INTEGRATING MONITORING AND DIAGNOSTIC EQUIPMENT ON AGING TRANSFORMERS - PART I

By Byron Flynn, Application Engineer, GE Energy

I. ABSTRACT

Valuable information from Monitoring and Diagnostics (M&D) equipment installed on aging power transformers helps utility personnel operate and maintain critical infrastructure.

M&D systems provide valuable on-line information from power transformers including gas in oil, internal hot spot temperature, insulation aging moisture content in winding insulation, bubbling temperature, and OLTC position tracking. This presentation reviews several methods of integrating M&D equipment to provide this information to SCADA and maintenance systems.

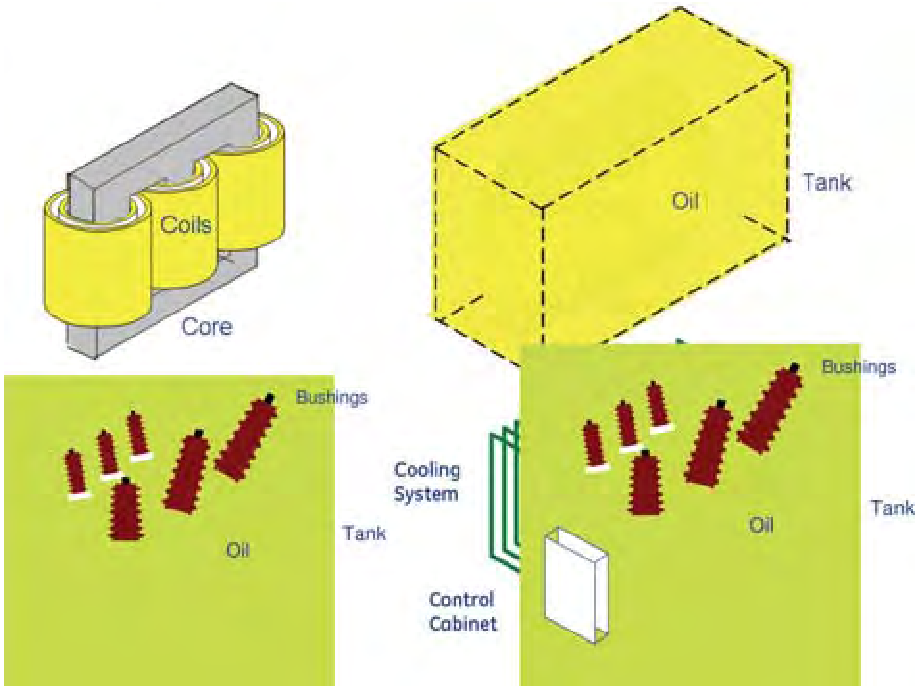


Figure #1: Basics of a Transformer

II. BACKGROUND

A discussion of Transformer Monitoring and Diagnostics has a basis on the fundamental construction of a transformer. The transformer is basically a machine consisting of several parts: This discussion, while seemingly overly simplistic, is useful to provide a basis of failure modes and monitoring and diagnostic methods.

The core and coil are the fundamental components of a transformer providing the coupling of magnetic flux between two windings. The core and coils are placed in a tank filled with oil and connected to bushings. The cooling system and control cabinet are the remaining fundamental components of a transformer. Additionally, many transformers in distribution substations include a Load Tap Changer (LTC) that provides additional voltage control on the distribution feeder.

There have been significant efforts to understand the various failure modes of power transformers. Applying the fundamentals of an FMEA analysis consisting of:

- Identify functions
- Identify failure modes
- Identify failure causes
- Identify effects of failure modes
- Identify criticality or risk
- Select on-line monitoring to match characteristic of developing failure cause(s)

The analysis of the failure modes of the various components then leads to a review of the inspection and maintenance procedures of power transformers. Then applying Reliability Center Maintenance (RCM) tools to the failure mode analysis information helps a utility design a monitoring system to optimize utilization and eventual life cycle.

