ҚАЗАҚСТАН РЕСПУБЛИКАСЫ
БІЛІМ ЖӘНЕ ҒЫЛЫМ МИНИСТРЛІГІ

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«ЖАСТАР ЖӘНЕ ҒЫЛЫМ – 2018»

атты V халықаралық студенттік ғылыми-тәжірибелік
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В сборнике опубликованы материалы докладов V Международной студенческой научно-практической конференции «Молодежь и наука - 2018».

В статьях отражены основные результаты исследований, приведен анализ аналогов литературы, раскрыты основные вопросы теоретического и практического характера, отмечены актуальность, элементы новизны и практической значимости.

Основные направления научных работ, представленных в сборнике: «Гуманитарные науки», «За строкой программной статьи Президента...», «Фундаментальные и методические основы математики, физики и информатики», «Технические науки», «Актуальные проблемы естественных и сельскохозяйственных наук», «Актуальные вопросы истории, экономики и права».

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INVESTIGATION OF THE POWER TRANSFORMER OF THE SUBSTATION «KRASNAYA GORKA» USING ACOUSTIC METHODS INVOLVING MODERN TECHNIQUES AND EQUIPMENT

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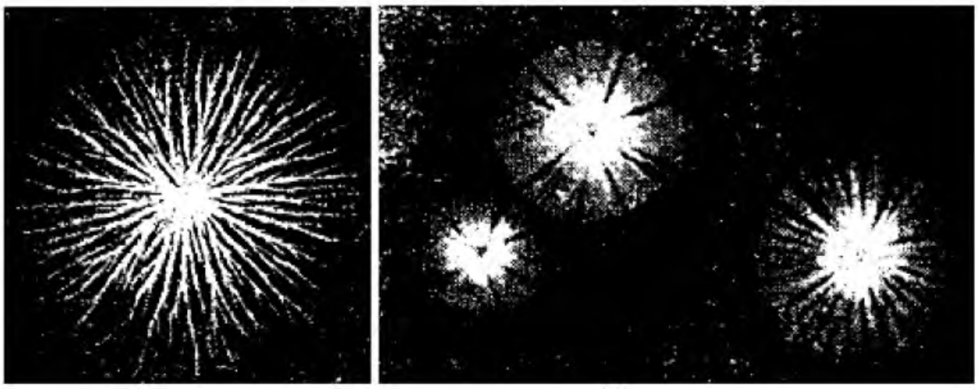
The evaluation of the actual state of power electrical equipment based on the results of diagnostic measurements is today a very complex and urgent task. Most of the electrical equipment of the stations, substations of the generation, transmission and distribution system of electric power has developed its own resource, but it continues to be used, since large financial resources are required to replace it. Accordingly, with each year, the costs of complex examinations and diagnostics are increasing. [1]

In recent years, in power plants of enterprises, as well as in the energy sector as a whole, there has been a tendency to a consistent transition from the system of preventive maintenance to repairs based on the actual technical condition of equipment adopted in developed countries. Such a transition predetermines the introduction and development of various methods for diagnosing the state of electrical equipment.

One of the most developing diagnostic methods of oil-filled equipment, and primarily power transformers, is the method of locating and measuring the level of partial discharges.

A partial spark (PS) is an electrical spark that shunts only a part of the insulation gap [2]. PS occur in local defects, i.e. in places where insulation is weakened due to the presence of gas inclusions (cavities) or sharp edges of metal elements of insulating structures (electrodes) (Figure 1) [3].



a) b)

Figure 1 – Recording of partial discharges by a high-speed camera:
a) surface discharge from the positive electrode;
b) surface discharge from the negative electrode.

Gas inclusions in liquid or solid insulation are weak points, because due to the difference in the dielectric permittivities of the gas and the surrounding dielectric inclusions, the electric field in the inclusions is several times higher than in the remaining insulation and, in addition, the electric strength of the gas is much lower, than the strength of liquid and solid dielectrics. PS can also occur directly in the oil near the sharp edges of the electrodes, where the electric field strength is sharply increased.

Partial sparks in oil interlayers in contact with solid insulation usually lead to damage to solid insulation and the formation of stable conductive traces on its surface. In the zone of these tracks, under the influence of overvoltages or even operating stress, conditions may arise for the continuous development of surface discharges, which result in complete breakdown of the insulation. Thus, the PSs represent a great danger for isolation due to its rapid destruction in local zones and subsequent breakdown of the insulation gaps.

