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Infra-red and ultraviolet control, LVI-testing, partial discharges and another diagnostic methods for detection of electrical equipment's faults, defects.

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***Abstract* — This paper presents an application's experience of LVI-testing to check the condition of transformer windings, infra-red control (IR-control) results of electrical equipment, inspections of the SF6 insulation current transformers by thermal-vision control, measuring the acoustic activity of the partial discharges (PD) into the insulation of transformers, the gas pressure in the housing, data of electrical tests, the results of analysis of the quality of SF6 by different methods. IR-control was used for detection of overheating of disconnector contacts, bushing condition of power transformers, condition of circuit breakers, arresters and limiters of overvoltages, coupling transformers, measuring current transformers, measuring voltage transformers and other. The LVI method and short-circuit inductive reactance measurements are sensitive for detecting such faults as radial, axial winding deformations, a twisting of low-voltage or regulating winding, a losing of winding's pressing and other.**

Keywords — IR-control, Low voltage impulse method, Short-circuit inductive reactance measurement, SF6 insulation, quality of SF6.

I. INTRODUCTION

Infra-red control was used for detection electrical equipment's faults, defects and weaknesses: overheating of disconnector contacts, bushing condition of power transformers, condition of circuit breakers, arresters and limiters of overvoltages, coupling transformers, measuring current transformers, measuring voltage transformers, control of connecting heads soldering quality of turbo-generator stator windings during repairing and other.

LVI-testing and short-circuit inductive reactance measurements are sensitive for detecting such transformers winding faults as buckling, axial shift and other. The 70 units of 25-240 MVA 110-500 kV power transformers were checked by low voltage impulse (LVI) method. A few power transformers were detected with winding deformations after short-circuit with aperiodical short-circuit current. The block 80 MVA 110 kV transformer had serious amplitude and frequency LVI LV1-LV2 winding oscillogram differences after generator side short-circuit. The low-voltage (LV) winding signal spectrum of 80 MVA 110 kV transformer changed after short-circuit.

22 units of power transformers extending in capacity range from about 25 MVA to over 666 MVA and in voltage range from 110 kV to 750 kV were tested at short-circuit at Togliatti Power Testing Laboratory (Russia) during 1983-1995. The application of LVI method and measurement of inductive reactance deviation allowed to detect a twisting of low-voltage winding and radial winding's deformations at tests of the 400 MVA and a 250 MVA block power transformers [1-5].

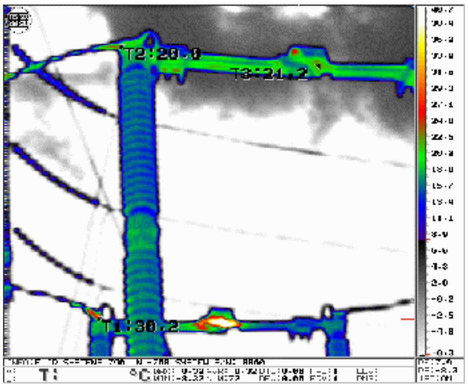
Power transformers are one of the basic parts in the circuitry of power transmission and delivery. Therefore the interest to perfection of the power transformers' fault diagnostic methods is being increased. The repairs of power transformers and other electrical equipment are carried on, using diagnostic measurement results [1,2,3, 5-9].

This paper presents inspection of SF_6 insulation current transformers by thermal-vision control, measuring the acoustic activity of the partial discharges (PD) into the insulation of transformers, the gas pressure in the housing, data of electrical tests, the analysis of the quality of SF_6 by different methods. The norms of the quality of SF_6 in the high-voltage equipment are accepted in accordance with IEC 60480–2004 and national standards [1]. Basic reasons for defects and damages of electrical equipment with the sulfur hexafluoride insulation: low mechanical strength, the low quality of SF_6 insulation (increased humidity, the appearance of decomposition products of SF_6), the unreliable fastening of protective hoods on the diaphragm devices, the defects of installation.