Preventive and predictive maintenance:

Reduces the risk and costs of unexpected failure

Actual conditions drive maintenance and repair

Extending life of assets

Reducing costs of maintenance

On-Line diagnostic condition assessment addressing common failure modes:

Multiple sensors

Multiple on-line models

All parameters are recorded automatically and continuously

Trend and limit alarms

On-Line Diagnostics Models

To deal with the potential overload of data, many utilities are installing systems with online diagnostics models. These models were installed to reduce the flood of raw data and to continuously provide information regarding the transformer health and operating history. Additionally, the Dynamic Loading Model provides a guide which can assist

Continued on Page 28

the dispatchers by calculating the overloading capabilities based on current operating conditions, especially useful during critical times.

Additionally, early detection of problems, at the incipient stage, will help extend the life of the transformer. Detection of these problems is accomplished with several models, which rely on various sensors installed on the transformer and in the substation, combined with other parameters manually entered. This data is then fed into industry standard and accepted models, which calculate the various outputs. These outputs are displayed and trended in the two Master Stations. These capabilities increase the useful data while significantly reducing the shear volume of data. The models focused on the main tank, the LTC and the cooling system and will be described briefly in this section. [1] & [2]

Load Current Model

The first two models use routine calculations. The Load Current Model calculates average and maximum current on each winding based on one-second measurements.

This data is available for display and for trending in the Master Stations. The model's block diagram is shown below.

Apparent Power Model

The Apparent Power Model simply calculates average apparent power (MVA) from the transformer's current and voltage. The average and maximum MVA readings are then displayed and trended. Warnings and alarms are also provided, if limits are reached.

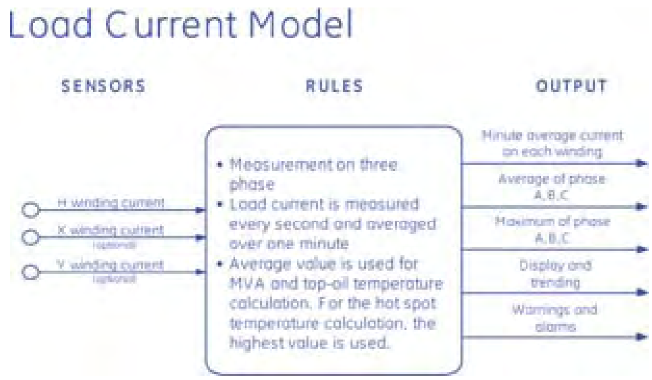


Figure #2: Load Current Model

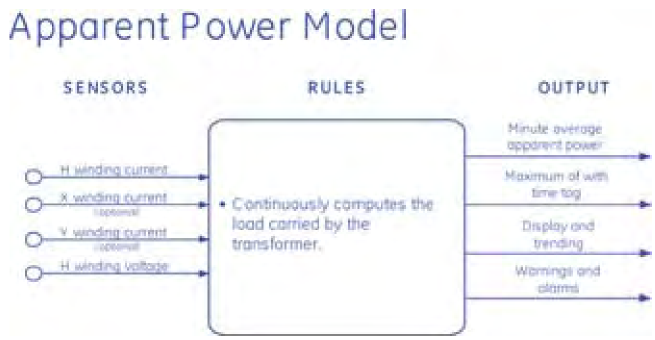


Figure #3: Apparent Power Model

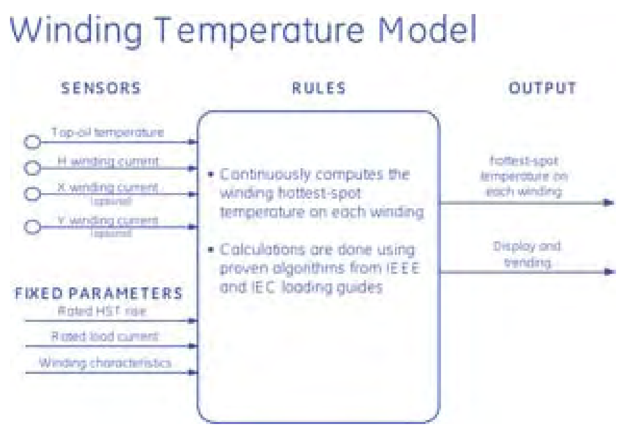


Figure #4: Winding Temperature Model

Winding Temperature Model

The Winding Temperature Model is based on IEEE and IEC loading guides. In accordance with these guides, it calculates the hottest spot temperature on each winding. The values

