IMPROVING ENERGY EFFICIENCY AND RELIABILITY IN DISTRIBUTION ELECTRIC NETWORKS THROUGH THE MODERNIZATION OF CABLE LINES

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ABSTRACT

This thesis examines the improvement of energy efficiency and reliability in distribution electric networks through the modernization of cable lines. The study focuses on 10/0.4 kV cable lines supplying consumers from a transformer substation and considers their technical condition, service life, current load, voltage drop and factors that influence emergency failures. The relevance of the research is associated with the growth of electrical loads in urban distribution networks, the aging of insulation systems and the need to reduce technical energy losses. The paper substantiates the importance of selecting an appropriate cable cross-section, verifying long-term current-carrying capacity, limiting voltage drop and assessing the economic feasibility of modernization measures. The results show that timely replacement and modernization of cable lines can reduce power losses, decrease the number of outages, improve voltage quality at consumer terminals and increase the operational stability of the distribution network.

Keywords: distribution network, cable line, modernization, energy efficiency, technical losses, reliability, voltage drop, current load.

INTRODUCTION

The reliability and energy efficiency of a power supply system largely depend on the technical condition of distribution electric networks. Networks with voltage

levels of 10/0.4 kV represent the final and most sensitive stage of power delivery, because they directly supply residential, municipal and small commercial consumers. Any fault in such networks may lead to interruptions in electricity supply and may negatively affect the quality of service provided to consumers.

In recent years, the increase in electricity consumption in urban areas has been driven by the growing number of household appliances, wider use of air-conditioning and electric heating equipment, and the connection of additional consumers to existing low-voltage networks. As a result, many cable lines that were designed for lower loads no longer fully correspond to current operating conditions. Long-term operation also accelerates insulation aging, increases the probability of mechanical damage and raises the risk of moisture penetration into cable structures.

Therefore, the modernization of cable lines should not be considered only as a repair activity after failures occur. It is a preventive and technically justified measure aimed at reducing losses, improving voltage quality and increasing the reliability of power supply. The purpose of this thesis is to substantiate the technical and economic significance of cable line modernization in distribution networks as a means of improving energy efficiency and reliability.

RESEARCH METHODOLOGY

The study is based on an engineering analysis of cable lines in a 10/0.4 kV distribution network. The methodological approach includes the assessment of technical condition, comparison of actual operating periods with normative service life, analysis of current loads, verification of voltage drops and evaluation of modernization options. The following criteria are used for selecting the cable cross-section and justifying the modernization solution:

- economic current density;
- long-term permissible current and thermal stability;
- allowable voltage drop;

• mechanical protection and suitability for underground installation;

• reduction of the number of joints and cable accessories;

• expected decrease in maintenance and emergency repair costs.

Such an integrated approach makes it possible to select a cable line that is not only technically reliable, but also economically justified over its service life.

MAIN PART

Cable lines are one of the key elements of distribution electric networks. Their technical condition affects not only the ability to transmit electricity, but also the voltage quality at consumer terminals, the number of emergency outages and the total operating costs of the network. When the cable insulation loses its dielectric strength, or when the number of cable joints increases, the probability of faults becomes considerably higher.

The need for cable line modernization is determined by several factors. First, many distribution networks contain cable lines that have been operated for a long period. With increasing service life, the insulation system gradually deteriorates, and the protective sheath becomes more vulnerable to mechanical and thermal effects. Second, the growth of current loads increases the thermal stress of conductors and accelerates insulation degradation. Third, connecting and terminating joints are among the most vulnerable parts of a cable route; therefore, a high concentration of joints reduces the overall reliability of the line.

For the considered modernization case, the recommended technical solution includes the use of AABl-1 4x50 mm² cable for 0.4 kV lines and AABl-10 3x240 mm² cable for 10 kV lines. These cables are selected with regard to permissible heating conditions, voltage drop limits and underground installation requirements. The armored construction increases mechanical protection in soil and contributes to longer service life under urban operating conditions.

Figure 1 illustrates the structural composition of the recommended 0.4 kV and 10 kV cable types. The main layers include aluminium conductors, paper insulation, an aluminium sheath, steel tape armor and an outer protective sheath. The visual representation helps to substantiate the proposed modernization solution and demonstrates why armored cable designs are suitable for underground distribution networks.

