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ENERGY AUDIT PROJECT FOR THE COOLING SYSTEM OF A HIGH-POWER HIGH-VOLTAGE TRANSFORMER

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Abstract. In this project, an energy audit was conducted on the cooling system of a large-capacity 220/110/10 kV transformer at the “Hoqon” substation. During the audit, the energy consumption of radiators, fans, pumps , and the oil temperature control system was measured and analyzed. The results showed that there was excessive energy consumption in the cooling system, and technical proposals were developed to reduce it, such as introducing a frequency control system, cleaning radiators , and optimizing control. According to calculations, there is a possibility of reducing energy consumption by 20-40 percent, which will increase the efficiency of the substation.

Keywords. Hakan substation, energy audit, transformer cooling system, fans, pumps, oil temperature, energy efficiency, loading, optimization, energy saving.

Introduction. “Khakan” is a 220/110/10 kV substation operating as the central transmission node of the Andijan region. This substation plays an important role in the power supply of several districts of the region, including Shahrikhan, Balikchi, Bo'ston and Ulug'nor, and is designed to ensure the stability of the regional power grid. In recent years, several projects have been implemented to improve the power supply of the Andijan region. The 220 kV “Saroy” substation, commissioned in November 2023, and the new 14 km 220 kV network leading to it, significantly reduced the load on the “Khakan” substation — according to official reports, the load on “Khakan” decreased by about 100 MW, which increased its stable operation. “Khakan” operates as a central transmission node, combining a 220 kV input line, 110 kV and 10 kV distribution networks. Official and industry sources indicate that a typical substation consists of 220/110/10 kV transformers, high-voltage outlets, switchgear cabinets, automated protection and control systems. Some presentation materials mention the upgrade or replacement of transformer capacity at the substation from 125 MVA to 200 MVA.

The “Hakan” substation acts as a “hub” for the infrastructure of the surrounding region: it is a central point for supplying electricity to surrounding districts and is important for eliminating interruptions. Connected by long-distance networks and transmission lines, it plays an important role in reducing technological losses in the networks, increasing stability, and servicing industrial and household consumers. Recent news reports have noted a decrease in electrical engineering losses as a result of load redistribution through new networks . The substation and the lines connected to it are regularly modernized and repaired. In social networks and official reports, information appeared that in the context of preparations for the autumn-winter season of 2025–2026, major repairs were carried out at the “Hakan” substation, which is aimed at ensuring safety and uninterrupted operation. It is also planned to reduce the load on the substation and simplify maintenance as other projects are completed [1-3]. And environmental norms established for high-voltage substations are strictly observed: appropriate measures are taken to reduce the negative impact of electromagnetic fields, noise,

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and technical emissions on surrounding settlements. When carrying out official work, technical regulations and safety rules are followed under the supervision of the Ministry of Energy and the National Power Grid Committees. The effective operation of the "Hakan" substation will provide reliable electricity supply to regional industrial enterprises, agricultural facilities , and household consumers. As a result of load reduction and the commissioning of new transmission networks, fewer outages and more stable supply are observed in the networks, which supports the sustainable development of the local economy.

Figure 1. Oil fire extinguisher and related devices.

The energy audit project for the cooling system of a large-capacity 220/110/10 kV transformer at the Hakan substation is aimed at determining the energy consumption of the transformer cooling equipment, assessing losses and developing practical proposals for improving efficiency. The main objective of the audit is to assess the energy efficiency of the fans (air flow generating device), pumps, oil circulation and control systems used in the cooling system, determine their current operating conditions and propose solutions that ensure energy savings. The scope of the project includes the transformer cooling radiator, air cooling fans, oil circulation pumps, oil temperature and flow control system, conservator and auxiliary cooling elements. The operation sequence of these systems, their response to temperature changes, duration of operation and electricity consumption indicators are studied. Also, the type of cooling method installed, for example ONAN - Oil Natural Air Natural, ONAF - Oil Natural Air Forced, OFAF - Oil Forced Air Forced or other combinations, the existing wiring diagram and technical condition are assessed. The project is prepared based on the international standard for transformers IEC 60076 and the energy audit methodology ISO 50002 [4-5].

