ASSET MANAGEMENT APPLICATION; INSTRUMENT TRANSFORMERS ONLINE MONITORING SYSTEM

Nuria CALVO
Arteche – Spain
nuria.calvo@arteche.com

Enrique CHÁVEZ
Arteche – Mexico
enrique.chavez@arteche.com

Rolando GÓMEZ
Arteche – Mexico
rolando.gomez@arteche.com

OBJECT

Nowadays the electrical sector is suffering many changes in terms of asset management, turning from classic solutions to newest systems aligned with smart grid philosophy. New systems are now connected to networks and able to interact with other complex and dynamic systems, so assets can be managed in a more effective way. These changes are linked to the embedded systems that give users more powerful tools.

This paper presents a comprehensive solution, based on modular, scalable and integrable systems, which analyzes the condition of the main insulation in oil-insulated instrument transformers, focused on providing solutions in changing electrical networks.

The state of insulation is diagnosed using non-invasive sensory coupling, thus incorporating an added value to this solution.

Both the multifunctional architecture and the technical specifications of operation required in the modules are exposed. This paper aims to explain the relationship between the multifunctionality and the processing resources that the solution must contain, as well as the method used to parameterize the voltage and current values, and the complementary systems needed (communications, data management SW ...). All based on the calculation algorithm, fundamental pillar to guarantee the reliability of the solution.

WHAT IS THE PROBLEM

The ever-increasing electric energy consumption puts a significant weight on the importance of an uninterrupted electricity supply.

Currently, electric power consumption has a positive trend; therefore, the production and uninterrupted transmission of electric energy are a fundamental objective to accomplish the supply that meets the growing demand.

The operation of power and instrument transformers in the electrical substations is 24 hours 7 days a week, uninterrupted. Therefore, the maintenance plans for the conservation of these assets must be carried out with the appropriate programming and shall be carefully observed to guarantee the reliability of the equipment in operation.

The main causes of failure in transformers immersed in oil are due to the condition of the internal insulation and windings, which can originate to a large extent a major failure (explosion.

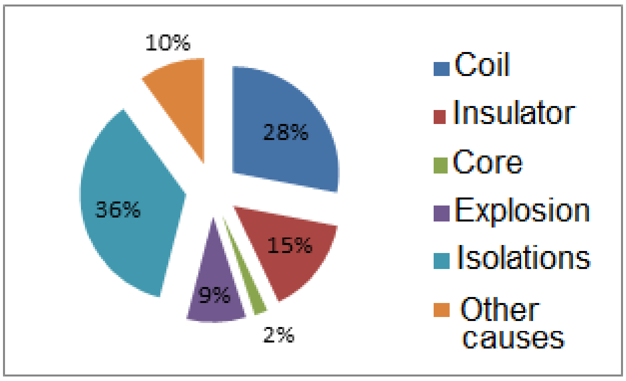


Figure 1. Causes of failure in transformers.

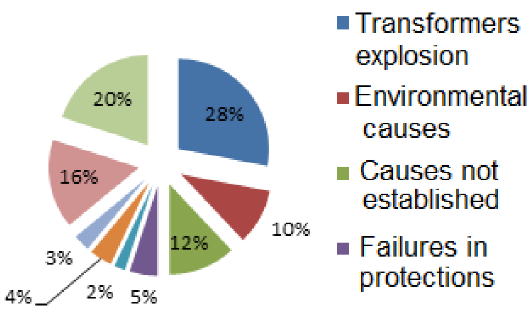


Figure 2. Causes of substation faults

The measurement of the delta tangent (dielectric dissipation factor) is one of the best methods for evaluating the state of the insulation.

According to the analysis and research that we are carrying out on the relationship of the delta tangent and the condition of the insulation, it has been shown that temperature plays an important role of the tangent delta.

Because the traditional measurement of this parameter is done with de-energized equipment and under laboratory conditions, we infer that it is of vital importance that this parameter can be measured while the transformer is under operation, with non-invasive measuring elements.

Even though personnel safety is one of the highest priorities in newest electrical systems, transition and implementation of new on line monitoring systems applied to High Voltage Instrument Transformers is being slow because:

- Installed batch of Instrument Transformers is too diverse in terms of brands, construction technologies and they are usually not compatible between them.
- There are almost no historical records, especially in relation with very old assets.
- Predictive and Preventive Maintenance plans are usually not related with current health of the assets, but with time-based plans.
- Reliability of traditional diagnosis methods is not sufficient.
- Analysis of failure causes, risks and limitations are usually in early phases.
- Limited knowledge of real time critical parameters of IT's, could drive to wrong decisions about expected lifetime of the assets.
- Commercial systems could usually not be compatible with other systems (SCADAs, geolocation, meteorological cells …).

HOW TO SOLVE THE PROBLEM

This work aims to offer an integral solution using embedded systems for online monitoring of the main insulation health in oil-immersed Instrument Transformers. This solution must be aligned with other smart grid solutions and philosophy.

The system must be able to provide an effective diagnosis of the main insulation using a non-invasive leakage current and line voltage sensors, suitable to be plugged to new transformers or already installed ones.

