DISTRIBUTION TRANSFORMER INTEGRATION IN ECO-GRID

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ABSTRACT

This paper describes the monitoring of distribution transformers (Cast Resin or Oil Immersed) and their integration in Eco-grid

INTRODUCTION

Nowadays, management of electrical equipment is becoming more and more important, especially for electrical distribution equipment involved in critical processes (Switchgear, Breaker, Motor, HVAC, Transformer, ...).
More and more substation components give the possibility to be monitored in real time (Digital Monitored Substations - DMS), which give possibility to oversee critical processes and materials. Eco-grid is an electrical network where all devices are monitored.The transformer being a key product of the electrical distribution, its outage represents a severe impact for end-users, therefore it is mandatory that they become integrated in this already existing connected architecture.
It is now current that substations with power transformers are digitized. On the other hand, substations with distribution transformers are today only either partially digitized (RMU) or not digitized at all. In order to increase safety, reliability and efficiency of distribution substations, it becomes necessary to digitize the full package including especially the transformer.

MONITORING DESCRIPTION

<u>What?</u>

The monitoring system developed for distribution transformers can be separated in two main families, one for each product.

For cast resin transformers it consists in 4 main bricks described below:

- Ambient temperature and humidity conditions
- Primary winding temperatures (terminals)
- Secondary winding temperatures (terminals and coils)
- Power supply quality

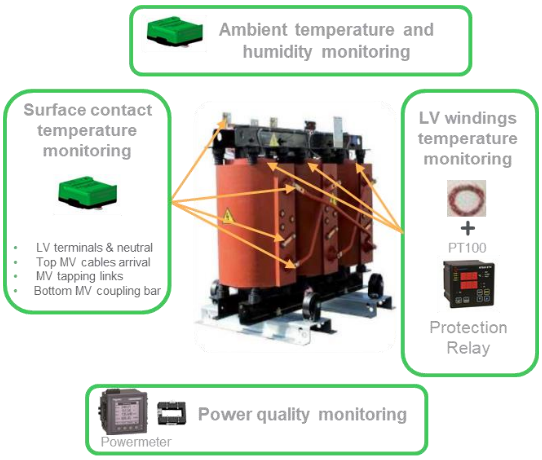

Figure 1Cast Resin Transformer monitoring [1]

For oil immersed transformers the system is based in 6 bricks:

- Ambient temperature and humidity conditions
- Internal tank pressure
- Top oil temperature
- Oil level
- Tank surfaces temperatures
- Power supply quality

Figure 2 Oil Distribution transformer monitoring

Why?

The main benefits of monitoring distribution transformers are :

- Increase the level of safety by anticipating some events which could lead to potential dangerous situation for operator
- Increase transformer efficiency by anticipating events which could lead to minors troubles, breakdown, emergency working modes
- Be permanently connected to the installed based in order to get immediately information and quickly take the right decision

Increase safety for both **operator and assets**

Increase asset management efficiency reducing unplanned downtime and scheduled maintenance cost

24/7 connectivity enabling better-informed decisions

How?

All gathered data can be easily displayed through any kind of HMI. But such a display does not bring any actual added value to the end-user, it consists only in a very basic information, without giving any helpful data on transformer health. A way to bring added value and useful information to the end-user is to analyse and post-treat the gathered data. This action can be performed through different commonly used devices such as:

- PLC (**P**rogrammable **L**ogic **C**ontroller)
- RTU (**R**emote **T**erminal **U**nit)
- Cloud computation

Using above mentioned devices, it is then possible to generate some alarms in order to warn end-users in case of need, which can be communicated by:

- SMS
- Mail

Alarms can be activated by different ways:

- When single data reached a defined threshold
- By computing single data using basic algorithms or formulae and comparing the result with thresholds
- By computing multiple data using advanced algorithms or formula and comparing the result with thresholds

DATA ANALYSIS

Algorithm introduction

Transformer algorithm can be separated in different blocks described below.