The audit is carried out in the following stages. First, all documents on the transformer's technical passport, existing service reports , previous energy consumption data and operating mode are collected. After this, a site visit is organized and a visual inspection is carried out. The mechanical condition of radiators, fans (a device that creates air flow), pumps, oil tanks, general oil quality indicators and cleanliness of cooling paths are checked. The transformer and radiators are scanned with an infrared camera to identify imbalances in heat dissipation. In the next stage, measurements are made on the main parameters of the cooling system. Oil temperature sensors are placed at the input and output points of the transformer , energy meters are installed in front of the fan (a device that creates air flow) and pump motors, and their real-time power consumption is determined. Ambient temperature and transformer load are also monitored.

are carried out for at least 7–14 days , during which the duration of operation of the fan (a device that creates air flow) and pumps, at what temperature they turn on or off, dynamic changes depending on the load are determined. The obtained data are recorded using a data logger and subsequently used for calculations of energy consumption. Based on the measurement results, the energy efficiency of the cooling system is calculated. The amount of heat released by the transformer and the electrical energy consumed by the cooling system are compared. The hourly, daily and annual energy consumption of the fan (a device that creates air flow) and pumps, their associated losses and optimization opportunities are determined [6-8].

are constantly running , energy losses may increase during periods of low load. Also, if there are uncertainties in the temperature control system , it is possible that the fans (a device that creates air flow) and pumps may work more than necessary. The oil temperature, flow rate and ventilation quality are also important to analyze. Based on the audit results , proposals are developed to increase efficiency. First of all, it is recommended to install frequency control systems on the fan (a device that creates air flow) and pump motors, since speed control depending on the load significantly reduces energy consumption. Mechanical and chemical cleaning of radiators improves the thermal regime of the transformer, which reduces the operating time of the fans (a device that creates air flow). Improving the quality of the oil, reducing humidity and increasing the efficiency of the filtration also facilitate the operation of the cooling system. In some transformers, automatic temperature control may not work properly, so it is recommended to calibrate or update the sensors.

If necessary, high-efficiency motors or additional radiator units can be installed. For example, if the cooling fans (the device that creates the air flow) and pumps consume 262,800 kWh of energy per year, a 20–40 percent savings can be achieved through the control system. For example, a 30 percent savings would mean an annual energy saving of approximately 78,840 kWh. This amount significantly reduces annual costs depending on the price of energy. Investment costs are estimated depending on the equipment installed, and the payback period is usually around 1.5–3 years . The energy savings also reduce carbon emissions, which increases environmental efficiency.

Figure 2. A 125 MVA transformer with a voltage of 220 kV at the Khakan substation in Andijan region.

At the final stage, a detailed energy audit report is prepared. It includes all measurements, graphs, temperature profiles, energy consumption calculations , images from a thermal camera, conclusions and practical recommendations. A step-by-step implementation plan for the project is also developed and maintenance recommendations are provided. The report will allow to increase the energy efficiency of the cooling system at the Hakan substation and make the thermal regime of the transformer more stable. This will serve as a reliable and cost-effective operation for the entire substation [9-10].

Conclusion: The results of this project showed that the cooling system of the high-voltage transformer at the Hakan substation has great potential for improving energy efficiency. The measurements and analyses revealed excessive operation of fans and pumps, insufficient optimization of the control system, and a decrease in the thermal efficiency of the radiators. It was found that the proposed technical solutions, including frequency control systems, radiator cleaning, oil quality improvement , and automatic control adjustments, can reduce energy consumption by 20–40 percent. This not only saves electricity, but also stabilizes the thermal regime of the transformer, reduces operating costs , and increases the reliability of the substation. Overall, the project provides practical and economically sound solutions for improving energy efficiency.

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