# TEMPERATURE DISTRIBUTION IN WINDINGS OF TRANSFORMERS WITH NATURAL OIL CIRCULATION

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The basic criterion for transformer loading is the temperature of the winding's hot-spot; it must not exceed the prescribed value in order to avoid the irreversible insulation faults as well as the premature long-term ageing. The determination of the temperature of the winding's insulation hot-spot represents a very complex task. To solve it, two approaches are possible: a1) to measure it, using fibre-optic techniques, which is still of no practical (commercial) use, and b1) to calculate it, using a thermal model of power transformer and real time-varying load information.

Due to the complexity of the phenomena there exists no exact thermal model. A number of papers have been published proposing improvements of the thermal model from the valid IEC standard. It is very advisable to establish a thermal model on results from general heat transfer theory. Unfortunately, it is possible very rear in a correct manner, i. e. in a way to keep the calculation accuracy. The reason is deviation of oil streaming conditions in real transformer and in setting under which the formulas are established in heat transfer theory.
Standard approach to hot-spot temperature calculation is through using characteristic points temperatures.

The fundamental idea of this contribution is to present experimental results and to check the validity of available thermal models on real windings. The highest value of the work are results of performed expensive and complicated experiments on two windings: the first one of a three-phase transformer 630 kVA (10 kV side) and the second one of a test winding consisting of 4 layers with 99 turns each (of 17.45 $mm^2$ cross-section). In the first winding were built 98 temperature sensors during the winding manufacturing process. The second winding was equipped with 30 sensors to measure temperatures in the first two (of total four) layers and in the oil. Measurements on the first winding are made in two cases: for the winding as normal transformer part and for the winding positioned autonomous in the tank. The second winding was loaded positioned autonomous in the tank only.

Experimental results made it feasible to check the validity of hot-spot factor $H$, i. e. to establish the precise relation between the hot-spot minus top oil temperature difference and average winding minus average oil temperature difference. For that purpose, a special measuring method of mean winding temperature, using superimposed measuring DC current, is developed. The method exposed here is related to the most complicated case of autonomous (single phase) winding and it represents the continuation of measuring methods for a transformer in short-circuit heating experiment and normally operated transformer.

Completed experiments, applied measuring techniques, illustration of space temperature distribution inside windings and verification of the most popular calculation procedures used nowadays are presented.