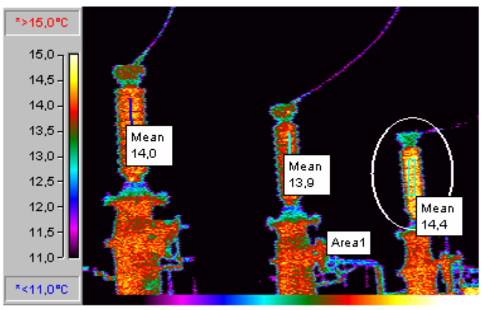
II. Infra-red and ultraviolet control results.

An examples of efficient application of infra-red control for electrical equipment faults diagnostic are in the fig. 1:

a) - overheating of 220 kV disconnector contacts (ΔT=48°C); b) – decrease of insulation resistance of 110 kV limiter of overvoltages to 300 MOm, moistening and the entry of moisture inside limiter of overvoltages, overheating (ΔT=0,5°C); c) - overheating of 330 kV measuring current transformer, tgϬ = 2,6%, according to the joint results of diagnostic measurements it is dismantled and substituted; d) - ultraviolet control, glow of surface PD in the cracks of stand-off insulators (defective insulator in the 500 kV disconnector with the worsened electrical properties of porcelain).



a)



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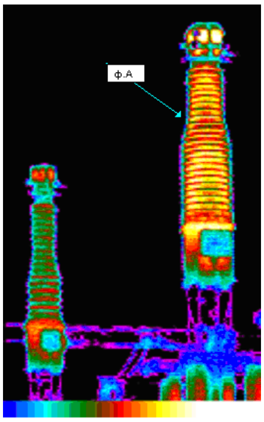

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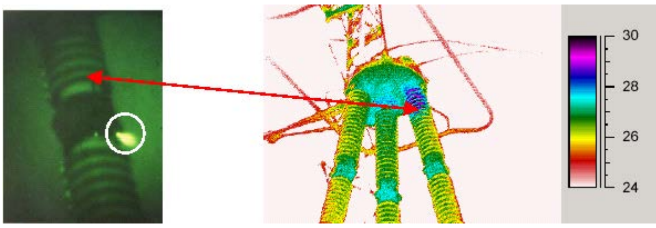


d)

Figure 1. An examples of efficient application of infra-red control for electrical equipment faults diagnostic : a) - overheating of 220 kV disconnector contacts (ΔT=48°C); b) – decrease of insulation resistance of 110 kV limiter of overvoltages to 300 MOm, moistening and the entry of moisture inside limiter of overvoltages, overheating (ΔT=0,5°C); c) - overheating of 330 kV measuring current transformers, tgϬ = 2,6%, according to the joint results of diagnostic measurements it is dismantled and substituted; d) - ultraviolet control, glow of surface PD in the cracks of stand-off insulators (defective insulator in the 500 kV disconnector with the worsened electrical properties of porcelain).

III. LVI-testing of transformer's winding and FRA method.

The LVI method is very sensitive to small local changes of winding geometry: turn-to-turn and coil-to-coil capacitances, mutual inductances between transformer windings. The LVI oscillograms, which contains basic resonance frequencies of transformer winding, are a "fingerprint" or condition state of transformer. Generally, windings of large power transformers have three basic resonance frequecies. Frequency Response Analysis (FRA) showed presence of 110 kHz, 320 kHz and 550 kHz frequencies for 250 MVA /220 kV transformer. An amplitude of these resonance frequencies changed 1,3-2 times after detection of radial buckling in LV winding at short-circuit tests (fig.2) [5-11].

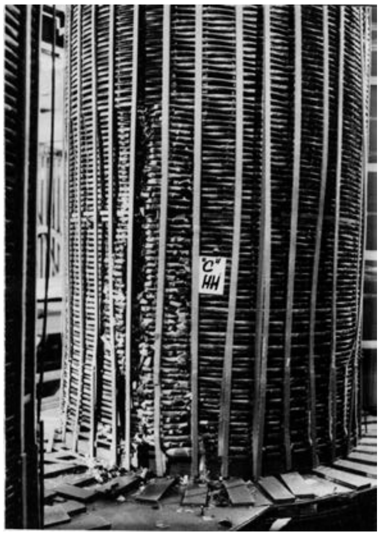
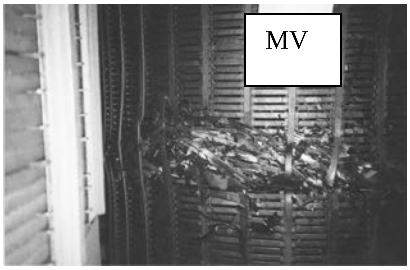