System configuration and technical specs will be explained in all its components: voltage and current capture, SW platform and all methods to estimate the results.

The system has to be able to analyze measured and calculated parameters using proper algorithms and software that could be also configured to create alerts and reports:

- Online IT-insulation monitoring
- Capacitance and tan δ for paper-oil IT's
- Data acquisitions
- Criteria to define the functionality of this system

Signal acquisition

The operating principle is based on the tan δ or power factor:

- Applying the direct relationship between the primary voltage to which the transformer is subjected and the leakage current of the same to calculate the capacitance and tan δ it is necessary to know the phasors of the primary voltage and the leakage current.
- The phasor of the primary voltage would be obtained by measuring directly from the secondary windings of the voltage transformers of the substation.
- The phasor of the leakage current would be obtained from the sensor ~~that would be~~ incorporated into the tan δ tap of the inductive current transformers, which would replace the current ground connection of the tan δ tap. The sensor will maintain the same short-circuit capacity as the current grounding plate, so that the safety of the system is not altered. The sensor installation must be done with the current transformers out of service, and with the line position grounded.

Both measurements are made in different monitoring equipment (different locations within the substation). The synchronization of the measurements in the equipment is critical.

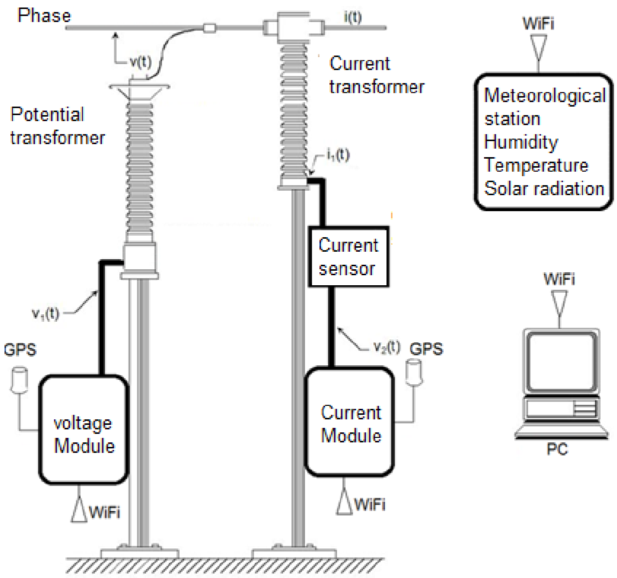


Figure 3. Block diagram of the monitoring system

The acquisition of the phasors would be done through acquisition equipment: After capturing the signal, and after applying a digital filter to the samples, the differential of voltage phasors will be calculated.

Every second, up to 10 phasors of the measured magnitudes are sent, with their corresponding time stamp.

The equipment (high impedance feedback boards) that monitor these signals must have a synchronization source with precision of less than one microsecond.

The installation is optimized if these devices also include WIFI communications, GPS synchronization and independent auxiliary power supply (additional batteries or even photovoltaic auxiliary systems).

The capture of voltage and current signals is done simultaneously with the collection of temperature and solar radiation parameters (used to estimate the temperature of the insulation).

Signals processing

After having captured the signals of the electrical parameters of the transformers in operation, these are stored in the software database of the monitoring system. The data that has been captured is used to estimate tan δ and the current capacitance of the measurement transformers.

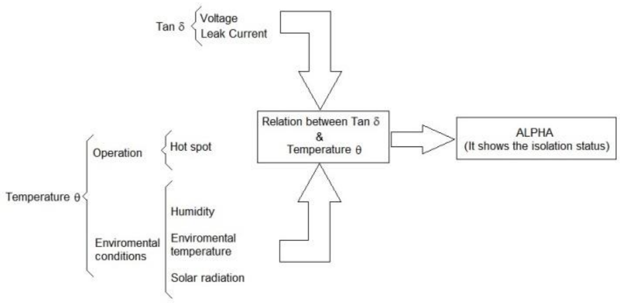
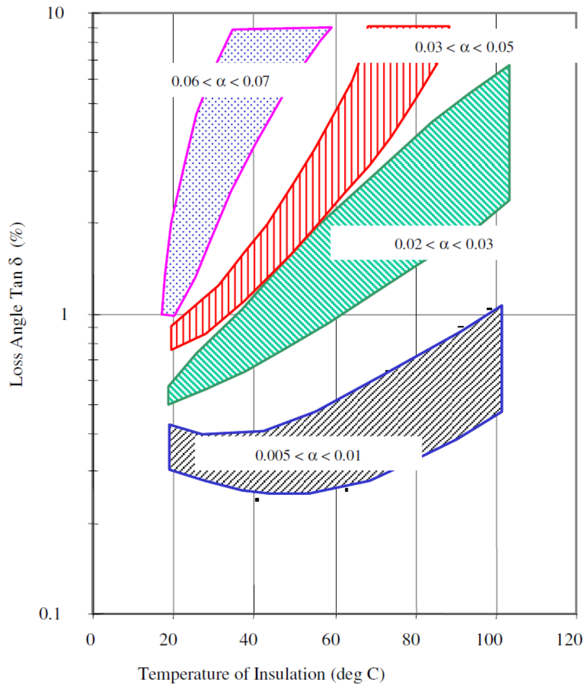


