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Dynamic Rating, Monitoring, Control & Communication for Power Transformers

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The DRMCC is a state-of-the-art monitoring and control system for oil-immersed power transformers. The system is suitable for new transformers and can also be retrofitted to old transformers in the field. It combines the following features at an affordable cost:

- Dynamic ratings
- Monitoring
- Control
- Communications

real-time measurements and calculations for dynamic rating, the enhanced DRMCC thermal model is more accurate. A transformer may typically be loaded 10-20% higher and with greater confidence with DRMCC dynamic rating than with static thermal rating. Instead of "flying blind" when operating close to the limits, dynamic rating provides timely and accurate information as to what the real thermal limit is at this moment.

Thermal rating

Thermal rating is based on a simple model. Losses in the core and windings cause the oil temperature to rise above ambient. Losses in each winding cause a winding hot spot temperature increase (the "winding gradient") above the top oil. Under transient conditions the rate of rise of oil and winding temperatures depends on the difference between rate of energy generation and dissipation and on the thermal capacity.

The loading guides define limits to loading based on various criteria. However it should be stated that the figures are for transformers in good ("as new") condition. For example, if the solid insulation moisture content is high, bubbling could commence at temperatures well below those stated. Thus the actual transformer condition must be assessed and taken into account before setting realistic limits to loading for that transformer.

Traditionally the loading guides have been used to prepare static thermal ratings for transformers for various ambient and operating conditions. Some SCADA and substation control systems include transformer thermal models with continuously monitored load currents, and sometimes, ambient temperatures. Typically this static thermal rating makes it is possible to load a transformer to 10-20% above nameplate rating for extended periods without risk of damage, but this is still not dynamic rating.

Dynamic rating

The dynamic rating of a transformer is the maximum load possible without exceeding predefined thermal and current rating limits, based on real time measured ambient and transformer temperatures, cooling status and load. In addition to This may be presented in two ways: given the present conditions as the starting point, how long can the transformer carry the present load (or a specified load), or what is the maximum load that can be carried for a specified time, without exceeding the pre-set limits to loading.

Monitoring

DRMCC is flexible in its application and not all available features have to be used. Depending on which control features are implemented, the data to be monitored may include: single or three phase amps and volts, watts and vars; frequency; tap position; ambient, oil and winding hot-spot temperatures; tap changer status and cooler status. It is important to note the improved accuracy of temperature measurements using Class A RTDs compared to traditional capillary tube instruments. This is important because the ageing rate of cellulose insulation increases rapidly with temperature above 100 °C. Oil and winding temperatures can be both measured and calculated (from ambient temperature and load), enabling the thermal model parameters to be calibrated to improve accuracy.

Additional I/O channels are available for on-line condition monitoring sensors such as dissolved water or gas in oil. Our philosophy is to monitor just sufficient diagnostic information continuously on-line to give an early warning of potential problems. This can then trigger more thorough oil diagnostics and site testing as required. This approach leads to savings in maintenance costs, improved reliability and reduced down time.DRMCC can keep track of fan and pump run hours, transformer ageing rates and accumulated age and the number of tap changes for each tap position.

The event recording and data logging facilities of the DRMCC have been made configurable to provide for the different monitoring requirements. The system stores data in 53 files, each with data for one week. These files can be downloaded and read into software such as spreadsheets for analysis.

Voltage & OLTC control

DRMCC provides the following OLTC operating modes:

- Independent - Manual
- Independent - Auto
- Parallel - Master - Manual
- Parallel - Master - Auto
- Parallel - Follower
- Parallel - VAR sharing - Auto
- Parallel - Circulating current - Auto
- Parallel - Reverse Reactance - Auto

Manual control can be at the DRMCC or from SCADA. Master / Follower and VAR sharing modes use serial communications between paralleled DRMCCs. Circulating current mode uses CT bus wires between parallel transformers. For retrofit applications DRMCC can be integrated into existing hard-wired parallel control systems and simply set to Independent mode. Parallel control will then be done by the external circuitry. In Auto mode LDC (Load Drop Compensation) may be activated. Bus wires to sum the transformer CT currents should be used with LDC to avoid the "double boost" effect when one or more of the transformers are off load.