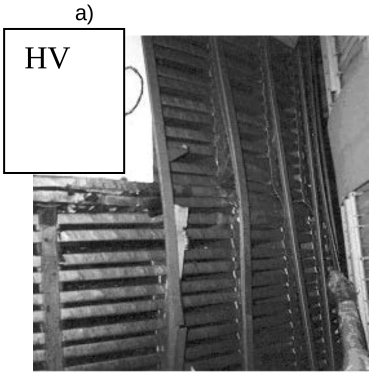
Figure 2. Typical example of deformation due to radial buckling in the C phase LV internal winding of 250 MVA /220 kV transformer (Δ Xk= +3,1%).

Inductive reactance deviation was Δ Xk= +3,1% in this case.

Radial buckling in MV 220 kV winding (a) and in HV 500 kV winding (b) of 167 MVA/500 kV/220 kV autotransformer after three short-circuits in service is in the fig.3.



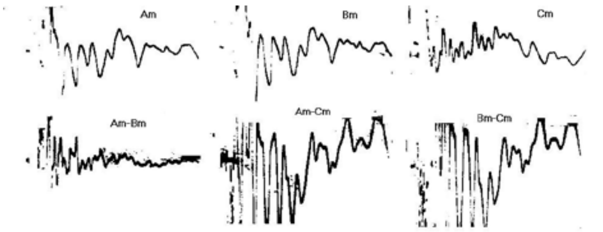
a)



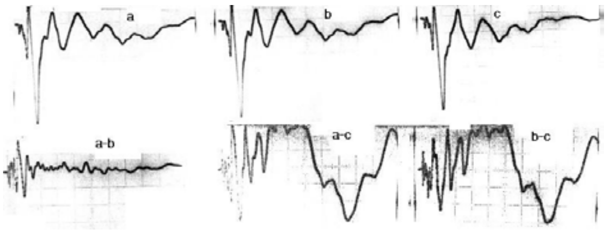
b)

Figure 3. An example of radial buckling in MV 220 kV winding (a) and in HV external 500 kV winding (b) of 167 MVA/500 kV/220 kV autotransformer after three short-circuits at "Bugulma-500 kV" substation in service.

125 MVA/220 kV/110 kV autotransformer was switch off by gas relay protection after internal short-circuit at the electrical substation in service. The tank of autotransformer was not deformed. Serious deformations and turn-to-turn internal short-circuit were detected in MV 110 kV winding, regulating winding and LV winding by LVI-testing, short-circuit inductive reactance measurements and iron core losses methods. LVI oscillograms of MV 110 kV winding, including turns of regulating winding (a), and oscillograms of LV winding (b) are in the fig.4. The LVI amplitude-frequency differences of C phase from A and B phases are noticeable. The short-circuit inductive reactance differences of C phase from A and B phases are Δ Xk= -11,6% in MV-LV winding regime, and Δ Xk= -7% in HV-LV winding regime. The main goal of diagnostic investigation of 125 MVA 220/110 kV autotransformer was to define the possibility of repairing. On the basis of results of this diagnostic investigation there was planed the substitution of autotransformer.



a)



b)

Figure 4. LVI oscillograms of MV 110 kV winding, including turns of regulating winding (a), and oscillograms of LV winding (b) of 125 MVA/220 kV/110 kV autotransformer after internal short-cirat at "Kostroma-2" substation, illustrating amplitude-frequency differences of C phase .

The block 80 MVA 110 kV transformer had serious amplitude and frequency LVI LV1-LV2 winding oscillogram differences after generator side short-circuit at Heat Electric Power Station. The LV-winding signal spectrum of 80 MVA 110 kV transformer changed after short-circuit. The original 300 kHz, 500 kHz, 700 kHz resonance frequencies disappeared and a new 400 kHz, 800 kHz resonance frequencies appeared in the FRA spectrum. The LVI-tests and spectrum analysis of 80 MVA 110 kV transformer's LV-windings detected axial electrodynamic deformations [5, 6, 7, 10-17].

