The transmission of electric power through electrical networks and overhead power lines (OHLs) plays a fundamental role in modern power systems, ensuring the reliable and efficient delivery of electricity from generation sources to consumers.*

With the continuous growth of electricity demand and the integration of renewable energy sources, transmission systems must operate under increasingly complex technical and environmental conditions. This study examines the principles, structure, and operational characteristics of electric power transmission through high-voltage electrical networks and overhead transmission lines. Special attention is given to power losses, voltage regulation, stability issues, and environmental impacts. The technical advantages and limitations of overhead power lines are analyzed in comparison with alternative transmission technologies.

Furthermore, modern improvements such as high-voltage alternating current (HVAC), high-voltage direct current (HVDC), and smart grid technologies are discussed. The results demonstrate that optimized network configuration, proper conductor selection, reactive power compensation, and digital monitoring systems significantly improve transmission efficiency and reliability. The findings provide a theoretical and practical foundation for enhancing long-distance electric power transmission systems.

***Key words:** Electrical networks, electrical energy, overhead lines, transmission system, reliability, voltage quality, insulator, support, conductor.*

INTRODUCTION

Electrical networks serve to deliver electrical energy from generation sources to consumers and to distribute it among them. A number of key requirements are imposed on power supply systems: reliability, power quality, economic efficiency, safety, ease of operation, and the possibility of system expansion.

Electrical networks serve to transmit electrical energy from generation sites to the locations of consumers and to distribute it among them. In this regard, five main requirements are imposed on electrical networks: operational reliability, quality, efficiency (economic feasibility), safety and ease of operation, and the possibility of future expansion.

Operational reliability: by the reliability of electrical networks, we mean the uninterrupted supply of high-quality electrical energy to consumers for the required period of time.

According to the Rules for Electrical Installation Design (EID), all electricity consumers are conventionally divided into three main categories based on their reliability requirements.

The first category includes such consumers that, in the event of a power supply interruption, may pose a danger to human life, cause significant economic damage, lead to damage of technical equipment, result in mass production of defective products, disrupt complex technological processes, and affect important elements of urban infrastructure.

The second category includes consumers for whom a power supply interruption leads to reduced production output, stoppage of production mechanisms and industrial transport, and disruption of normal living conditions for a large part of the urban population. The rapid development of industry, urbanization, and digital technologies has led to a continuous increase in global electricity demand. Efficient transmission of electric power from generation stations to distribution systems is essential for maintaining economic stability and energy security. Electrical networks and overhead power lines form the backbone of modern power transmission infrastructure.

Electric power transmission involves transferring large amounts of electrical energy over long distances using high-voltage systems to minimize energy losses. Overhead transmission lines are the most widely used method due to their economic efficiency, ease of maintenance, and flexibility in large-scale deployment. However, they are also exposed to environmental conditions such as wind, temperature variations, lightning, and pollution, which affect operational reliability.

Transmission efficiency depends on several factors, including conductor resistance, voltage level, reactive power flow, network topology, and system stability. Increasing transmission voltage significantly reduces current and, consequently, resistive losses (I^2R losses).

Therefore, modern systems operate at voltages ranging from 110 kV to 750 kV and above.

This study aims to analyze the technical principles, structural components, operational challenges, and performance optimization methods of electric power transmission through electrical networks and overhead lines.

The third category includes less critical consumers, such as small workshops producing non-serial products, small villages, small enterprises, and similar facilities.

According to the rules for the design of electrical installations, electricity consumers are divided into three categories:

- Category 1 – facilities where power outages may endanger human life and cause significant economic damage;
- Category 2 – consumers for whom interruptions in power supply significantly affect production processes;
- Category 3 – consumers with relatively low responsibility.

Consumers of the first category must be supplied by at least two independent power sources. For the second and third categories, a certain duration of power interruption is permitted.

The reliability of power supply depends not only on backup sources but also on relay protection and automation systems.

Voltage Value. A decrease or increase in voltage from the required level is undesirable.