The problem of the formation and development of the PS in the isolation of oil-filled equipment of high and ultrahigh voltage in the conditions of its operation is of great practical interest for the personnel operating the equipment.

The registration of PS in high-voltage equipment of power systems under operating conditions is used for diagnostic purposes during the last 10-15 years. The monitoring of the state of transformer equipment on the characteristics of the CR showed that it can be very effective.

The following methods of PS registration are known [4]:

- An electrical method based on the measurement of signals in electrical circuits associated with a controlled object;
- Electromagnetic method based on remote registration of electromagnetic radiation of the PS in the microwave range;
- optical method based on remote registration of optical radiation of the PS;
- an acoustic method based on the measurement of acoustic oscillations produced in the PS by means of contact or remote devices.

During acoustic study [5], measurements are carried out using acoustic sensors mounted on the tank, with a frequency range of 60-150 kHz, with a sensitivity of 100 mV/Pa. This ultrasonic range, close to audible, is chosen because in the audible range the transformer creates a strong noise, against which the sounds of discharges are not audible.

The noise of the transformers is caused by the vibration of the active part, as well as by the fans and pumps.

Vibration of the active part is due to magnetostriction and magnetic forces in the magnetic system and dynamic forces in the windings. Magnetostrictive component of vibration predominates in transformers. In magnetic systems of reactors with non-magnetic gaps, magnetic forces of traction in the gaps may predominate.

Magnetostriction is the phenomenon of deformation of the crystal lattice of a magnetic material when it is magnetized. In the process of increasing induction, first the crystal boundaries of the material are shifted, and then their rotation, which leads to a change in the linear dimensions of the steel.

Together with forces of magnetostrictive origin, the magnetic system experiences the influence of magnetic attraction forces. Most clearly, magnetic forces manifest themselves in the butt joints. In magnetic-bonded magnetic systems, the magnetic flux is forced to flow from the sheet to the sheet in the air or oil gaps that result from the loose joining of the steel sheets.

One of the sources of noise of transformers is the winding, the conductors of which are vibrated under the action of mutual attraction forces when AC current flows in them under load conditions.

In addition, the winding experiences the effects of forces caused by the current flowing in it and the magnetic flux of scattering. These forces act both in the transverse direction, and, especially, in the longitudinal direction with respect to the winding.

For transformers that have a cooling system with forced air circulation, the noise generated by the fans can be predominant. The sound power of the fan depends on its performance, speed and design. The high-frequency components of the noise spectrum of the fan are due to the breakdown of the vortex from the blades and the turbulent flow of air flowing onto the elements of the structure.

The sound levels of fan-equipped coolers are higher than those of stand-alone fans. This is due to their greater surface sound emission and, often, the resonances of the individual parts of the cooler.

Radiators of the cooling system with natural air circulation and oil can have increased noise due to the transmission of vibration from the tank.

Used in cooling systems, oil pumps do not affect the overall noise level of the transformers. The sound power level of the pumps is several orders of magnitude lower than that of the transformers. Increasing the sound level of the oil pump usually means its emergency state: the failure of the bearing, the impeller of the impeller on the body or the motor rotor behind the stator.

The noise of the transformer is significantly reduced in the ultrasonic range, and the sounds of the discharges become more noise at frequencies above 60 kHz. Near the discharge, its sound occurs in a wide frequency range of up to 1 MHz, but their high-frequency component attenuates when spreading in the transformer oil, so the upper frequency of the operating frequency band of the sensor to select above 200 kHz is impractical.

The acoustic method does not give exact values of the discharge values (it is customary to measure them in pC). However, the signal from pre-emergency discharges is 1000 times larger than from the initial ones, and if it decays due to propagation conditions and becomes 10 times weaker, it still remains significant.

To diagnose the transformer, ultrasonic modulator «Dolphin» was used as the recording device, which allows recording of signals for 40 ms with a sampling rate of 800 kHz and then 100 times slower (in 4 seconds) to reproduce this record. A portable computer is used to store the measurement results.

Figure 2 – Ultrasonic moderator "Dolphin"

During the survey, the sensors are installed in series through 30-40 cm around the perimeter of the transformer at different levels in height (through 40-50 cm). At each point, an oscillogram of ultrasonic signals is recorded over two periods of the network frequency, or the delayed sound of the sensor is heard.

