A Step-Up Transformer Online Monitoring Experience at Euzébio Rocha UTE [Thermal Power Plant]

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ABSTRACT

The step-up transformers at the Euzébio Rocha Thermal Power Plant in Cubatão - SP [São Paulo] are key for the Brazilian national electric power supply. Due to their significance and to their severe operating conditions, Petrobras has always invested on and kept a strict preventive maintenance program for this equipment. Leader in technology and committed to keeping a high power supply quality level, Petrobras installed an online monitoring system on its step up transformers, with the purpose of identifying early possible incipient defects and mitigate catastrophic failure risks even more.

The implementation of this system, with sensors and software, took place in 2014, and four transformers which were already operating at the plant began to be monitored. The implementation of the monitoring system used IEDs which were already in place and took advantage of the modularity and expandability features of the decentralized architecture.

Here we describe the architecture and the solutions used in system implementation, as well as the results obtained, successfully reaching goals such as maintenance focused in reliability and greater personal, equipment and facility safety.

KEYWORDS:

Online monitoring, Diagnosis, Prognosis, Predictive Maintenance, Sensors, Software,

Transformers.

1.0 - INTRODUCTION

Natural gas-fired Euzébio Rocha Thermal Power Plant, in Cubatão-SP, one of Petrobras's power plants, contributes with over 200MW to the Brazilian Electric Power System. With the ability to supply a 600-thousand inhabitant city with electric power, it demands great operating efficiency to guarantee seamless electric power supply.

It operates with two step-up transformers: a 225 MVA one and a 70 MVA one, plus two ancillary 16MVA transformers. They entered operation in 2009.

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These transformers play a key role in the transmission of the electric power generated by the plant. Due to their significance and to their extreme operating conditions, including high temperature, strongly corrosive atmosphere and the normal dielectric requirements for system operation, Petrobras has always kept a strict preventive maintenance program for them.

However, conventional practices are not enough to ensure plant reliability. Therefore an online monitoring system was implemented to reduce failure risk with the detection of the main types of defects at an incipient phase - the monitoring of the transformer operating status.
Some of the sensors which were needed for the project were already in place in the transformers and were used.

2.0 - TRANSFORMER FAILURE STATISTICS

An international research of operating power transformers performance [1], carried out by Cigré with data from failures occurred between 1968 and 1978 involving over 1,000 failures revealed the main causes of downtime, both forced and planned, for several transformer kinds and applications.

Figure 1 shows those data for NLTC transformers in power plants. According to those statistic data, the bushings are the main cause for transformer failure, responsible for one third of the occurrences, with the active part virtually tied with it, in second place, followed by tank and oil. These three subsystems of the transformer together answer for virtually 84% of the equipment downtime.

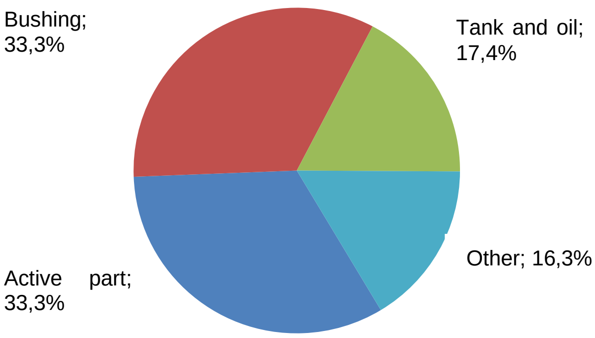

Fig. 1 - Statistics of the causes for NLTC transformers downtime [1].

Based on these statistics and on the previous experience by Petrobras, step-up transformer and ancillary transformer variables to monitor were selected. This was done in addition to the required data processing functions so the measured variables could be turned into useful information for transformer diagnosis and prognosis. That procedure aimed at covering the main transformer subsystems and therefore reducing failure and unavailability risks.

3.0 - TRANSFORMER SENSING

The variables measured in step-up transformers in Mauá and Cubatão plants are shown in table 1, grouped by subsystem.

Table 1 - Variables monitored in the step-up transformers grouped by subsystems.