Continued on Page 30

55TH ANNUAL **Electric Utility Fleet Managers Conference**

Powering Your Fleet Toward the Future

June 15 – 18, 2008

Williamsburg Lodge & Conference Center, Williamsburg, Virginia

The EUFMC is open to fleet representatives from investor-owned utilities and electrical contractors. Conference activities include a drive-thru utility equipment demonstration and equipment show, and a general session program of speakers and presentations on industry issues.

"I have been attending EUFMC for seven years and find it to be very informative and also very beneficial to be able to discuss topics of concern that effect all of the various fleets represented. The equipment show is as good as it gets, with time to talk to the various vendors and discuss new technologies and concerns that the future may hold from a fleet perspective. Also, the topics of discussion during the sessions are full of useful information."

Richard Rourk
Supervisor, Fleet Operations
South Carolina Electric & Gas

REGISTER TODAY! (757) 220-1795 • www.eufmc.com

Aging Transformers
Continued from Page 28

are then made available for trend and display on the master stations. The following block diagram illustrates this model's inputs and outputs.

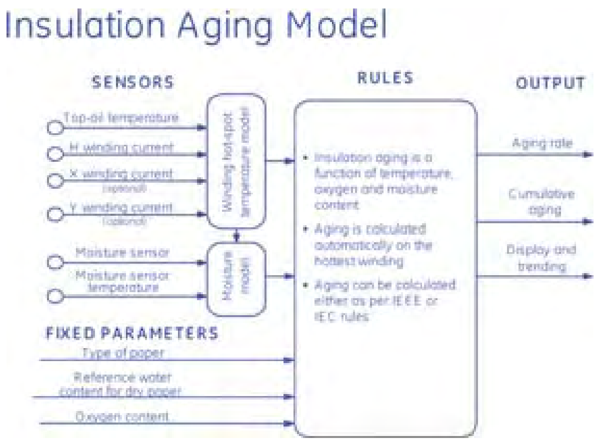
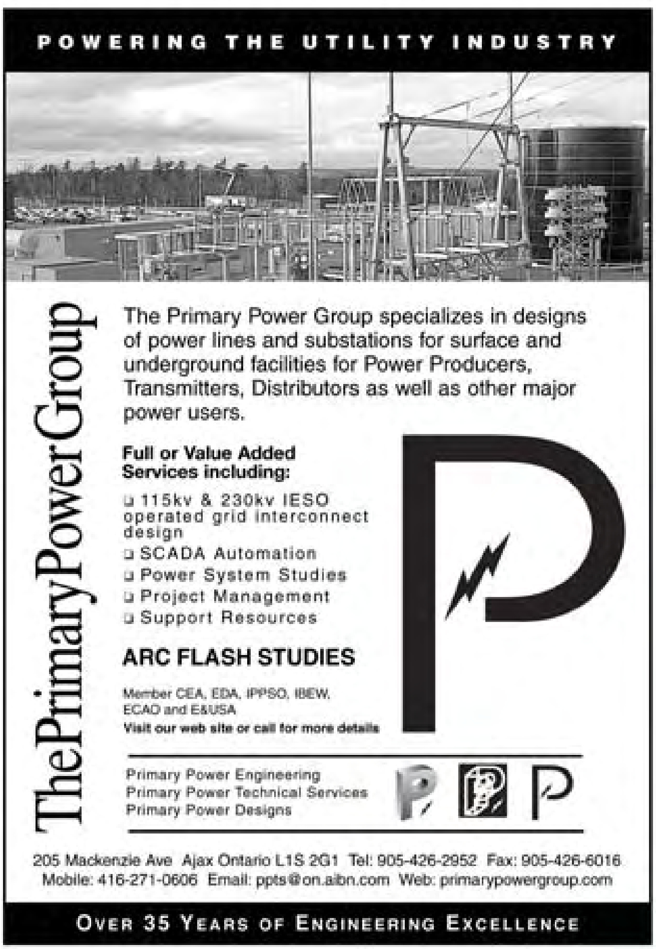


