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THE IMPORTANCE OF IMPROVING THE STRUCTURAL DESIGN OF HIGH-VOLTAGE OVERHEAD TRANSMISSION LINES

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Abstract. This article analyzes the scientific and technical foundations for improving the structural design of high-voltage overhead transmission lines. During the study, the main structural factors affecting the operational reliability of high-voltage electric transmission networks, support tower structures, material selection criteria, and technological stages of manufacturing were investigated. Particular attention was given to evaluating the influence of using welded steel support structures on mechanical strength, corrosion resistance, and economic efficiency.

In addition, wind loads, icing effects, geometric parameters, and structural configurations of support towers were analyzed, and improved solutions aimed at increasing the stability and reliability of power transmission systems were substantiated.

Based on the research findings, scientific and practical recommendations were developed to optimize the structural elements of high-voltage overhead transmission lines, reduce metal consumption, and extend service life.

Keywords: high-voltage overhead transmission line, steel support structure, welding technology, structural optimization, wind load, corrosion protection, operational reliability, power system.

INTRODUCTION

Today, the electric power industry is considered one of the strategic sectors of the economy. High-voltage overhead transmission lines (HVOTLs) serve as one of the main components of energy infrastructure for transmitting electrical energy over long distances. The efficiency and uninterrupted operation of these systems largely depend on the strength and operational stability of their supporting structures.

High-voltage overhead transmission lines make it possible to transmit electrical energy with minimal losses and are considered more economically efficient compared to underground cable systems. As the voltage level increases, energy losses decrease and transmission distance increases.

Steel support towers are the primary load-bearing elements of overhead transmission systems and must withstand wind pressure, icing conditions, conductor tensile forces, temperature variations, and external environmental impacts. Therefore, improving structural design is considered one of the important directions in the development of modern energy systems.

The purpose of this study is to evaluate the technical and economic efficiency of improving the structural design of high-voltage overhead transmission lines and to develop optimal structural solutions.

MATERIALS AND METHODS

During this study, theoretical analysis, structural comparison, materials science analysis, and engineering calculation methods were employed to evaluate the technical and technological aspects of improving the structural design of high-voltage overhead transmission lines. The research object was defined as welded steel support tower structures used for high-voltage transmission networks and their manufacturing technology.

In the study, the initial data used for designing support structures of high-voltage overhead transmission lines were classified into four main groups:

regulatory and standard requirements;
climatic and geographical loads;
technical parameters of the power transmission network;
geometric and structural parameters.

At the first stage of the research, the structural configurations of existing high-voltage support towers were investigated. Suspension, anchor, angle, terminal, and transposition towers were analyzed according to their functional characteristics and load-bearing capabilities. It was determined that the selection of the tower type directly affects the operational reliability of the transmission line.

At the second stage, material selection criteria for steel support structures were evaluated. The application of high-strength structural steels, including S355JR and St3sp5 steel grades, was considered for structural elements. Yield strength, corrosion resistance, and long-term operational performance were adopted as the main criteria for material selection.

At the third stage of the study, external loads affecting the support structure were analyzed. Wind pressure, ice loading, conductor tensile forces, and the self-weight of the structure were included in the overall loading system. Wind load was considered the main parameter in structural calculations, and the aerodynamic behavior of the support structure was evaluated.

For evaluating the manufacturing technology of steel structures, the following technological sequence was adopted:

Stage 1 – preparation and cutting of steel elements;
Stage 2 – forming and assembly of structural components;
Stage 3 – execution of welding operations;
Stage 4 – inspection and control of welded joints;
Stage 5 – application of corrosion protection;
Stage 6 – preparation of the completed structure for installation.

In assessing the quality of welded joints, the application of non-destructive testing (NDT) methods was analyzed. In particular, the role of Visual Testing (VT), Ultrasonic Testing (UT), and Radiographic Testing (RT) in improving operational reliability was evaluated.