Experience has shown that acoustic signals can have an origin not associated with discharges, for example, knocking in oil pumps, vibration of loose parts on the transformer, corona in the air at the inputs, fan noise, vibration of the magnetic circuit. Therefore, according to the frequency spectrum of acoustic signals, their relation to the voltage phase, amplitude and stability, classification of the defect type is carried out.

Signals from discharges have a high-frequency spectrum, occur twice during the mains voltage period, are unstable in amplitude, short in duration. On hearing, the slow sounds of discharges are clicks, usually following every second. The acoustic signal spectrum was determined using the Sound Forge program by the current Fourier transform.

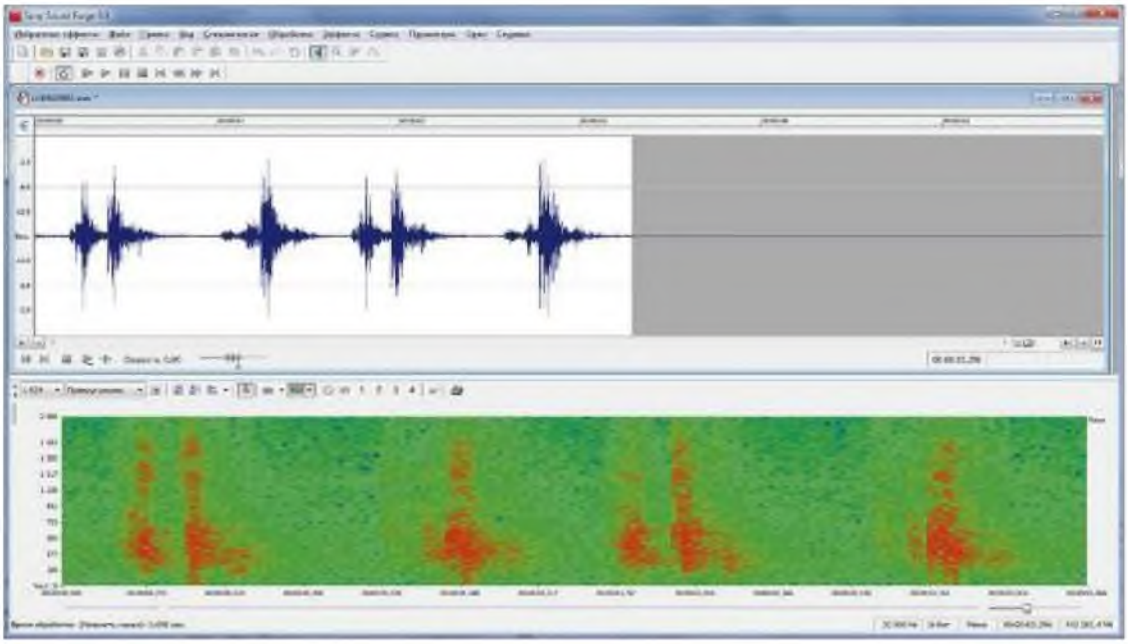


Figure 3 – Oscillogram and spectrum of the acoustic signal from the surface of the transformer tank

Figure 3 shows the oscillogram (top) and the spectrum of the maximum acoustic signal (bottom). The high-frequency signal (red dot on the spectrum) up to 130 kHz is repeated twice in half a period of the network. The signal amplitude is 1.5 V. This signal in the upper part of the tank between the phases A and B on the HV side is caused by discharges. If this were a partial discharge, its value could be estimated as 100,000 pC. Discharges of this magnitude are emergency. The sound of the discharge process corresponds to a bad contact.

As a result of acoustic examination, it was established that acoustic signals were found in the upper part of the tank from the HV side between phases A and B, indicating the presence of electrical discharges in the active part of the source associated with the igniting contact. It was decided to inspect the lower parts of the transformer inputs. It turned out that the contact connection of input B MV is burning. The maximum sound from the discharge in this connection was from the HV side.

The discharge in the contact was spark (close to the arc), and the sound from it is close in magnitude to the emergency partial discharge.

Using a personal computer with the appropriate software, spark and partial discharges were determined.

As a result of the experimental research work the following conclusions were obtained:

- timely inspection of the active part with knowledge of the place of the discharge process helps prevent damage to the power transformer;
- it is possible to establish the presence of discharge processes in the transformer and to determine the location of their occurrence, one can use acoustic signals.

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