Voltage variation depends on changes in the electromotive force of generators or load fluctuations, which affect voltage losses in electrical networks. In incandescent lamps and other lighting sources, a decrease in voltage leads to reduced illumination and other unfavorable effects.

An increase in voltage shortens the service life of lamps. Thus, both an increase and a decrease in voltage result in economic losses. The minimum economic loss occurs at the optimal voltage level.

Overhead power transmission lines (OHL) are used to transmit electrical energy over distances by means of conductors. The main structural elements of OHL include conductors, ground wires, supports, insulators, and line fittings. Conductors serve to transmit electrical energy.

Ground wires are installed at the top of the supports to protect the overhead line from atmospheric overvoltages (such as lightning).

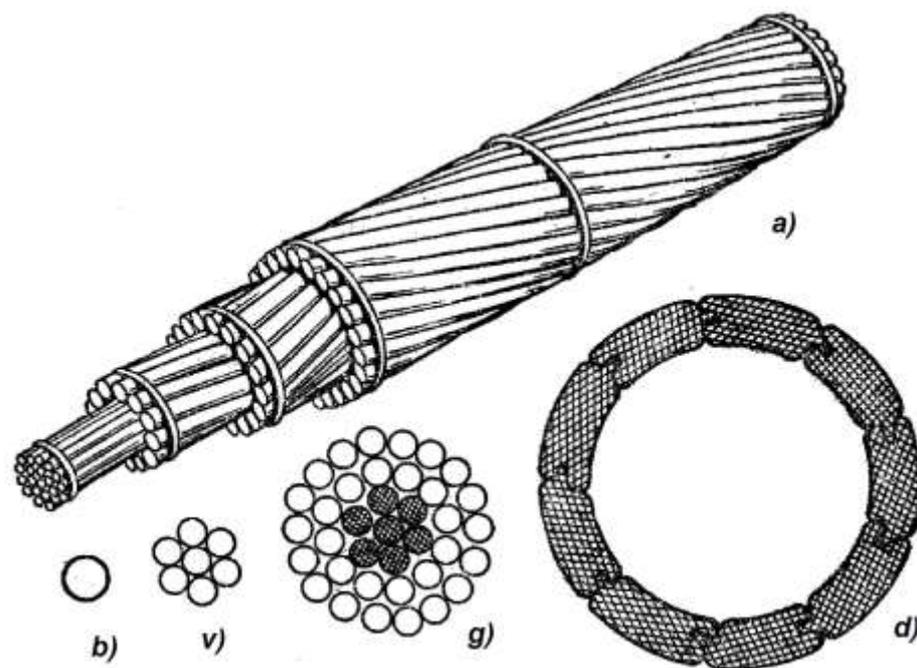


Figure 1. Structure of overhead line (OHL) conductors

a) general view of a stranded conductor;

b) single-wire conductor — four to five conductors are used, and at 1150 kV — eight to twelve conductors are used.

The quality of electrical energy is determined by voltage and frequency stability, phase symmetry, and the waveform of the voltage curve. An increase or decrease in voltage negatively affects lighting devices, technological equipment, and other electrical installations.

Overhead power transmission lines play an important role in transmitting electrical energy over long distances. Their main elements include conductors, ground wires, supports, insulators, and fittings.

LITERATURE REVIEW

Numerous studies have investigated electric power transmission technologies, focusing on efficiency improvement, loss reduction, and system reliability enhancement.

Research on high-voltage transmission systems emphasizes the importance of increasing transmission voltage levels to reduce line losses and improve power transfer capability.

High-Voltage Alternating Current (HVAC) systems remain dominant worldwide due to their compatibility with existing infrastructure. However, High-Voltage Direct Current (HVDC) technology has gained importance for long-distance and submarine transmission due to lower losses and better controllability. Several authors have analyzed power losses in overhead transmission lines, identifying conductor resistance, corona discharge, and dielectric losses as major contributors. Advanced conductor materials such as aluminum conductor steel reinforced (ACSR) and high-temperature low-sag (HTLS) conductors have been proposed to enhance performance. Recent literature also focuses on smart grid integration, digital monitoring systems, and real-time fault detection using SCADA and IoT-based technologies. These innovations improve reliability and reduce outage duration.

