IMPROVING THE RELIABILITY OF TRANSFORMERS IN DISTRIBUTION NETWORKS

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Abstract
Various methods for improving the reliability of transformers in distribution networks are considered, and the reasons for their reduced service life are analyzed.

Keywords: Distribution transformers, regeneration, diagnostics, monitoring, adsorbent, insulation wear, load flow.

Introduction

Transformers are the most important devices in the power supply systems of agricultural facilities within distribution networks (substations). This is due to the fact that electric energy is delivered to all industrial, municipal, and household agricultural consumers directly through distribution networks. Distribution networks with voltages of 10...0.38 kV represent the most branched and extended parts of the power grid system and are a critical link in the infrastructure of the agro-industrial complex [4]. The reliability of personal computers (substations) greatly affects the stability of agricultural production. Personal computers are often constructed using radial circuits with the help of overhead lines (OHL) and cable lines (CL). In the Republic of Uzbekistan, there are power transmission lines with voltages of 110, 220, 330, and 500 kV for long-distance transmission. These lines are under the service of the main power grids. The total length of power transmission lines in the Republic exceeds 260,000 km, of which more than 2,000 km are 500 kV lines, more than 5,300 km are 220 kV lines, more than 5,600 km are 110 kV lines, more than 12,600 km are 35 kV lines, more than 98,100 km are 6-10 kV lines, and 137,000 km are 0.4 kV lines [10]. The main characteristic of supplying rural consumers with electricity is that electricity needs to be delivered to a large number of relatively low-capacity objects spread over a large area. As a result, the length of networks per unit of consumer capacity is several times greater than in other sectors of the national economy. The cost of supplying electricity to rural consumers, taking into account the cost of vehicles, accounts for 75% of the total cost of electrification [5].

Improving the reliability of the power supply to agriculture contributes to increasing the quality and quantity of agricultural products. According to the forecast for improving the rural power supply system by 2010, power networks should [3]: adapt to variable loads; reduce line operating and maintenance costs by decreasing the level of accidents; enhance reliability using modern equipment, protection devices, and automation for both electrical and environmental safety [2]; improve the electricity accounting system, and automate control and sales management of electricity; achieve economic efficiency in distributing and delivering electricity with minimal losses; and ensure technical and technological sensitivity to automation and telemechanization.

There are 25 distribution transformers of 6 - 10 kV voltage with a capacity of 630 kV•A, the most common transformers produced and operated. Their total number exceeds 3 million units, with an installed capacity of over 350 million kV•A. The production and operation of these transformers require significant material and labor costs, and any cost reduction would provide significant savings for the national economy. Annually, the service cost of a single distribution transformer of conventional design is 7-8% of its initial cost, with about 260 rubles per kW spent each year to compensate for no-load losses and 44 rubles per kW for short-circuit losses [1].

Overall, 4% of the country's electrical energy is lost in magnetic circuits, with a significant portion of these losses occurring in distribution transformers. Reducing the production and operating costs of transformers is the main task for manufacturers, which requires:

Reducing the consumption of active materials by using the most efficient magnetic systems;

Decreasing material consumption by using corrugated additional insulation;

Improving the reliability of transformers;

Studying the actual operating conditions of transformers;

Aligning real operating conditions with the technical requirements of the product.

To solve these issues, the method of functional-cost analysis was chosen [1]. Therefore, improving the reliability of distribution transformers is key to ensuring high-quality power supply to various consumers. Next, we will consider the main methods for improving the reliable operation of transformers and the reasons for reducing their service life.

Today, the most effective way to improve the reliability of transformer equipment is through the introduction of operational diagnostic methods and tools. These include using monitoring tools for oil transformers, controlling the temperature of the upper oil layers, identifying the maximum and minimum temperature values for a controlled period (day, week, month, year), adjusting the cooling system, signaling the occurrence of emergencies when temperature parameters are exceeded, storing all controlled parameters in non-volatile memory, and providing all of this data to an automated process control system via an interface [6]. Additionally, by monitoring load flow and oil temperature, the temperature of the hottest spot in the winding (HSP) can be determined using a well-known thermal modeling scheme. Knowing the temperature of the lowest winding allows for calculating the transformer's remaining service life [7].

Studies conducted at repair plants [5] show that the main causes of failure for 6...10/0.4 kV transformers are high-voltage winding failures and the burning of fasteners on low-voltage terminals. High-voltage windings can fail due to poor voltage protection or overload. Low-voltage bushings are destroyed only due to overloads, so improving the reliability of relay protection in distribution networks, shortening the disconnection time of fault sections of 10 and 35 kV lines, reducing the extent of damage, and lowering the cost of operation and maintenance of lines are critical [9].

Using functional-cost analysis methods greatly improves the technical and economic indicators of agricultural power supply systems, reduces power shortages for consumers, and significantly decreases labor costs to detect losses [5]. The transformer oil is used to remove heat from the winding and magnetic circuit to the tank walls and to increase the electrical strength of the insulation. During operation, the oil gradually deteriorates, its viscosity increases, and its electrical insulating properties worsen. The deterioration rate increases at high temperatures, exposure to air, and especially in contact with ozone. To restore the oil's properties, regeneration is used [8]. For the continuous regeneration of oil in operating transformers, they are equipped with thermosiphon filters with adsorbents. Adding stabilizers (antioxidant additives) to transformer oil is recommended, which slows down oil aging, extends its service life, and provides substantial economic benefits [7].

Partial discharges are the main cause of degradation in electrical quality over long service periods. They are local breakdowns in weakened areas of high-voltage insulation. Moisture and heating of the insulation, in turn, reduce the service life. Therefore, special attention should be paid to monitoring and drying the insulation to improve transformer reliability. Various monitoring methods are used, including monitoring insulation through absorption phenomena, capacitance characteristics, dielectric loss tangent, partial discharge intensity, and gas chromatographic analysis of oil samples [7].

The most common method of monitoring the insulation of high-voltage electrical equipment is to measure the dielectric loss angle tangent, as dielectric defects (moisture, ionization of gas inclusions) lead to increased dielectric losses.

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