Diagnostics experience was showed that the transformer plant documentation should be include: normograms of LVI-testing, data bases of partial discharge technique, normograms of infra-red diagnostics (for first models) during heat testing, data bases of winding pressure by vibration measurements of transformer. Short-circuit reactance measurements (Zk) and LVI-testing should be carry out together. The necessity of LVI-normograms of all new manufactured transformer with capacity over 2,5 MVA, which are produced at the transformer manufacturers, is came. It's necessity for data bases of the mechanical winding conditions for the future LVI-testing at the energy system after probable short-circuit [8, 9, 15-20].

IV. DIAGNOSTIC METHODS OF INSTRUMENT TRANSFORMERS WITH SF6 INSULATION

In fig. 5 are given the basic methods of complex diagnostics of instrument transformers with SF_6 insulation [3]. These are thermal-vision inspection, the measurement of the acoustic activity of the partial discharges (PD) into the insulation and the analysis of the quality of SF_6 by different methods [3, 7, 8].

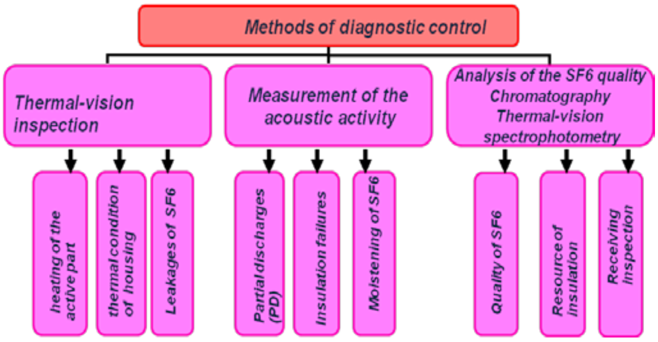


Fig. 5 Basic methods of complex diagnostics of instrument transformers with SF_6 insulation.

Thermal-vision inspection is very effective for predictive diagnostic for SF_6 insulation current and voltage transformers, and it is achieved in accordance with national standard RD 153-34.0-20.363-99 "The basic condition of the procedure of infrared diagnostics of electrical equipment and transmission airlines" (Fig. 6).

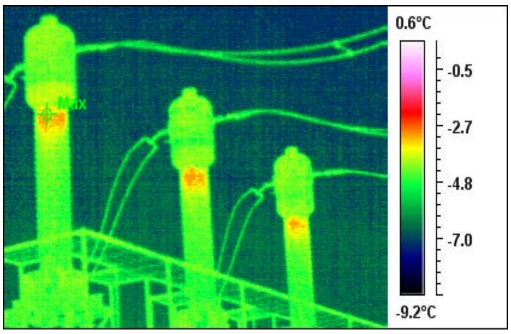
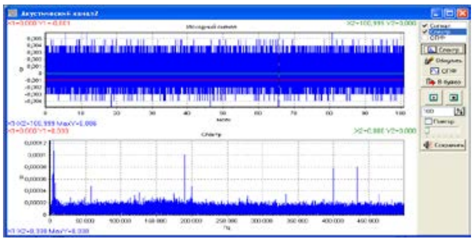
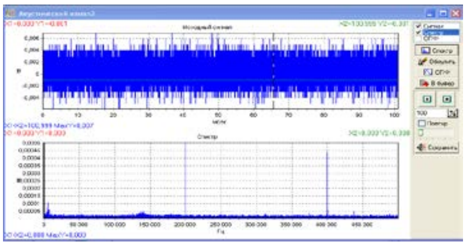


Fig. 6 Heat-gram of SF_6 insulation current transformer (ΔT=2,1 oC).

An acoustic activity of the partial discharges (PD) into the insulation of SF6 insulation current and voltage transformers is one of the basic methods of complex diagnostics. Acoustic signals of PD into the insulation of SF6 insulation current transformer and their spectra are in the fig. 7.



a) AA= 0,9 dB;



b) *AA= 50,3 dB*

Fig. 7 Acoustic signals of PD into the insulation of SF6 insulation current transformer and their spectra.

An electrical activity of the partial discharges (PD) into the insulation of 80 MVA/110 kV power transformer are in the fig. 8. Color shows intensity PD per second (from the dark-blue to the red).