Environmental studies highlight the impact of electromagnetic fields (EMF), visual pollution, and land use constraints associated with overhead lines. Comparative analyses between overhead and underground transmission systems indicate that overhead lines are more cost-effective but more vulnerable to environmental factors. Overall, previous research confirms that optimizing network configuration, improving insulation systems, and implementing reactive power compensation significantly enhance transmission efficiency.

DISCUSSION

The structural components of overhead lines operate under the influence of mechanical and climatic factors. Conductors may deform due to wind, ice loads, temperature changes, and their own weight. These factors can lead to breakage of line elements or damage to insulation.

When selecting conductor materials, electrical conductivity and mechanical strength are the main criteria. Although copper has high conductivity, aluminum and steel-reinforced aluminum conductors are widely used in practice because they are relatively lightweight and economically efficient.

The main elements of overhead lines include:

- Conductors – transmit electrical energy;
- Supports – hold conductors at a certain height;
- Insulators – provide electrical insulation;
- Fittings – fasten and connect structural elements.

Electric power transmission through overhead lines involves complex electromagnetic, mechanical, and thermal processes. The efficiency of transmission depends primarily on voltage level, conductor characteristics, line length, and load conditions.

One of the main technical challenges in overhead transmission lines is power loss.

Resistive losses occur due to conductor resistance and increase proportionally with the square of current.

Therefore, high-voltage transmission is essential for reducing current and minimizing energy losses. Corona losses also occur at very high voltages due to ionization of surrounding air, especially under humid conditions.

Voltage stability is another critical factor. Long transmission lines experience voltage drops and reactive power imbalances.

Compensation devices such as capacitor banks, reactors, and FACTS (Flexible AC Transmission Systems) devices are widely used to maintain voltage regulation.

Mechanical reliability is equally important. Overhead lines are subjected to wind loads, ice accumulation, thermal expansion, and lightning strikes. Proper tower design, conductor tension calculation, and grounding systems are required to ensure operational stability. Modern digital monitoring systems enable real-time diagnostics of line temperature, sag, and fault location. Smart sensors and automated protection relays improve system response during disturbances. Compared to underground cables, overhead lines are more economical and easier to repair. However, they are more exposed to environmental and climatic risks. The selection between HVAC and HVDC transmission depends on distance, capacity, and economic considerations. HVDC systems show superior performance for distances exceeding 600–800 km.

CONCLUSION

Electrical networks are a key component of modern energy systems and play an important role in ensuring the continuous, high-quality, and safe delivery of electrical energy. To increase the reliability of power supply, it is necessary to use backup sources, automatic control systems, and relay protection.

Overhead power transmission lines are one of the most effective means of transmitting electrical energy over long distances. Proper selection and operation of their structural elements ensure system stability and economic efficiency. In the future, the modernization of electrical networks, improvement of power quality, and enhancement of transmission efficiency will remain among the most important tasks in the energy sector.

The transmission of electric power through electrical networks and overhead power lines remains a cornerstone of modern energy systems. High-voltage transmission significantly reduces power losses and improves efficiency in long-distance electricity delivery. This study confirms that transmission performance depends on voltage level, conductor material, network configuration, and reactive power control. Overhead transmission lines provide cost-effective and flexible solutions, although they require careful design to withstand environmental impacts.

Advanced technologies such as HVDC systems, smart grid integration, and digital monitoring tools substantially enhance transmission reliability and operational efficiency. Future developments should focus on improving conductor materials, implementing intelligent monitoring systems, and integrating renewable energy sources into high-voltage networks. The findings contribute to the theoretical understanding and practical optimization of electric power transmission systems, supporting sustainable and reliable energy infrastructure development.

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