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Thermal Vision Control of a Power Autotransformer At the Yuksak Substation

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ABSTRACT: This article discusses the thermal imaging method for diagnosing a power autotransformer. Thermal imaging control of the power autotransformer of the ATDTsTN type was carried out at the Yuksak substation, using a thermal imager of the FLIR T530 type. Research and analysis of existing approaches and methods for analyzing and diagnosing power autotransformers have been carried out. Due to the fact that each group of analysis and diagnostic methods is designed to detect a specific defect, it is advisable to consider emerging defects and methods for their detection, systematizing them by types of defects and causes.

KEY WORDS: power autotransformer, diagnostics, analysis methods, thermal imaging control, service life, monitoring.

I.INTRODUCTION

The fleet of power autotransformers, as in the European Union and Russia, and Uzbekistan has a long service life, from 10-25 years or more. In order for the operation of power autotransformers to be long-term and reliable, it is necessary to carry out diagnostics and analysis in a timely manner, standard diagnostic methods cannot always reliably predict the presence and development of damage and identify the precursors of emergency operation. Despite the fact that power autotransformers are designed and manufactured at a qualified level, in use they require cumulative preventive work: electrical tests, thermal imaging control and chromatographic oil analyzes, maintenance and overhauls, etc.

II. SIGNIFICANCE OF THE SYSTEM

Due to the fact that not everywhere the use of the power autotransformer was carried out and is carried out properly, as well as due to the physical and expiration of the service life of the power autotransformer, the admissibility of an accident today is quite high, which is unsuitable due to such considerations as: failure of the power autotransformer, large material investments in the restoration of equipment and waste of time, the likelihood of a "domino effect" when an emergency affects equipment and the environment; interruption in the power supply to consumers. A power outage can cause large damages that can exceed economic losses. Circumstances will be complicated by the fact that in electric networks and stations the use of a power autotransformer that has exhausted or has long been depleted of its regulatory resource continues and will continue.

Based on this, we can say that any research and development aimed at improving the reliability of operation of power autotransformers with an overdue service life are the most relevant.

III. LITERATURE SURVEY

A power autotransformer can be operated for years (there are cases when a power autotransformer has worked for 35 years or more), despite external influences and in any modes. The main condition for extending the service life of a power autotransformer is its timely and reliable diagnostics. In order to investigate the power autotransformer, the limits are organized, which are provided for within the framework of the regulatory, technical and design documentation.

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The need to replace a power autotransformer and its service life is determined in such cases as:
- failure of the power autotransformer;
- expenses for economic expenses;
- with a heavy load on the equipment, which leads to physical wear.

In this case, a complete and final analysis of the state of the power autotransformer should be carried out, and its further operation. Let us indicate some diagnostic methods that control the state of the power autotransformer. External diagnostics includes: inspection of the condition of inputs and outputs, control of instruments and measuring devices, thermal imaging control, control of temperature and color of oil and its level, inspection of insulators and cables, as well as inspection of contact connections and busbars. This control is carried out by inspection and special equipment and devices.

IV. METHODOLOGY

One of the most productive methods of control over the state of a power autotransformer is thermal imaging control, which includes thermography. Thermal imaging control is carried out using a special apparatus - a thermal imager (Fig. 1).

This device is designed to monitor the temperature distribution of the surface under study. The temperature distribution is displayed on the display as a color picture, where different temperatures correspond to different colors. The study of thermal images is called thermography.

Fig.1. General view of the thermal imager

Measurements were made with a FLIR T530 thermal imager, which has an infrared resolution of 120 × 90.
- Temperature measurement range: - 20 ~ 400 ℃;
- Temperature measurement mode: center point, tracking high and low temperatures;
- Photo storage: micro SD card up to 16 GB;
- High and low temperature alarm: image, sound signal, LED flashing signal;
- Laser indication/LED;
- Water protection class. IP54/antique case;
- Software for device analysis;
- Operating time up to 9 hours;
- 3.7v/2600mah rechargeable lithium battery;
- Bottom design ¼ screw holes can be used with a tripod.