System	Sensor	Variable
Bushings	Bushing Monitor	Capacitance
		Tangent Delta
		Leakage current
		Phase-ground and phase-phase voltages
Active part	Temperature Monitor	Oil Temperature
		Winding temperature (hot spot)
		Ambient temperature
		Load percentage
Tank and Oil	Moisture Monitor	Water content in oil (ppm)
		Relative water saturation (%) in oil;
		Saturation relative to the ambient temperature
		Saturation relative to the reference temperature
		Water content evolution trend
Other		Alarm contacts: - Buchholz relay, - Pressure relief valve, - Oil level, etc..

In order to completely comply with its objectives, the monitoring system must process the data listed above so useful information is obtained about transformer status, as detailed below.

4.0 - DATA HANDLING FOR DIAGNOSES AND PROGNOSES.

To handle the data obtained from the sensors mentioned above, the installed monitoring system has in its software an Engineering Module, which includes the engineering models shown in table 2.

Table 2 - Engineering Models for transformer condition diagnosis and prognosis.

System	Engineering Model	Diagnoses and Prognoses
Bushings	Bushing Status	Capacitance evolution trend (pF/day)
		Tangent delta evolution trend (%/day)
		Remaining time before critical capacitance levels are reached (days)
		Remaining time before critical tangent delta levels are reached (days)
Active part	Insulation aging	Remaining Insulation service life
		Insulation service life trend (% / day)
		Remaining isolation service life (years)
	Moisture in Paper	Water content in the role (% dry mass)
		Acceleration factor of isolation life loss through

		hydrolysis
		Bubble formation temperature
		Free water formation temperature
	Gases dissolved in oil	Gas chromatography test offline reports
	Temperature prediction	Future hot spot temperature after stabilization
		Time to reach alarm temperature
		Time to reach shutdown temperature
	Simulation	Temperature evolution simulation with load step
		Temperature evolution with load curve 24h
		Hypothetical loss of service life
Tank and Oil	Physicochemical	Physicochemical test offline reports
		Water content evolution trend (ppm / day)
Cooling system	Cooling efficiency	Top oil calculated temperature
		Difference between measured and calculated temperatures
		Cooling system efficiency
	Cooling maintenance	Cooling group total operating time
		Cooling group operating time after maintenance
		Remaining time before cooling group maintenance
		Pump vibration alarm

Therefore, raw data from sensors allow of useful information to be obtained for transformer status diagnosis and prognosis [2], [3].

5.0 - MONITORING SYSTEM ARCHITECTURE

Euzébio Rocha Thermal Power Plant 's transformer monitoring system architecture is shown in figure 2.

Variables already shown in Table I were measured through intelligent sensors (Intelligent Electronic Devices), designed and tested to be specifically used in the substation yard environment, which allows them to be installed directly in the transformer body.

Those sensors are provided with communication ports that allow them to be directly connected to a communication network, which makes it possible to directly transmit measurements to a transformer monitoring server. The sensors communicate with the server via Modbus-RTU protocol.

The server, in turn, also communicates with the Supervisory Control System of the Thermal Power Plant UTE-EZR through OPC protocol. Therefore the data can be monitored by the operations team, stored in a history server or even be made available for other systems.

In the transformer monitoring server, the Sigma monitoring software, which processes the date shown in Table II, is executed.

Through Petrobras's Intranet, the users have remote access to the monitoring system through an HTML interface with Web 2.0 technology.