The criteria used for evaluating technological efficiency included metal consumption, production cost, ease of installation, corrosion resistance, and service life indicators.

RESULTS

The results of the conducted research demonstrated that improving the structural design of high-voltage overhead transmission lines has a significant impact on the operational reliability and economic efficiency of electric power transmission systems. The analysis confirmed that optimization of the structural parameters of steel support towers enables more efficient load distribution, reduction of deformations, and extension of service life.

During the study, the operational characteristics of various structural configurations were evaluated. The results showed that welded steel support structures offer greater rigidity, lower structural mass, and improved manufacturability compared to conventional assembled structures. It was determined that reducing the number of joints through the use of welded elements contributes to improving the overall structural stability.

Analysis of wind and ice loads indicated that uniform redistribution of loads within the tower structure reduces the formation of localized stresses. In particular, increasing the spatial rigidity of support towers in high-elevation transmission lines was identified as an important factor in ensuring structural safety. The improved structural configuration made it possible to reduce the amplitude of tower deflection under wind pressure.

According to the material selection results, the use of high-strength structural steels allows not only a reduction in metal consumption but also optimization of overall structural weight. Proper selection of steel grades was found to have a positive effect on weldability, corrosion resistance, and long-term operational performance.

The evaluation of manufacturing technology demonstrated that technological accuracy during the preparation, assembly, and welding stages of steel elements is one of the key factors determining the quality of the final structure. It was found that weld quality control and the application of corrosion-protective coatings significantly improve operational reliability.

In addition, it was established that improving manufacturing and installation technologies can reduce construction time and lower operating costs. The results confirmed that the application of modern steel support structures for high-voltage overhead transmission lines is both technically and economically justified.

DISCUSSION

The obtained results demonstrated that improving the structural elements of high-voltage overhead transmission lines plays an important role in ensuring the uninterrupted and safe operation of power systems. During the research, it was determined that the geometry of support structures, material properties, and manufacturing technology collectively influence the overall operational efficiency of electric transmission lines.

The analysis showed that replacing conventional steel support structures with welded spatial structures makes it possible to reduce structural mass, improve load redistribution efficiency, and simplify installation processes. At the same time, maintaining high quality standards for welded joints was identified as an essential factor in ensuring operational safety.

For structures operating under wind and ice loading conditions, increasing geometric rigidity ensures structural stability and reduces the risk of failure. In particular, minimizing spatial deformations in high-elevation support structures has a positive effect on maintaining the uninterrupted operation of electric power transmission systems.

Furthermore, the implementation of automated cutting, welding, and inspection methods in manufacturing technology provides opportunities to increase production efficiency and ensure stable quality. Therefore, the application of modern structural and technological approaches can be considered one of the priority directions for the development of energy infrastructure.

CONCLUSION

The results of the conducted research demonstrated that improving the structural design of high-voltage overhead transmission lines is one of the key factors in increasing the technical, economic, and operational efficiency of electric power transmission systems. The findings confirmed that the relationship between the geometric parameters of support structures, material composition, and manufacturing technology has a significant impact on the overall reliability of the system.

Based on the conducted analysis, it was determined that the use of welded steel support structures ensures high mechanical strength, structural rigidity, and manufacturing efficiency. It was substantiated that optimization of structural configurations makes it possible to reduce metal consumption, improve installation convenience, and extend service life.

The developed structural solutions, taking into account wind and ice loading conditions, were shown to enhance the spatial stability of support towers and reduce the risk of emergency situations. At the same time, improving corrosion protection technologies and implementing quality control procedures for welded joints were confirmed as essential conditions for increasing operational reliability.

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Based on the research results, scientific and practical recommendations were formulated for the development of modern steel support structures and the improvement of manufacturing technologies for high-voltage overhead transmission lines. The proposed approaches may contribute to increasing the efficiency and operational stability of electric power transmission systems in energy enterprises.

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