Definite time delay or inverse N time delay modes may be selected in Auto mode. OLTC blocking is provided for under voltage, over voltage and over current conditions, also if transducer errors are detected. Alarms are generated if the control voltage is outside tolerance for to long, or if a tap change fails to complete once initiated.

DRMCC can be configured to control two- and three-winding transformers, separately and auto wound.

Cooler control

Manually and automatic cooler control is provided for 1 or 2 pumps (1 spare with optional duty cycling) and 1 or 2 separately controlled banks of fans. This allows using either bank on its own to reduce noise level or both banks to boost cooling for short times. Also VS fan motors can be controlled. The cooling can be turned on early if the load increases suddenly ("Smart Cooling"). If DRMCC detects failure of a temperature transducer or its own communications or power fails, it will switch on the cooling ("Fail Safe").

Communications

Interfaces include RS-232, RS-485, optic fibre and optional 10 Base T. Protocols include Modbus, DNP3, Hayes and TCP/IP. The Modbus and DNP3 data mapping may be user defined in a text file.

Copper connections may be used if the equipment is in the same cubicle. Optic fibre connections should be used across long distances in HV substations.

This enables communications such as:

- DNP3 or Modbus communication over a serial link to a substation controller or SCADA RTU
- A PC or laptop computer may be plugged into the front RS-232 port or connected via modem or WAN or intranet. A web browser with HTTP can then be used to view the present data. FTP can be used with a password to download data files or upload configuration files. Telnet or HyperTerminal can be used with a password to log onto the DRMCC for diagnostics or control.

Design Features

The DRMCC comprises a "UIM" (User Interface Module) and one or more I/O modules. The I/O modules should be situated close to the input sensors such as RTDs and equipment being controlled such as fans and pumps. Usually the I/O units will be DIN rail mounted in a weatherproof cubicle at the transformer. The UIM may be housed in the same cubicle or in the substation building. The UIM communicates with the I/O units using a subset of DNP3 level 1 protocol. The connection may be RS-485 multi-drop shielded twisted pair copper cable if they are all in the same cubicle or optic fibre across the substation yard.

The UIM contains the CPU and comms cards, pushbuttons, LCD and LEDs. The information in the UIM can be displayed on the LCD in the form of text-based menu pages. It can also be displayed as a web page on a PC or laptop computer suitably connected - see Communications.

Features to enhance robustness and reliability include:

- extended operating temperature range (-40 °C to +80 °C)
- designed for EMC, both emissions and immunity (tests pending)
- 2 kV rms 60 second insulation level to earth on all I/O circuits
- optic fibre communications
- self-test at boot-up
- continuous internal self checking

The design philosophy behind the DRMCC remains to provide a "value for money" system. This is achieved by keeping the system simple yet flexible and customisable. The modular PC/104 architecture in the UIM provides an easy upgrade path allowing further improvements to be added without making existing installations obsolete.

There are no moving parts such as fans or disc drives. The software, data log and event record are stored on a removable / replaceable compact flash disc to simplify field upgrades.

Savings

Dynamic rating enables controlled emergency loading beyond nameplate rating and beyond what is possible with conventional static thermal rating based on the loading guides, without undue risk. In substations with N transformers, where the combined load exceeds the sum of the nameplate ratings of N-1 transformers, this could result in very large dollar savings due to deferred capital expenditure and reduced number of outages.

When sufficient continuous on-line monitoring is installed to provide early warning of most types of potential problems and faults, further large savings can be achieved by:

- Reducing the risk of failure and improving reliability
- Reducing maintenance costs by using condition-based rather than time-based maintenance

Improved control and communication capabilities will facilitate the trend to unmanned substations and reduce the need for operators and maintenance personnel to visit the substation.

Conclusion

In 1995 Wilson Transformer Company introduced their PLC-based "WTMS" for transformer monitoring and control. The concept proved successful but it was decided to introduce the DRMCC with more rugged hardware in 1999.

The next generation and much-improved DRMCC-T2 was released in Australia at D2001 and in the USA at TechCon 2002. It promises to be the best monitoring and control system for power transformers on the market.

For further information, visit the DR website www.DynamicRatings.com or phone us at +61 3 9560 0411