Common to Dry Type and Oil-Immersed Transformers:

- Environmental ambient condition (temperature, humidity)
  - Ensure transformer works in normal environmental conditions
- Voltage monitoring
  - Overvoltage & over-induction detection
  - Other power quality parameters surveillance
  - Counter for number of energizations
- Load monitoring
  - Overload & unbalance load detection
  - Other power quality parameters surveillance
- Advanced monitoring
  - Possibility to detect short-circuits between turns & windings deformation

Specific to Dry Type Transformers:

- Thermal monitoring on different external spots
  - MV and LV windings temperature calculation, windings hot-spot determination and lifetime consumption computation
  - Loose connections and local hot spots detection

Specific to Oil-Immersed Transformers:

- Bushings thermal monitoring:
  - Loose connections and local hot spots detection

- Combined top-oil temperature, internal pressure and oil level monitoring
  - Degassing or leakages detection
  - Abnormal behaviour

The output of continuous above-described data computation can be considered on 3 different levels:

- Informative: no action needed from end-user (example: lifetime consumption = 20%)
- Basic alarm: action needed to avoid any further

transformer deterioration
(example: temperature slightly exceeds limits)
- Critical warning: Urgent action needed to avoid breakdown
(example: quick increase of internal pressure)

Threshold

The first level of the algorithm generates alarms by comparison between a single data and a threshold.
(Example: tank pressure exceeds 200 mbar)

These thresholds settings are obtained by two ways:
- IEC 60076 and other transformers related standards
- Manufacturer's own knowledge and experience

Standard Algorithm

The second level of algorithm perform basic calculations based on collected single physical data.

Example: calculation of actual induction based on voltage monitoring and some constants initially inputted, using BOUCHEROT formula:

$$U = 4{,}44\,.\,B\,.\,N\,.\,f\,.\,S$$

Where:

U = RMS Voltage on the transformer
B = Maximal amplitude of induction
f = frequency of the voltage
N = Number of turns of the winding
S = Magnetic section

Parameter f, N and S stay constant during the working of the transformer and the equation can be resume at

$$U_1 = k\,.\,B_1$$
$$U_2 = k\,.\,B_2$$
$$B_2 = \frac{U_2\,.\,U_1}{B_1}$$

Where :
B1 = Rated induction
B2 = Induction during operation

Computed data are then compared to thresholds, which may be defined either by commonly used and admitted limits, or based on manufacturer own knowledge and experience

Advanced Algorithm

The third level of the algorithm is also the more complex, by performing calculations based on multiple simultaneous parameters, which can be combined with time to determine some trends. It also means that a single data will be used at the same moment for different computations.
Example: a temperature measurement on a dry-type transformer upper bushing will be used in:
- Winding temperature rise computation coupled with other temperature measurement points
- Internal defect detection when coupled with load monitoring
- Local hot-spot when compared with other upper-bushing temperatures
- ….

Most of limits leading to an alert in this advanced algorithm are not defined in standards, and are based on manufacturer experience and knowledge. One solution is to build a database for transformer behaviour in different situations, in order to know where are the limits.
In the case no transformer in the database matches with a newly requested design, 2 possibilities exist to define the alerting:
- Perform a specific behaviour test on the new design (and consequently improve the database)
- Extrapolate the behaviour from the closest transformers already existing in database, and then adjust some parameters after some months of operation

NEXT STEPS

In the future (next 10 years), integration of transformer in ECO-grid can allow the end user to:

- Protect people and assets
- Operate at nearby distance
- Optimize its OPEX
- Cut down outages
- Optimize life span, maintenance and replacement of transformers
- Define in a more accurate way the future specifications, based on the actual need and use of the transformer for a given application

REFERENCES

[1] A.Hammen, G.Ranalletta, C.Macri 2017 Management and easy comunication of temperature rise, CIRED Glasgow, N°0876