With the help of thermography, any damage, malfunctions are detected and, accordingly, assumptions are made about a defect in the equipment, for example: destruction of the insulation of the studs can lead to heating of the walls of the power transformer tank; increase and rise in temperature; heating of the windings leads to the destruction and destruction of the insulation; turn short circuit in equipment windings; possible formation of sludge formation when the temperature rises during the operation of the power transformer in idle mode; at low temperatures of radiator pipes, the possibility of pipe corrosion and sludge formation; heating of the expander of a sealed oil-filled high-voltage bushing is possible when a short-circuited circuit is formed inside the expander; ingress of moisture and violation of the tightness of the oil conservator gaskets; uneven temperature leads to a violation of the circulation of oil in it [1]. This method is a rather complicated procedure, since when local defects form in autotransformers, they are “muffled” by natural heat flows from the magnetic circuit and windings. In addition, the operation of cooling devices, which promotes accelerated oil

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circulation, smoothes the temperature distribution at the defect site. When considering the results of computer diagnostics, it is necessary to take into account the design features of power autotransformers, the type of winding and magnetic circuit cooling system used, the criteria and duration of operation, design technology, and many other factors. In addition, the measurement error is affected by massive metal parts of autotransformers, including a tank, pressing rings, screens, studs, etc., in which heat is released due to additional losses from eddy currents induced by stray fields [2].

With the help of thermal imaging technology in power autotransformers, the following defects can be detected:
- coil short circuit in the windings of integrated current transformers;
- malfunctions of the contact control system under voltage (OLTC);
- the occurrence of magnetic stray fields in the transformer due to the violation of the insulation of individual components of the magnetic circuit (consoles, studs, etc.);
- defects in the transformer cooling system (oil pumps, filters, fans, etc.) and evaluation of its ef- change in the internal circulation of oil in the transformer tank (formation of stagnant zones) as a result of sludge formation, design miscalculations, swelling or displacement of the winding insulation (typical for transformers with a long service life);
- heating of internal contact connections of low voltage windings (NI) with transformer leads;
- breakage of grounding bars;
- heating on hardware clamps of high-voltage bushings;
- malfunction of heating of OLTC drives, etc. [3, 8,9].

This diagnostic method uses the following concepts:

ΔT - temperature rise, defined as the difference between the measured heating temperature and the ambient air temperature;

δT - excess temperature, defined as the excess of the measured temperature of the controlled node over the temperature of similar nodes of other phases under the same conditions;

$k_{Д} = \frac{\Delta T_{КС}}{\Delta T_{Ш}}$ - defectiveness coefficient, which is the ratio of the measured temperature rise of the contact connection to the temperature rise measured on the entire section of the bus (wire), separated from the contact connection at a distance of at least one meter.

When assessing the state of contacts and bolted contact connections by excess temperature and load current 0.5 Inom, the following areas are distinguished according to the degree of malfunction:

- δT = 5…10 ºC- the initial degree of failure, which should be kept under control and taken to eliminate it during the repair, planned according to the schedule;
- δT =10…30 ºC -a developed defect that requires measures to be taken to eliminate the malfunction at the nearest withdrawal of electrical equipment from operation;
- $\delta T \hbar$ 30 ºC- an emergency defect that requires immediate elimination.

Based on the defectiveness coefficient, the following degrees of malfunction are distinguished:

$k_{Д} \leq$ 1.2 -the initial degree of failure to be kept under control;

$k_{Д} =$ 1.2 ... 1.5 - a developed defect, it is necessary to take measures to eliminate the malfunction at the nearest withdrawal of electrical equipment from operation;

$k_{Д} \hbar$ 1.5 - emergency defect requiring immediate elimination.

Assessment of the thermal state of electrical equipment and current-carrying parts of the transformer substation, depending on the conditions of their operation and design, can be carried out:
- according to normalized heating temperatures (temperature exceedances);
- by excess temperature;
- according to the defectiveness coefficient;
- based on the analysis of the dynamics of temperature changes over time;
- by comparing the measured temperature values within the phase, between phases, with known good areas.