Figure #5: Insulation Aging Model

Computations are carried out according to:

• IEC 354, Loading Guide for Oil-Immersed Power Transformers, Section 2.4, Equation 1



• IEEE C57.91-1995/Cor 1/ July, 2001 Guide for Loading Mineral-Oil-Immersed Transformers, Section 7.2.6, Equation 16, 17, 18

Insulation Aging Model

The Insulation Aging Model calculates transformer aging data based on two different methods, daily & cumulative (IEEE + IEC). The computations are carried out according to:

• IEC 354, Loading Guide for Oil-Immersed Power Transformers; Section 2.6.2, Equation 7, 8

• IEEE C57.91-1995/Cor 1/ July, 2001 Guide for Loading Mineral-Oil-Immersed Transformers; Section 5.2, Equation 2 for 65°C thermally upgraded paper; Annex D, Equation D2 for 55°C normal Kraft paper.

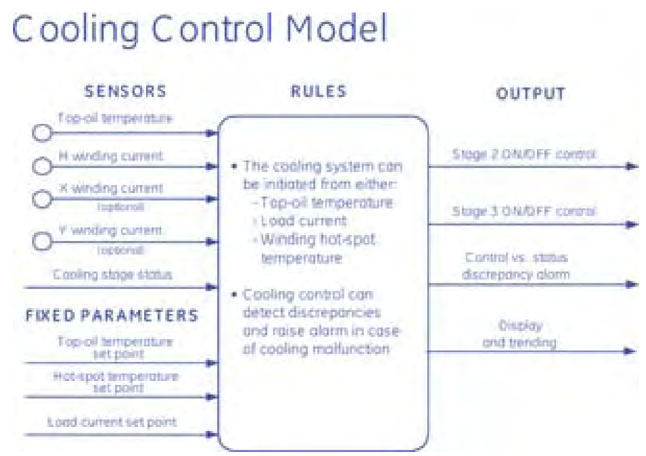


Figure #6: Cooling Control Model

Cooling Control Model

The system can also be used for cooling control using the model described in the block diagram below. The system is used as a backup.

Cooling Efficiency

The Cooling Efficiency Model is used to determine if the Cooling system can lose efficiency over time due to fan failure, physical failure or coolers clogged with pollen, dirt, or nests.

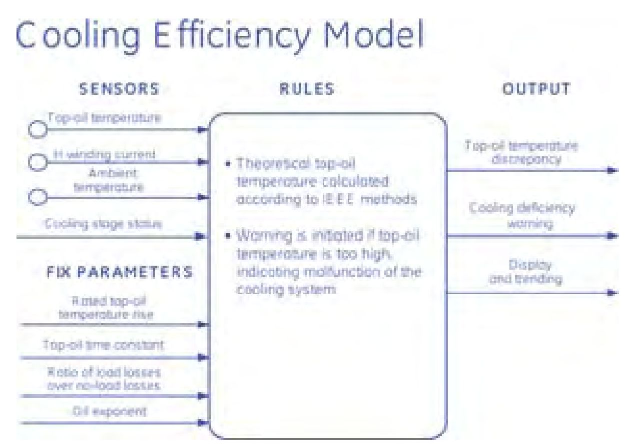


Figure #7: Cooling Efficiency Model

Continued on Page 32

Delivering true AMI technology requires more than changing a letter

Some companies will sell you a residential energy meter that generates interval data and call it advanced metering infrastructure (AMI). But collecting 15-minute interval data from a million advanced meters creates 35 *billion* readings annually. How will you realize the full value of that much data?

OpenWay® by Itron draws on Itron's unrivaled expertise in solutions for collecting, managing, and applying interval data to drive your business. **OpenWay**® integrates easily with leading meter data management systems, such as Itron Enterprise Edition™ Meter Data Management, which combines the scalability and throughput to manage 10 million meters, the security and interoperability to share data easily across your enterprise, and two-way control to every meter.