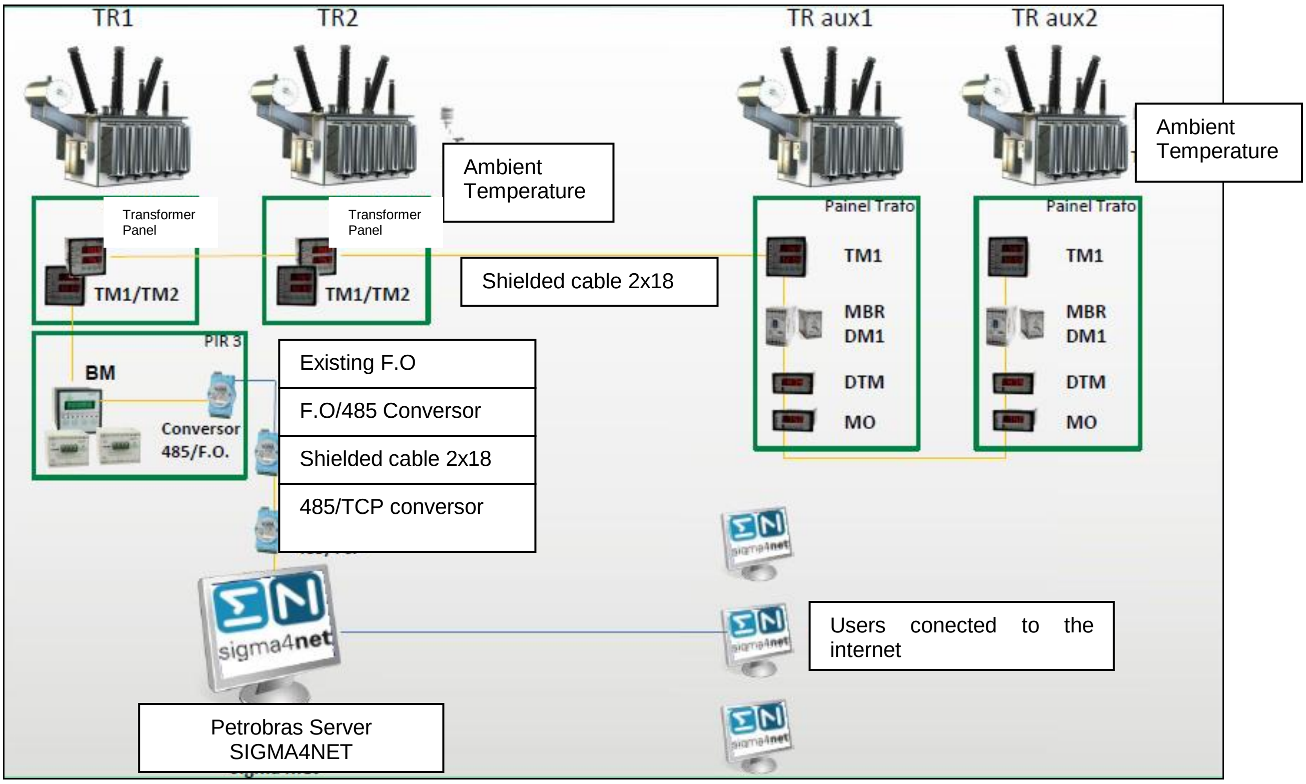

Fig. 2. Transformer monitoring system architecture

The architecture chosen by Petrobras is decentralized [4], that is, it does not utilize a sole central element in the transformer body, thus avoiding additional costs and eliminating a failure point [5]. This architecture has also brought some additional benefits in installation, listed below:

- Due to its modularity, the system can be easily expanded to several transformers in the plant.
- It is also possible to expand it to include other equipment in the plant, such as circuit breakers, disconnect switches, current transformers (CTs) etc.
- It is possible to expand the system by adding new sensors

6.0 - SYSTEM FUNCTIONALITIES

The main functionalities available through monitoring software are:

- Local access in the plant and remote access from any point of the Petrobras network through Web pages, eliminating the need for plug-in installation in end-user computers.
- Possibility of remote access through smartphones, with permission by system and network administrators;
- Alerts sent by email if there are any diagnosis alarms or alerts,
- Sensor data and engineering data storage in an SQL Server database, keeping a track record of the whole transformer service life;
- Access to online or historic data for viewing;
- History consultation through graphs, tables or exportation to XLS files (MS, Excel)
- Alarm issuing interface with alert and alarm beginning, acknowledgment and resolution information recorded in the database;
- All access and operations by users are recorded by the system;
- Access is protected by username and password, with a specific access category for each user. Viewer, Operator and Administrator
- Easy integration with other systems through the OPC communication protocol;

7.0 - SYSTEM INSTALLATION

The first IEDs entered operation with the energizing of the first transformers in 2009. Petrobras already had the basic online monitoring setup, and was already making use of the sensor-equipped assets's benefits.

The installation of the complete monitoring system was finalized in the first semester of 2014, during the technical downtime scheduled for that year. All installation and commissioning services respected the plant's scheduling availability.

Installation details are shown in figures 3 to 6 below.


Fig. 3. One of the 225MVA, 18/230 kV step-up transformers


Fig. 4. Detail of adapter installation on the 230 kV bushing capacitive tap to monitor their capacitance and tangent delta.


Fig. 5. Panel with intelligent sensors (IEDs) in the transformer's body.