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LossesKT, kVt			Weight, T				Manual type	Manual type KKU (RPN)	Oil protection	Group connection diagram
HV-MV	HV-LV	CH-LV	General	active part	Oils	Shell				
302	246	235	186	82	63	11	ПДП-4У	РНОА	Пленоч.	Yo Auto/Δ-0-11

dispatcher name	Type of transformer	Power MVA	Nom.voltage, kV			Nom. winding current, kA			Uk %			Ixx %	Po kVt
			HV	MV	LV	HV	MV	LV	HV-MV	HV-LV	MV-LV		
AT-1	ATDCTN	125	230	121	10,5	313	595	3464	9,97	31	19,4	0,39	95,3

Thermal imaging control of a power autotransformer with a capacity of 125 MVA was carried out at the Yuksak substation. This ATDCTN type autotransformer was installed in 1981, the last overhaul was made in 2010.

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V. EXPERIMENTAL RESULTS

Figure 2 and Figure 3 show the inputs of a power autotransformer, a thermogram is shown without a defect, temperatures are within the normal range and is 41.7 ºC, the allowable temperature of this type of AT is 75 ºC.

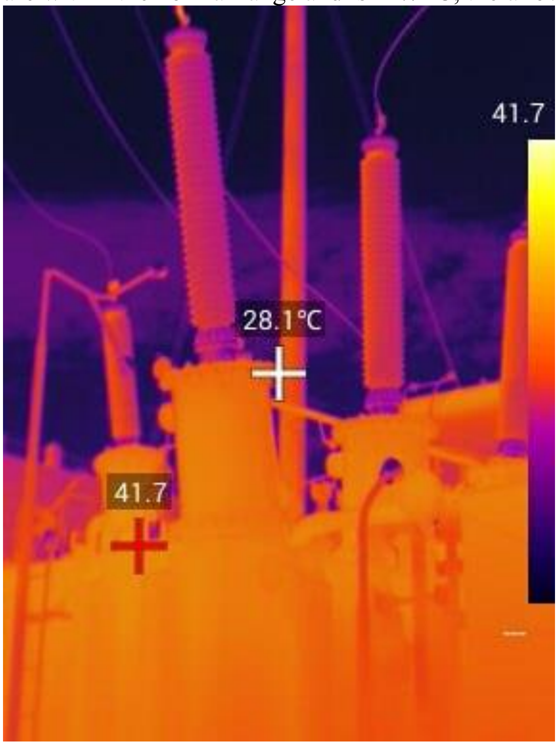

Fig.2. Thermogram of AT inputs

Fig.3. Appearance AT

Figure 4 shows a thermogram of a bushing with a defect in the attachment point of the outlet cable to the 110 kV bushing.

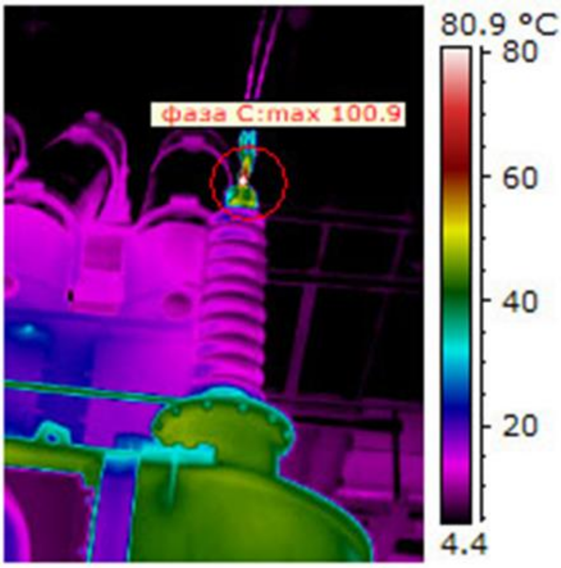

Fig.4. Thermogram input AT

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Fig.5. AT radiator thermogram

Fig.6. The appearance of the radiator AT

Fig. 5 and Fig. 6 show a thermogram of a radiator without a defect, the temperature of the AT radiator is within the normal range and is 31.6 ºC.

