CIGRE WG A2.38 - Transformer Thermal Modelling
Progress Report, August 2009

Prepared by: Patrick Picher
For John Lapworth, Convenor

Summary

The Working Group was initiated as a result of a proposal at the CIGRE SC meeting in Bruges, October 2007, and became operational in mid 2008.

Members

The membership comprises a good balance between manufacturers and utilities and includes several young engineers, as well as members of the IEC 76-2 maintenance team. The membership is restricted to active participants who can contribute to the development of the subject. We do not intend to distinguish between full and corresponding members: any members who cannot attend meetings in person are expected to contribute via webcam. Inactive members will be removed from the circulation list.

	Members	**Company**	**Country**
1	John Lapworth	Doble Powertest	UK
2	Dejan Susa	SINTEF	Norway
3	Guenter Fleck	Siemens	Austria
4	Patrick Picher	Hydro-Québec (IREQ)	Canada
5	Hasse Nordman	ABB	Finland
6	Frank Trautmann	Siemens	Germany
7	Shinji Yamamura	Toshiba	Japan
8	Cees Spoorenberg	Smit	Netherlands
9	Jurjen Kranenborg	ABB	Sweden
10	Mohamed Ryadi	Areva	France
11	Nico Gunter	Powertech	South Africa
12	Stefano Zunino	Terna	Italy
13	Valery Davidov	Monash University	Australia
14	Edward Simonson	Southampton Dielectric Consultant	UK
15	Oleg Roizman	IntellPower	Australia
16	Zhongdong Wang	U. of Manchester	UK
17	Gordon Wilson	National Grid	UK
18	Jeroen Hermans	Pauwels	Belgium
19	Jacques Aubin	GE	Canada
20	Damien Laval	EDF	France
21	Hugo Gago	Iberdola	Spain
22	Joaquin Gortazar	Union Fenosa	Spain
23	Mohinder Pannu	Wilson	Australia
24	Zhong JUNTAO	Shenbian	China
25	Zoran Radakovic	University of Belgrade	Serbia
26	Tim Gradnik	EIMV	Slovenia

Meetings

Our meeting schedule has been as follows:

Meeting	Venue	Date
1	Godalming, UK	June 16-17, 2008
2	Paris	August 28, 2008
3	Stuttgart	December 9-11, 2008
4	Montreal	June 9-11, 2009

It is proposed to hold the next meeting at ABB Cordoba, Spain, in January or February 2010.

Progress

During the first two meetings members gave presentations outlining the state of the art in their companies/countries and identified areas where the Working Group could usefully contribute to the development of the topic.

Out of these discussions and presentation arose a general desire to improve knowledge and understanding of differences in the oil flow distributions between the parallel ducts of zig-zag cooling arrangements under OD/ON and OD/OF flow regimes – under OF conditions the minimum flowrates/maximum temperatures are generally agreed to be in the middle of each 'pass', whereas for ON flowrates some workers have predicted minimum flowrates at the ends of the passes.

We then agreed to compare thermal calculations for a common example - of an ON cooled transformer with a zig-zag cooling arrangement of disc type windings from a utility in Canada. The results of the members were presented at meetings 3 and 4, and ranged from simplified network models to detailed computational fluid dynamics (CFD) modelling.

Some additional simulations are required to complete this exercise. For example, in addition to comparing different methods of calculating winding temperatures we have investigated differences in the calculation of stray losses, comparing results from proprietary tools with those from a commonly used package (Andersen). The preliminary findings are promising. This comparison of modelling using different tools on a common geometry will be reported in the brochure and we expect that it will form an interesting new contribution on the topic to the transformer industry.

There is also an intention to investigate the state of the art regarding the modelling of cooling in shell form transformers. This will be a major topic at the next meeting.

There is also a desire to improve the accuracy of thermal characteristics obtained during factory heat run tests – by improvements to measurement technologies and methodologies for carrying out the tests.

The annex presents a proposed outline (first draft) of the brochure.

Annex: Proposed outline of A2.38 Brochure (draft #1)

Introduction

Definitions

Steady state & dynamic thermal modelling

Purpose of thermal modelling

Applications for new and existing transformers
Example of failures caused by poor thermal performance

Steady state modelling

Losses calculation (Q factor)
- List of parameters required (geometry, material characteristics, etc.)
- RI2 losses
- Eddy & stray losses calculation
  - Eddy losses in windings
  - Stray losses in other metallic parts
- Critical parameters affecting the accuracy

Temperature calculation (S factor)
- List of parameters required (geometry, material characteristics, etc.)
- Analytical model
- Thermal Network Modelling (TNM)
- Computational Fluid Dynamic (CFD)
- Typical S factors vs. winding/cooling design? S vs. flow rate?
- Critical parameters affecting the accuracy

<u>Example: 66 MVA transformer LV winding</u>

Losses calculation by WG members
- Summary of results
- Derivation of Q factor
- Discussion / conclusion

Temperature calculation by WG members
- Summary of results
- Derivation of S factor
- Discussion / conclusion

Dynamic thermal modelling

State of the art (IEEE 'Annex G', IEC 60076-7, 'improved' models from D. Susa)
List of parameters required to perform dynamic thermal modelling

Heat Run Test
- Normal
- Extended

Parameters determination from factory testing
Exponents x, y, z
Time constants
'Hot spot' factor
Examples

Direct measurements

Applications
FO for windings
Thermocouples for other metallic parts
Good practices for FO measurement
Examples

Annex : Thermal modelling of shell-type transformer

Review of the design
List of parameters required for thermal modelling
3D calculation of leakage flux and eddy losses
Temperature calculation
Critical parameters affecting the accuracy
Application of direct measurement