INCREASING ENERGY EFFICIENCY OF 0.4 KV FEEDERS OF TP-142 TRANSFORMER SUBSTATION BASED ON THE ANALYSIS OF ELECTRICAL ENERGY LOSSES

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Abstract

The efficient use of electrical energy is one of the key priorities in modern power systems. Distribution networks, especially low-voltage 0.4 kV feeders, often experience considerable technical and non-technical losses that reduce overall system efficiency. This study analyzes electrical energy losses in the 0.4 kV feeders of the TP-142 transformer substation and proposes practical measures for improving energy efficiency. The research applies analytical, comparative, and statistical methods to evaluate energy losses in the distribution network. The results show that conductor resistance, load imbalance, outdated equipment, and inefficient operational practices significantly contribute to energy losses. Based on the analysis, several optimization strategies are proposed, including feeder load balancing, replacement of aging conductors, reactive power compensation, and implementation of modern monitoring systems. The results demonstrate that applying these measures can significantly reduce electrical losses and improve the overall performance and reliability of the distribution network.

Introduction

Energy efficiency in electrical distribution systems has become a critical issue worldwide. With increasing electricity demand and limited energy resources,

reducing electrical losses in power networks is essential for sustainable development. In many countries, a significant portion of electrical energy losses occurs in low-voltage distribution networks, particularly in 0.4 kV feeders connected to transformer substations.

Transformer substations serve as the central nodes of electrical distribution systems. They convert medium voltage electricity into low voltage levels suitable for residential, commercial, and industrial consumers. However, inefficiencies in feeder lines, outdated equipment, and improper network configuration often lead to unnecessary energy losses.

The TP-142 transformer substation is a typical example of a local distribution point supplying electricity to several residential and small industrial consumers. Over time, increasing load demand and aging infrastructure may result in higher energy losses in the feeders connected
to the substation. Therefore, analyzing the sources of these losses and identifying effective methods to reduce them is essential.

The objective of this study is to analyze electrical energy losses in the 0.4 kV feeders of the TP-142 transformer substation and develop recommendations for improving energy efficiency. The study focuses on identifying the main factors influencing energy losses and proposing
technical solutions that can be implemented in similar distribution networks.

Literature Review

Numerous studies have investigated electrical energy losses in distribution networks and methods for improving efficiency. Researchers generally classify losses into two categories: technical losses and non-technical losses.

Technical losses occur due to the physical characteristics of electrical components such as conductors, transformers, and switches. These losses are mainly caused by resistance in conductors, magnetic losses in transformers, and inefficient system operation. According to several international studies, technical losses in distribution networks can range between 5% and 12% depending on network condition and operational practices.

Non-technical losses are associated with electricity theft, metering inaccuracies, and administrative inefficiencies. Although these losses are not directly related to equipment performance, they significantly affect overall energy efficiency.

Many researchers emphasize that the largest portion of technical losses in low-voltage networks occurs in distribution feeders. Long feeder lengths, overloaded conductors, and unbalanced phase loads increase current flow and consequently increase I^2R losses.

Modern approaches to reducing energy losses include network reconfiguration, conductor replacement, installation of capacitors for reactive power compensation, and implementation of smart monitoring systems. Several studies also highlight the importance of automated
metering infrastructure (AMI) and digital monitoring platforms for identifying inefficiencies in real time.

Despite the extensive research in this field, many local distribution networks still operate with outdated infrastructure and lack systematic monitoring. Therefore, practical case studies focusing on specific transformer substations are necessary to develop targeted solutions for energy efficiency improvement.

Methodology

This research applies a case study approach focusing on the TP-142 transformer substation and its connected 0.4 kV feeders. The methodology includes data collection, loss calculation, and analysis of operational conditions.

Data collection was carried out using operational records from the distribution network, including feeder load data, conductor parameters, and transformer characteristics. The analysis also considered feeder length, conductor cross-section, and daily load variations.

Electrical losses in feeders were estimated using standard power loss calculation formulas based on conductor resistance and current magnitude. The general relationship between power loss and current flow indicates that losses increase proportionally to the square of the current passing through the conductor.

Field observations were also conducted to evaluate the physical condition of the network, including conductor aging, connection quality, and load distribution across phases. Additionally, interviews with maintenance personnel helped identify operational issues that may contribute to inefficiencies.

The collected data were processed using comparative and statistical analysis methods. Different feeders were compared in terms of load level, length, and estimated losses in order to identify the most inefficient sections of the network.

Based on the analytical results, possible technical solutions for reducing energy losses were evaluated. These solutions were assessed according to their feasibility, cost implications, and expected efficiency improvement.

Results

The analysis of the TP-142 transformer substation feeders revealed several important findings. First, the level of electrical energy losses in some feeders was

significantly higher than the recommended values for low-voltage distribution networks.

One of the primary causes of losses was the high resistance of aging conductors. Many feeder lines were installed several decades ago and no longer meet modern efficiency standards. The relatively small cross-section of these conductors increases electrical resistance and consequently increases I^2R losses.

Another factor contributing to energy losses was uneven load distribution between phases. In several feeders, one phase carried a substantially higher load than the others. This imbalance increases current flow in certain conductors and leads to additional losses.

Long feeder lengths also played a significant role. Feeders supplying distant consumers experienced higher voltage drops and increased power losses compared to shorter lines.

The analysis further revealed that the absence of reactive power compensation equipment resulted in increased apparent power flow through the network. This condition increases current magnitude and consequently increases power losses.

Based on the obtained data, the estimated energy losses in the analyzed feeders ranged from 7% to 14% of transmitted energy, depending on load conditions and network configuration.

Discussion

The results of this study confirm that improving the efficiency of low-voltage distribution networks requires a comprehensive approach combining technical modernization and operational
optimization.

Replacing aging conductors with larger cross-section aluminum or copper conductors can significantly reduce resistance and therefore reduce power losses. Although this solution requires investment, it provides long-term economic benefits through energy savings.

Load balancing between phases is another effective measure. Proper redistribution of consumer connections can reduce phase imbalance and decrease excessive current flow in overloaded conductors.

The installation of reactive power compensation devices, such as capacitor banks, can improve power factor and reduce unnecessary current circulation in the network. This measure directly decreases power losses and improves voltage stability.

Another promising approach involves implementing modern monitoring and control systems. Digital energy meters and automated data collection platforms allow operators to detect abnormal losses and respond quickly to network problems.

Finally, preventive maintenance plays an essential role in maintaining network efficiency. Regular inspection of connections, replacement of damaged components, and timely upgrading of outdated equipment can significantly reduce energy losses.

Conclusion

This study analyzed electrical energy losses in the 0.4 kV feeders of the TP-142 transformer substation and proposed several strategies for improving energy efficiency. The results indicate that conductor resistance, feeder length, load imbalance, and absence of reactive power compensation are the main factors contributing to energy losses.

Implementation of technical measures such as conductor replacement, load balancing, and installation of reactive power compensation equipment can significantly reduce these losses. Additionally, the adoption of digital monitoring systems can improve operational control and support data-driven decision making.

The findings of this research demonstrate that targeted improvements in local distribution networks can lead to substantial gains in energy efficiency. Future research may focus on developing automated optimization algorithms and smart grid technologies to further enhance the performance of distribution systems.

References

1. Gonen, T. Electric Power Distribution Engineering. CRC Press.
2. Kersting, W. Distribution System Modeling and Analysis. CRC Press.
3. Short, T. Electric Power Distribution Handbook. CRC Press.
4. International Energy Agency. Energy Efficiency in Power Systems.
5. IEEE Power and Energy Society. Distribution System Analysis Reports.