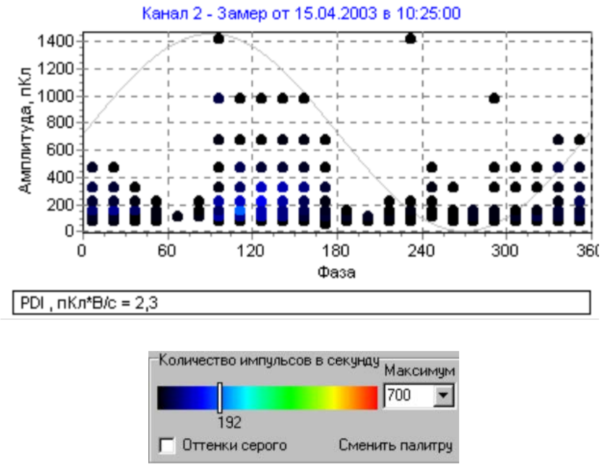


Fig. 8 An electrical activity of the partial discharges (PD) into the insulation of 80 MVA/110 kV power transformer.

Normative documentation during PD measurements are national standard GOST-20074-83 "Method of measuring the PD characteristics and IEC-60270 "The measurements of PD characteristics" [8].

Compositional analysis of SF6 is carried out by spectrophotometry by portable dissolved multi-gas analyser TRANSPORT X.

Analysis of a transformer oil sample for dissolved gases by a laboratory is an established technique recognized as the most important test for monitoring power transformers.

The Kelman TRANSPORT X is a compact portable Dissolved Gas Analysis (DGA) system which can be used to analyze oil samples for all dissolved fault gases and moisture. If abnormal levels are detected, it further provides a diagnostic using various IEEE/IEC approved interpretation rules.

This is a vital piece of equipment when more frequent oil tests need to be performed on aging transformers or when an immediate on-site diagnostic is required following an alarm from a single gas DGA monitor.

Normative documents and national standard is RD-16.066-05 "Sulfur hexafluoride electrotechnical equipment technical requirements for the production" and IEC 60480-2004.

The tracks of partial discharges during the insulating construction are on the fig.9.

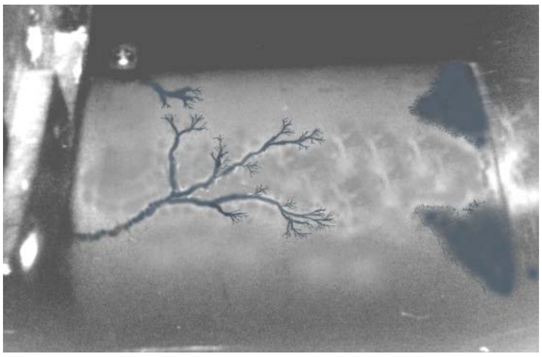


Fig. 9 The tracks of partial discharges during the insulating construction

CONCLUSIONS

Infra-red control was effective for detection electrical equipment's faults, defects and weaknesses: overheating of disconnector contacts, bushing condition of power transformers, condition of circuit breakers, arresters and limiters of overvoltages, coupling transformers, measuring current transformers, measuring voltage transformers, control of connecting heads soldering quality of turbo-generator stator windings.

The low voltage impulse testing is a very sensitive and reliable method of deformation's detections of transformer windings. The LVI oscillograms are a "fingerprint" of transformer.

This winding "fingerprint" are defined by major resonance frequencies (a winding spectra). The 250 MVA 220 kV winding transformer's FRA spectrum was contained a 110 kHz, 320 kHz and 550 kHz frequencies, which are changed 1.3-2 times after the mechanical radial winding deformations. The FRA spectrum of 80 MVA 110 kV transformer changed after short-circuit. The original 300 kHz, 500 kHz, 700 kHz resonance frequencies disappeared and a new 400 kHz, 800 kHz resonance frequencies.

The results of the carried out complex inspection showed that the basic reasons for the failure of instrument transformers they are the low quality of SF_6 (sulfur hexafluoride), design deficiencies in the transformers, the absence of absorbers for adsorbing of moisture and decomposition products of SF_6, the application of not corrosion-resistant materials for manufacturing the transformers and the low quality of service maintenance [3-9]. The quality of SF_6 must correspond to the norms, indicated in IEC 60480-2004.

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