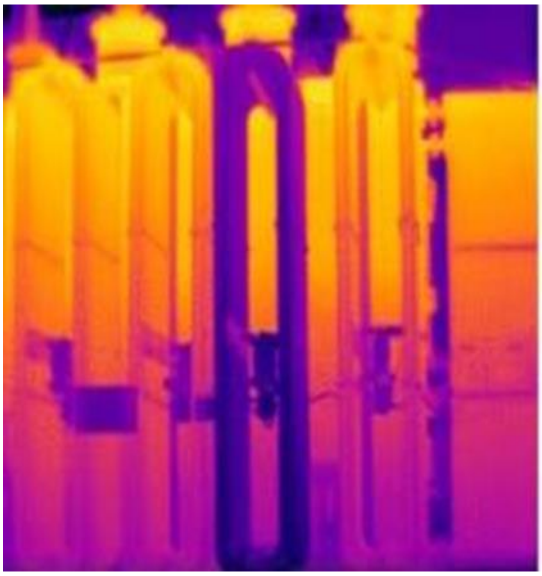

Fig.7. AT radiator thermogram

Fig.8. The appearance of the radiator AT

In Fig.7. a thermogram of a radiator with a defect is presented, the radiator does not work. According to the thermogram of the power autotransformer, it can be seen that the temperature of one radiator is purple, which means that it is cold. This could be for two reasons:

1- one of the radiator pipes is clogged;

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2- the valve can be closed.

This type of power autotransformers has a DC-type cooling system, because of this, when the load on the radiators is exceeded, the maximum temperature is permissible up to 75 degrees.

The operation of the cooling system affects the operational reliability and service life of the power autotransformer, and because of this, the control of this system is one of the most important maintenance tasks.

The traditional criterion for the effectiveness of coolers is the value of the heat flow cooler Rohl. All other things being equal, it is a function of the excess temperature of the oil supplied to the cooler over the temperature of the air at its inlet:

$$\mathbf{P_{охл} = \mathit{f}(\Delta \nu_{м}).}$$

A similar dependence is given in the documentation of manufacturers. At the same time, the heat flow of the cooler is equal to the heat output given off by the oil, which, all other things being equal, is proportional to the difference in oil temperatures at the inlet and outlet of the cooler:

$$\mathbf{P_{охл} = \mathit{f}(\Delta \nu_{охл})}$$

Therefore, knowing the parameters of the cooler, it is possible to calculate the dependence for each of its types:

$$\mathbf{\Delta \nu_{охл} = \mathit{f}(\Delta \nu_{м})}$$

The values of the quantities included in this dependence can be easily measured using infrared technology devices on a working power transformer. Therefore, it is advisable to use the oil temperature difference at the inlet and outlet of the cooler as the main diagnostic criterion in assessing the efficiency of the cooling system. Under real operating conditions, the temperature difference of serviceable coolers is in the range of 1–10 °C [7].

VI. CONCLUSION AND FUTURE WORK

Thus, thermal imaging control in relation to power autotransformers can be used as the main method for detecting internal anomalies that lead to a change in thermograms. Also, timely thermal imaging control of power autotransformers will ensure that defects are detected at the early stages of their development, and then the problem is eliminated in a short time. From a financial point of view, this is very cost-effective in comparison with the restoration of the power autotransformer after its failure.

Compared to other methods of analysis and diagnostics of a power autotransformer, thermal imaging equipment control has a big plus:

- firstly, for the period of diagnostics it is not required to stop production, the autotransformer is not de-energized;
- secondly, the analysis is carried out with the help of one employee using one device;
- thirdly, during the analysis of a thermal imaging survey, it is not necessary to contact the power autotransformer, this ensures the safety of personnel, there is no threat to life;
- fourthly, there is no need to disassemble electrical equipment or other equipment under test;

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