Fig. 6. Monitoring server in the control room

8.0 - RESULTS

Several results are expected with the installation and operation of the monitoring system we have just described, with the following objectives in mind:

- Increased power supply availability and system continuity.
- Reduction of the risk of catastrophic failure, with the detection of early defect onset 6];
- Consequently, increase in plant personnel safety, both for the equipment and for the facility;
- Extension of equipment service life due to faster accelerated aging detection;
- Preservation of the corporate image by reducing accident chance;

- Maintenance routine optimization, which allows gradual migration from preventive to predictive maintenance - based on equipment status rather than on time;
- Equipment preparation for the application of Reliability-Centered Maintenance (RMM) philosophy;

With the graph generation feature available in the monitoring software (Fig. 7) it was possible to follow the evolution of defects in real time, thus allowing a comparative analysis between several operational values, which brought easy and increased reliability when issuing diagnostics of incipient defects.

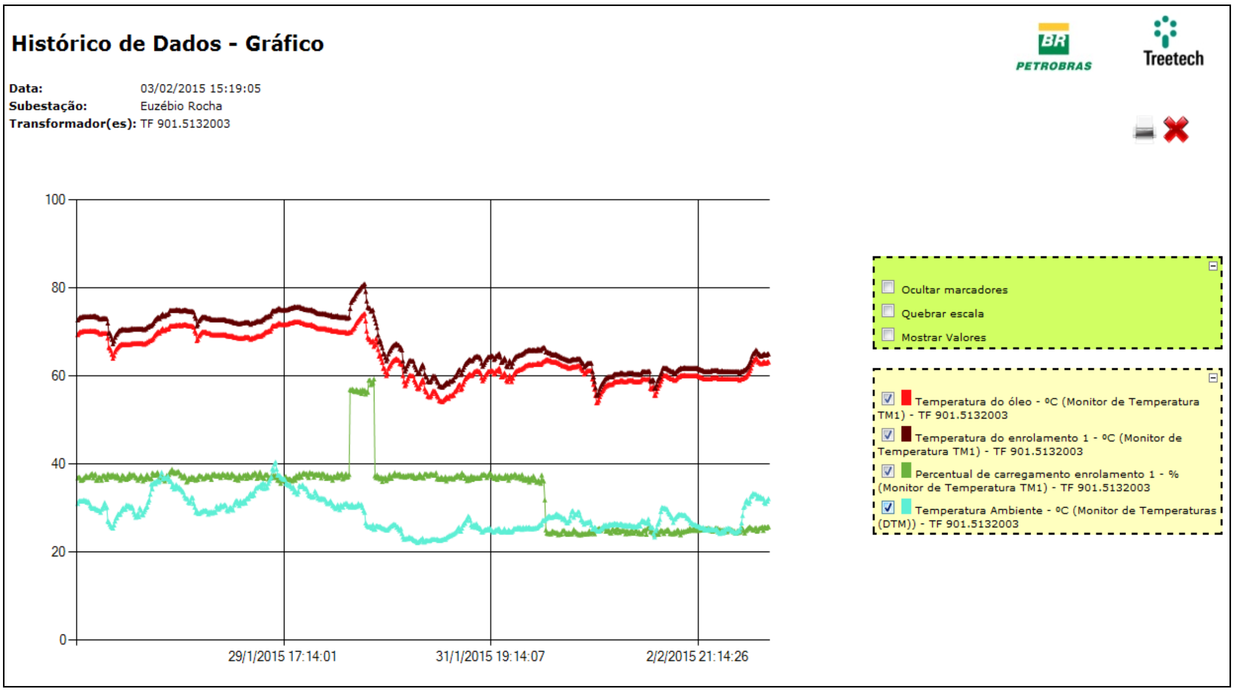

Fig. 7. Monitoring software graph generation tool

9.0 - CONCLUSION

Considering the importance of the contribution of the electric power supplied by Euzébio Rocha Thermal Power Plant for the Brazilian national electric power grid, the implementation of an online monitoring system on its step-up transformers is a significant measure to increase power generation reliability and availability.

With the implementation of this system Petrobras has also reached an important corporate goal: To stay ahead of the competition by installing state-of-the art equipment in their physical facilities. Furthermore, the installation of monitoring systems has received a highly positive evaluation by insurance companies, which brings benefits at the time of purchasing coverage with those companies for the Petrobras's Thermal Electric Power Plant.

10.0 - REFERENCES

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