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SUMMARY OF PROFESSIONAL ACCOMPLISHMENTS

DIAGNOSTICS OF ON-LOAD TAP CHANGER BASED ON AN ANALYSIS OF DYNAMIC CONNECTION PROCESS

Currently produced transformers of high and medium power are equipped with on-load tap changers (PPZ) of different types and with different adjustment scope dependent on local requirements. Tap changers under load are one of the most unreliable elements of a transformer. In domestic conditions a large number of changers of the old type is in use and the largest group consists of PO type changers produced for many years by the national factory of transformers ELTA. Breakdowns of this type of changers account for approximately 40% of all breakdowns of transformers of high and medium power. Such a high failure frequency of the on-load tap changers was the reason why, in the past, a set of actions was prepared and implemented, leading to a periodic control of technical condition of the changer. These activities, in the form of formalized procedures laid down in the Framework Instruction on Exploitation of Transformers (IET) [3], include both reviews of the on-load tap changers and control measurements, usually accompanying them.– Both of them are carried out on a closed-down transformer. The control measurements (periodic, post-assembly/installation) of the on-load tap changers include a measurement of proper time (time of contact input and output on particular phases) of a power switch and selector cage as well as verification of resistance of degree resistors. For measurement of proper time, which makes it possible to check the condition of springs, contacts and backlash in mechanical elements of the tap changer, an original method is applied for oscillographing/scanning current flows with power supply of a measurement system connected to the on-load tap changers by means of direct current [3]. The method has also been recognized abroad [16,22]. Use of computerized systems for monitoring and diagnostics of transformers working in parallel with a transformer in real-time is an alternative solution ("on –line") [5, 9, 20], one of the main advantages of which is the possibility of continuous diagnosis of technical condition of a transformer without closing it down. A system for measurement of power on a drive motor shaft of the on-load tap changers ensures such a possibility of diagnostics. Monitoring the on-load tap changers status within on-line mode is an alternative solution. Most frequently, load current before and after switching, temperature in a power switch head and time-flow of power drawn by motor of the on-load tap changer drive are subject to an analysis [5]. The object of the work is to extend

diagnostics of switches by an analysis of dynamic process of switching over the scale of current changes, caused by deteriorating surface of contacts. Execution of this task required to organize a measurement station for testing an influence of additional active resistance set in a series: with contacts of a selector cage and with a contact of a changer into current waveforms (stimulating worn-out elements of a power switch). Measurements for over a dozen systems of connections were carried out. The tests were conducted on an active part of transformer with power with an installed switch.

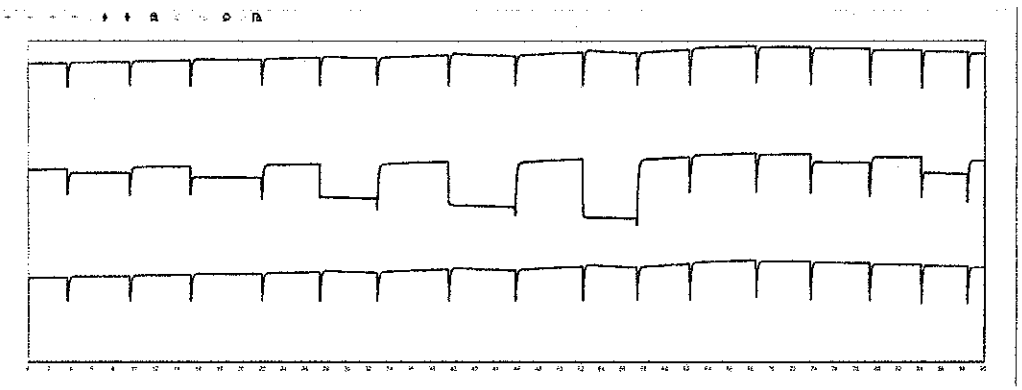
Current was registered within the entire adjustment scope of the on-load tap changer.

The registration was carried out while examining an influence of connection of line terminals of secondary winding not equipped with a switch on the character of the waveforms. The measurement was conducted while measuring changes in current in three phases during in-line insertion with contacts of a selector cage of resistance with different value. During the measurements with an open secondary side of the transformer identical changes of current on all phases was identified.

Closure of the secondary side of the transformer considerably changed the character of the waveforms.