Applications for data presentation, demand response, revenue protection, and distribution asset analysis, such as those built with Itron Enterprise Edition, give you the tools for applying meter data to improve your business and connect with your customers.

The **OpenWay**® service-oriented architecture is built on industry leading hardware and software platforms from IBM, HP, Microsoft and Oracle. **OpenWay**® seamlessly integrates with existing networks and IT systems using standards such as ANSI C12.22, Web Services, XML, TCP/IP and WMI.

A complete solution that delivers the full value of AMI data—just what you should expect from the industry leader.

* IBM is a registered trademark of the IBM Corporation. HP is a registered trademark of the Hewlett-Packard Corporation. Microsoft is a registered trademark of the Microsoft Corporation. Oracle is a registered trademark of the Oracle Corporation.

OpenWay® by Itron

Smart Metering for the Smart Grid

To learn more about how OpenWay by Itron can support your AMI business case, contact your Itron representative.
www.itron.com

> Visit Itron at CUEE May 13-14, 2008 at Booth #400 <

Continued from Page 30

These conditions need to be detected before a transformer overload occurs. The model uses the following calculation methods:

• IEC 354, Loading Guide for Oil-Immersed Power Transformers; Section 2.4.1, Equation 1

• IEEE C57.91-1995/Cor 1/ July, 2001 Guide for Loading Mineral-Oil-Immersed Transformers; Section 7.2.4, Equations 8, 9, 10, 11, 15

Moisture and Bubbling Model

Moisture content of paper is critical because it reduces dielectric strength and increases risk of bubbling at high load resulting in accelerates. The calculations are carried out in line with the following recommended methods:

• T.V. Oommen, "Moisture Equilibrium in Paper-Oil Insulation Systems", Proc. Electrical Insulation Conference, Chicago, October 1983

• W.J. McNutt, G.H. Kaufmann, A.P. Vitols and J.D. MacDonald, "Short-Time Failure Mode Considerations Associated With Power Transformer Overloading", IEEE Trans. PAS, Vol. PAS-99, No. 3, May/June 1980

• T.V. Oommen, E.M. Petrie and S.R. Lindgren, "Bubble Generation in Transformer Windings Under Overload Conditions", DobleÒ Client Conference, Boston, 1995

• V.G. Davydov, O.M. Roizman and W.J. Bonwick, "Transformer Insulation Behavior During Overload", EPRIÒ Substation Equipment Diagnostic Conference V, New Orleans, February 1997

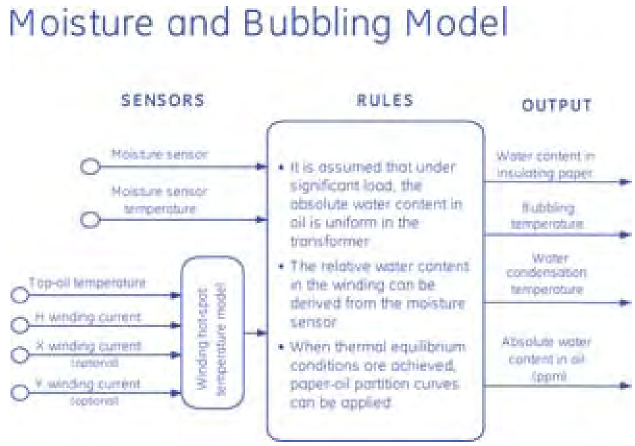


Figure #8: Moisture and Bubbling Model

Tap Changer Temperature Model

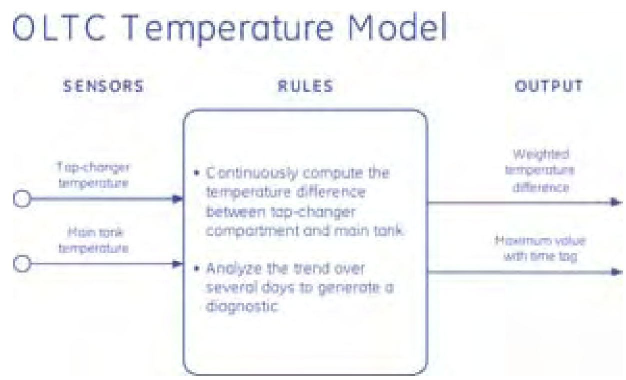


Figure #9: OLTC Temperature Model

Over the life of the transformer, the Tap Changer is a significant source of potential maintenance issues. Many problems with the tap-changer (contact coking) lead to temperature rise in the tap-changer compartment. This failure mode is easily detected by monitoring tap-changer temperature compared

