IEEE/PES Transformers Committee
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"Application of Fiber Optic Sensors in Transformers"

-- Technical Presentation --
Thursday, March 21, 2013

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1. Abstract

The presentation will cover three topics:

- Optimum quantity & locations of fiber optic sensors in core-form & shell-form transformers
- Error due to locating the sensors in radial spacers
- Hot-spot response to dynamic load variations

One of the major issues when deciding where to locate discrete fiber optic sensors is that thermal scatter will often override the local loss density distribution. Thus, it is not enough to install one or two sensors at the location with the highest calculated loss density to obtain a proper value for the hot-spot temperature. Dr. Nordman will show a number of measurements from real practice and make a suggestion for the installation of sensors in core-form transformers. Mr. Cuesto will show examples of installations in shell-form transformers.

The sensors are typically installed in slots in radial spacers instead of inside the paper wrapping to touch the metallic conductor. The reason for this is to avoid probes breaking during installation and final compacting of the windings. This causes some inaccuracies in the temperature measurements. Mr. Heinzig will quantify this inaccuracy and judge whether it is significant or not for the safe operation of the transformer.

The phenomenon of "hot-spot overshoot" has been an actual topic within IEEE for many years, in connection with the work on the Loading Guide. Dr. Susa will summarize the conception of hot-spot overshoot. He will also give some examples of hot-spot overshoot from real practice and show how dynamic thermal models can be tuned by recordings from fiber optic probes. He will also show how the IEEE Annex G method fits with fiber optic measurement results.

2. Learning Objectives

This presentation will demonstrate the following:

- How thermal scatter overrides loss density distribution
- Why it is necessary to install more than two sensors in a winding
- Why discrete sensors are used instead of continuous probes with embedded sensors along their length
- Why sensors should <u>not</u> be installed in layer windings
- Why it is proper to install sensors in radial spacers
- About the hot-spot overshoot at sharp load increases in ONAN, ONAF and OFAF cooled transformers

3. Learning Outcomes

As a result of attending this tutorial session, participants will gain an understanding of the following:

- Observe from examples the range of thermal variations at the top of a winding
- Help transformer users to specify and transformer manufacturers to select the number and locations of fiber optic sensors
- Help interpreting the fiber optic sensor recordings
- Increase the understanding of the inaccuracy caused by the installation of the fiber optic probes in the radial spacers
- Understand the behavior of the hot-spot at sudden and sharp load increases

4. Presenters' Biographies

Miguel Cuesto is a senior specialist on shell type power transformers. Miguel joined ABB in 2005 for electrical design of shell type transformers. Since 2008 he has also been involved in shell-type R&D projects as well as direct measurements inside transformers. He has collaborated in the publication and presentation of a number of technical papers in CIGRE. Presently Miguel is participating in the CIGRE working group A2.38; Thermal Modeling, regarding two task forces: thermal modeling and fiber optic measurements of shell-type transformers.

Peter Heinzig is responsible for innovation management and development of monitoring products in the end-user segment of WEIDMANN Electrical Technology in Switzerland. He graduated from the Technical University Ilmenau and received his Dipl.-Ing. degree in High Voltage Engineering and Insulation Technology in 1989. From 1990 to 2008 he worked for Siemens Power Transformers in Nuremberg Germany in electrical design, as technical director and test bays manager. He is CIGRE member and was German representative in the CIGRE Study Committee A2 from 2004 to 2008. He worked in the CIGRE joint working group A2/B4.28 regarding HVDC Transformers and is presently participating in the new CIGRE working group D1.52, "Moisture Measurement in Insulating Fluids and Transformer Insulation". He is also a member of IEEE Transformers Committee and vice chair of WG Revisions to Impulse Test Sections.

Dr. Hasse Nordman is the leader of ABB's global R&D activities in the area of "transformer leakage flux and hot-spots" since 1994. Hasse received his Ph.D. degree in Mathematics from the Abo Akademi, Turku, Finland in 1977. From 1970 to 1982 he was with ABB Corporate Research in Vaasa, Finland, working on current related phenomena (losses, temperatures, short-circuit forces) in electric power equipment. From 1982 to 1994 he was with the Power Transformer R&D Department of ABB, Vaasa, Finland. He has published and presented a number of technical papers in CIGRE and IEEE. Dr. Nordman is a contributing member of the IEEE Transformers Committee and also an active member of the IEC Power Transformer Committee (TC 14). He is presently heading the task force on "Direct Measurement" (thermal sensors in transformers) in the CIGRE working group A2.38; Thermal Modeling.

Dr. Dejan Susa is the special advisor for power transformers at Statnett (Norwegian transmission system operator), where he is working on different research topics, including losses, temperatures, aging, moisture, gassing, on-line monitoring. He received his D. Eng degree in electrical engineering from the University of Nis, Nis, Serbia in 2000, and M.Sc. and D.Sc. degrees from the Helsinki University of Technology, Espoo, Finland, in 2002 and 2005 respectively. He was with the Power Systems Laboratory, Helsinki University of Technology, Finland, from 2001 to 2006. He joined the Center for Power Transformer Monitoring, Diagnostic and Life Management, Monash University, Clayton, Australia from 2006 to 2007, and was with SINTEF Energy Research Department, Trondheim, Norway from 2007 to 2012. He has published and presented a number of technical papers on dynamic thermal modeling, especially in IEEE Transactions on Power Delivery. Dr. Susa is a member of Norwegian IEC National Committee, convener of the recently established IEC TC 14 MT1, with the task to prepare the next version of the IEC Loading Guide 60076-7. He is also task force leader of "Dynamic Thermal Modeling" in the CIGRE working group A2.38; Thermal Modeling.