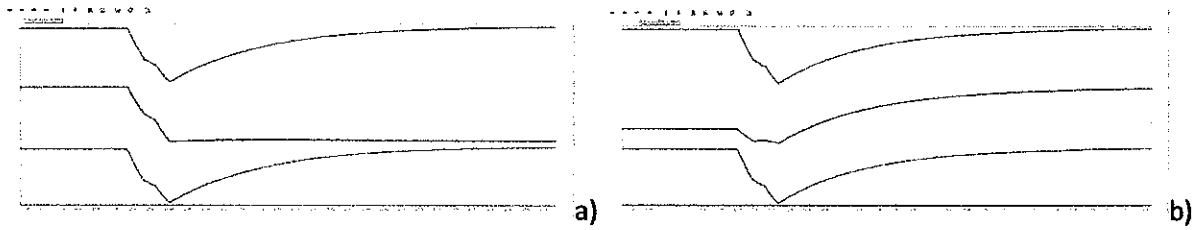
Oscillograms showed only change on the phase in which additional resistance was inserted.

In addition, an amplitude of signal was much larger. Oscillogram of the switching over cycle from the 1st to the 14th tap is shown in drawing 1



Drawing 1. Diagram with the cycle of switching over a selector cage from the 1st to 14th tap with resistors attached to even contacts on phase B GN no. 2-0,2Ω, no. 4-0,5Ω,no. 6-2,2 Ω, no. 8 3Ω, no.10-5Ω and closed secondary side of the transformer.

Selected diagrams with proper time in case of switching over from the 5th tap into the 6th tap and installed additional resistor with value of 2.2 Ω on the phase and closed secondary clamps of the transformer are shown in drawing 2



Drawing 2. Diagram with proper time of the switch with closed DN side and dropping resistor with value of 2,2Ω on the contact no. 6; a) while switching over from the tap 5/6; b) while switching over from the tap 6/7.

As you can see on the contact 6 values of current are identical in all phases, whereas after reaching the contact no. 5 there is a visible change in amplitude on the second phase from the top of the diagram.

The work presents a method of diagnostics based on an analysis of the process of switching over values of current changes. Apart from time criteria, it was suggested introducing

- A current amplitude marking
- Waveforms time constant

One of the methods of quick assessment of correct operation and lack of defects which result in an increase of resistance is the comparison of oscillograms.

The work showed usefulness of this method by overlapping diagrams of proper time of switches with inserted additional resistors of different value.

Differences in amplitudes of current are visible and their value depends on the value of additional resistance

The work also presents the analytical method making it possible to project the oscillogram of proper time on the basis of formulas describing the cycle of switching over the tap changer.

During the projection, formulas describing the cycle of switching over the power changer were used, considering changes in resistance on contacts of the tap changer.

A way of determining self-inductance and mutual-inductance was discussed in detail on the basis of two calculation methods. The first one was based on formulas describing an inertial element of the first series which allows projecting a current growth curve while feeding voltage on line clamps of the transformer. The second method allows determining a time constant defined as the relation of surface over the current waveform diagram to the fixed current. Both calculating methods made it possible to obtain similar values. Inductance of winding was calculated as a product of the determined time constant and resistance. The other elements of the substitute scheme were determined by using results of measurements carried out on the transformer. Formulas required for calculations are included in the work. A mathematical model was made by using the calculations of

the active resistance value of the substitute scheme and analysis of starting current allowing to determine a time constant and further self-inductance and mutual inductance by inserting, into formulas, obtained results of measurements and calculations which made it possible to theoretically determine the course of current changes during the switching over cycle.

The final stage of the work presents the values of current flow, obtained from the calculations, during the switching over cycle received after insertion of the additional resistance in-line with the contacts of the selector cage. The obtained result is similar to results of tests on the transformer.

The object of the work was to extend diagnostics of switches by an analysis of dynamic process of switching over the scale of current changes, caused by deteriorating surface of contacts.

The presented results of the measurements and calculations confirmed the possibility of extending the hitherto prevailing measurement diagnostics by such an analysis.

The possibility of determining the scale of changes in the current amplitude and time constant in combination with knowledge about construction and rules of operation will make it possible to track the deterioration of working parameters of the on-load tap changers.

The work presents typical damage of the power switches, selector cages and drives.

The measurement method presented in the work may be applied to all types of on-load tap changers.

However, this requires to become familiarized with the specific character of their work.

Lack of knowledge about the construction and rules of work will only make it possible to establish existing differences in time waveforms. However, this will not make it possible to precisely determine the location of an irregularity and provide advice to carry out a repair.