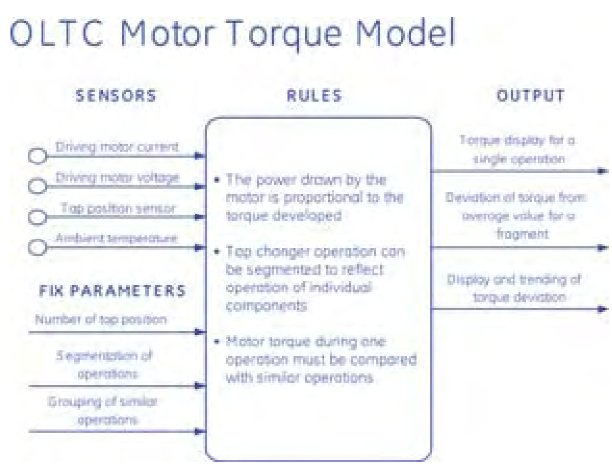


Figure #10: OLTC Motor Torque Model

to main tank temperature.

Tap Changer Motor Torque Model

A change in the motor torque pattern is another indicator of mechanical failures of a tapchanger component. The Tap Changer Motor Torque Model provides a means of detecting a fault in the tap changer, the reversing selector, the gears or energy storage device.

Dynamic Loading Model

The Dynamic Loading Model provides the operators with a perspective of the overloading capabilities, based on current operating conditions. As the load grows in the area, this capability will become more critical in the operation of the transformer.

The Dynamic Loading Model is based on the following models:

- IEC 354, Section 2.4
- IEEE C57.91-1995, Section 5.2 & 7.2.6

See the May issue of Electricity Today for Part II.

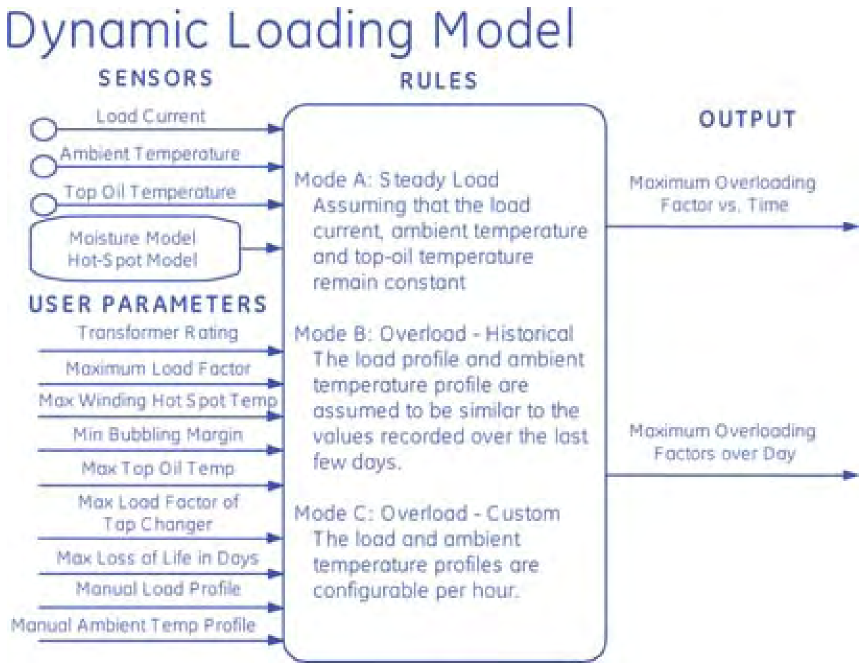


Figure #11: Dynamic Loading Model