Figure 4. Block diagram of the estimative algorithm status of the internal insulation of the transformer

The constant α is used to know the state of the insulation; it is calculated by reading tan δ at different temperatures. The result is positioned on the graph to be able to know the behavior of the isolation.

$$\alpha = \frac{\ln(\tan \delta_2) - \ln(\tan \delta_1)}{\theta_2 - \theta_1}$$



Based on the theory of the constant α [1], the temperature estimation of the insulation is carried out by means of an algorithm, taking into account both the operating conditions and the environmental parameters.

STATUS OF ISOLATION	LOWER LIMIT	UPPER LIMIT
OPTIMUM	0.005	0.01
GOOD	0.02	0.03
MEDIUM	0.03	0.05
CRITIC	0.06	0.07

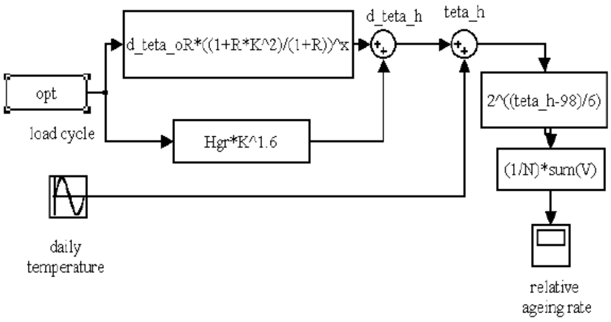
Table 1. Condition of the internal insulation according to the variable δ.

Table 1 lists the boundary values of α; with these values the current state of the transformer is diagnosed.

In addition to the constant α, it is possible to know the lost life-time of the transformer [2] in the period of time since the monitoring system has been installed.

For the calculation of losses of hour of life per day, the equations of the IEC60076 standard will be used, integrating them in the internal calculation algorithm:

$$L = \frac{1}{N}\sum_{n=1}^{N} V_n \qquad V = 2^{\frac{\theta_{HS} - 98}{6}}$$



Information management: Signal management

One of the features of the software for the treatment of signals and information are the customizable graphics, with which you can graphically visualize and compare energy consumption data and system indicators.

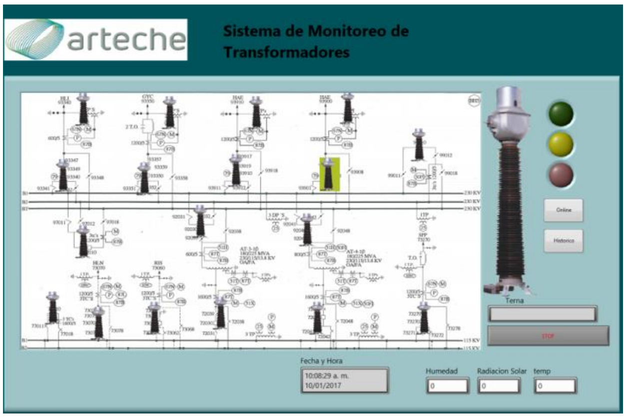


Figure 5. Real-time status display screen of a monitored transformer: SW own development by Arteche

The objective of this software is to provide an Asset Management System [3] based on Predictive Maintenance, with a maximum reliability at an optimal cost.

The information management SW through predictive models should allow automation in the variable calculation that affects the transformer, thus obtaining very accurate forecasts of the future replacement of the asset and determining more accurately the status of the insulation.

This type of SW will also have the capacity to receive another series of inputs from other complementary systems of the Substation (SCADAs, Geolocation ...).

CONCLUSIONS

Practical results in internal tests with pilot project in Arteche:

• The capacitances and tan δ of 10 different transformers Arteche, mod.CA-245 have been measured.
• The measurements were made simultaneously with a standard system of the TETTEX laboratory model 2767
• Results obtained:

- Average capacitance value: 995.7pF
- Average value tan δ: 0.33
- Difference% with our capturing cards in development: ± 0.5%.

The analysis of the results obtained shows that this difference is within the permitted limits.

Therefore, we can conclude that the system under development by Arteche is reliable, both in values obtained by the method and by those obtained by the algorithm.

REFERENCES

[1] Bhumiwat, S., Srihatajati, 1993, "Ageing insulation study of Instrument Transformers in EGAT System after several years in service ", Proceedings CIGRE conference, Berlin, paper 110-12

[2] K. Najdenkoski, G. Rafajlovski,V. Dimcev, “Thermal aging of distribution transformers according to IEEE and IEC standards”, IEC 60076

[3] UNE-ISO 55000, 2015, "Asset management. Overview, principles and terminology"; UNE-ISO 55001, 2015, “Asset management. Management systems. Requirements”; UNE-ISO 55002, 2015, “Asset management. Management systems. Guidelines for the application of ISO 55001”