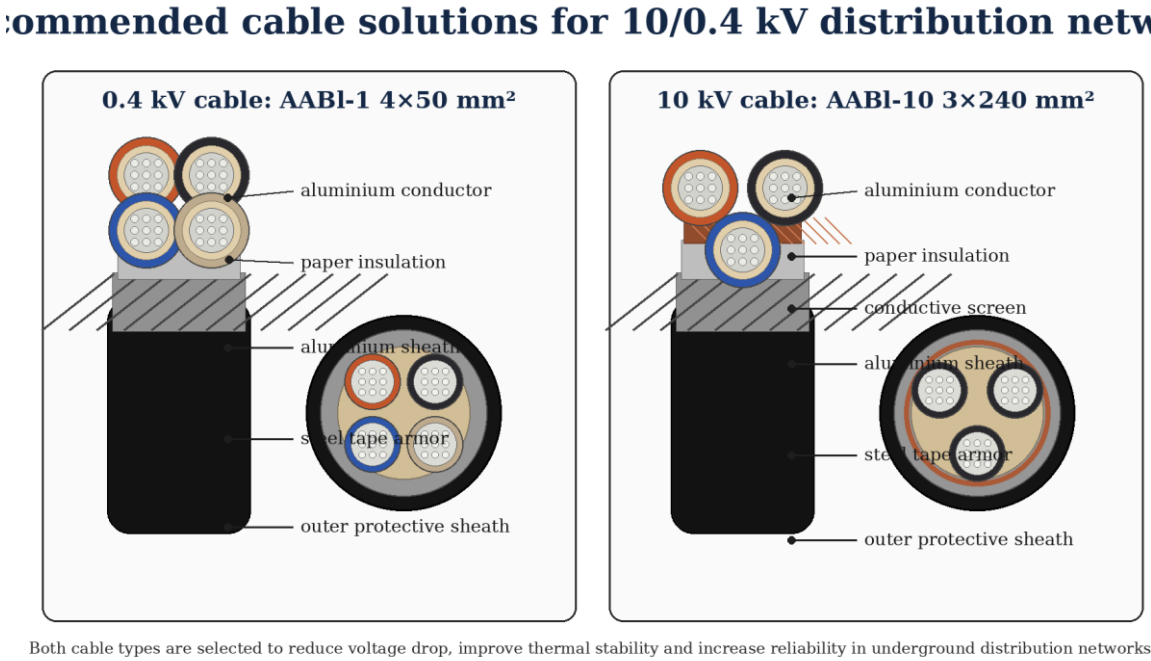


Figure 1. Recommended cable solutions for 10/0.4 kV distribution networks

COMPARATIVE TECHNICAL ASSESSMENT

The technical effect of modernization can be described through the comparison of key operating indicators before and after cable replacement. The values in Table 1 are presented as generalized engineering indicators for the considered 10/0.4 kV distribution network and reflect the expected improvement in operating performance after modernization.

Table 1. Generalized comparison of distribution cable line indicators before and after modernization

Parameter	Before modernization	After modernization	Expected effect

Technical losses in cable lines	Higher due to increased resistance and aging	Reduced due to optimal cross-section	Lower energy losses
Voltage drop	May approach the permissible limit	Within normative limits	Improved voltage quality
Emergency outages	More frequent because of aged insulation and joints	Less frequent owing to new cable routes	Higher reliability
Maintenance costs	High because of repeated repairs	Reduced during the initial service period	Lower operating costs
Expected service life	Limited residual resource	Long-term operation under normal conditions	Improved asset sustainability

RESULTS AND DISCUSSION

The analysis confirms that the modernization of cable lines in distribution networks is an effective measure for improving both energy efficiency and reliability. Selecting a cable cross-section according to economic current density, long-term permissible current and voltage drop requirements reduces active resistance and decreases technical power losses. At the same time, the use of mechanically protected cable designs improves operational stability in underground installation conditions.

A significant reliability effect is achieved by reducing the number of joints along the cable route. Since joints are among the most failure-prone components of cable systems, their reduction decreases the probability of insulation breakdown, moisture ingress and contact overheating. From an economic point of view, modernization requires initial capital investment; however, it provides a return through lower emergency repair costs, reduced losses and improved continuity of supply.

CONCLUSION

The modernization of cable lines in distribution electric networks is a technically and economically justified measure for improving energy efficiency and power supply reliability. The assessment of cable condition, current loading, voltage drop and operating environment allows the selection of technically appropriate and economically efficient cable solutions.

The study shows that replacing cable lines with limited residual service life by properly selected modern cable solutions creates the opportunity to reduce technical energy losses, decrease the number of emergency outages and improve the quality of electricity supplied to consumers. Therefore, systematic assessment and timely modernization of cable lines should be considered an important direction in the development of reliable and energy-efficient distribution networks.

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