ON-LINE AND OFF-LINE TRANSFORMER MONITORING

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by
George Anders, *Fellow IEEE* and Meir Klein

The on-line monitoring of a transformer's condition or rather of the condition of its insulation involves recording of the voltage and current as well as monitoring of the top oil temperature and, on this basis, estimation of the windings' hot spot temperature to determine the paper insulation deterioration rate. Following standard practices, it is assumed that the paper insulation lifetime is identical with the transformer's lifetime and that it may be defined by using Arrhenius-Dakin [1-3] or Montsinger [4] equations.

The oil temperature may be measured or computed, while the hot spot temperature can only be computed, although direct measurement methods are already available. However, they can only be applied to newly built units, where the manufacturer can install technically advanced measuring facilities (for instance based on fibre optic measurements).

The international standards [1-4], or rather the guides to power transformer rating calculations, offer calculation algorithms for the computations of all the key temperatures in transformer insulation and the loss of the paper-oil insulation life.

Any complete and practical numerical program must, however, take into account a number of parameters that are barely mentioned or completely omitted in the standards. Transformers very often are characterized by complex structures of the windings, the number of which often exceeds two. The calculations can become especially complex in the case of the transformers with an on-load voltage regulator. The transformers are often also provided with multi-stage cooling systems. In addition to changing tap positions, the transformer also experiences changing loads and ambient temperatures during a 24-hour period as well as in the course of a year

A practical numerical program must model a variety of winding types, especially the regulating ones, and represent a variety of tap changers. Such program, codenamed DTR (**D**ynamic **T**ransformer **R**ating), has been developed by Kinectrics Inc. for Hydro One Inc. and will be presented during this meeting.

Special features of the program include, but are not limited to

1. Modelling of all types of transformers that are installed on Hydro One's transmission system (e.g., autotransformers, 2- and 3-winding transformers, units with the under load or/and off-load tap changers on either HV or LV side, or both, shell or core construction, phase shifting transformers, etc.)
2. Analysis is performed for either IEEE [1-3] or the IEC [4] standards. In the first case, both Chapter 7 and Annex G methods are encoded with two versions of the aging curves.
3. Modelling of arbitrary load curves (with two different load curves on the LV side of thee-winding transformers) and ambient temperature changes during a 24h period described by a cosine function or a user-specified curve.
4. Modelling of various cooling conditions.
5. A true-up module that adjusts model parameters based on real-time measured values of voltage, current and top oil temperatures.

Several issues related to rating of power transformers on- and off-line will be discussed and the operation of the program will be demonstrated.

References

[1] IEEE Std C57.91-1995 and C57.91-1995 "IEEE Guide for Loading Mineral-Oil-Immersed Transformers"
[2] IEEE Std C57.91™-1995/Cor 1-2002, C57.91TM-1995/Cor 1-2002 IEEE Guide for Loading Mineral-Oil-Immersed transformers Corrigendum 1,
[3] ANSI/IEEE C57.92-1981 – " Guide for Loading Mineral-Oil-Immersed Power Transformers up to and including 100 MVA with 55^{o}C or 65^{o}C winding rise", December 14, 1981
[4] IEC 60354," Loading guide for oil-immersed power transformers", 1999