OUR EXPERIENCE WITH THE PREDICTIVE MONITORING SYSTEM FOR HIGH VOLTAGE TRANSFORMERS INSTALLED IN BRASKEM'S PLANTS

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ABSTRACT

This work analyzes the practical results from implementation and operation of a modern predictive monitoring system in high voltage transformers of the Braskem unit substations in São Paulo (PE8 Cubatão and PP4 ABC). This project has achieved the purpose of guaranteeing better company reliability and profitability by applying the right actions at the right time at an adequate cost, since these are the input transformers of the 88kV substations.

The efficient management of substation electric assets demands tools able to show the current equipment status and the future equipment scenarios; this allows the best technical and financial decisions to be made, so the park is kept intact and available. Inside industries, electric power is an irreplaceable input, and its outage can cause great losses to the organization. In seeking maintenance excellence and the continuity of its electric system, Braskem has implemented online monitoring in 2011 as a way to prevent catastrophic failures in power transformers in 88kV substations.

This article discusses Braskem's most successful experience in applying this technology and in practicing predictive maintenance to increase reliability. The system, -- made of a set of intelligent sensors (IEDs), and specialist software to generate diagnoses and prognoses -- has been operating at full capacity for over three years. The software counts on mathematical engineering models, based on artificial intelligence, to help in the decision-making process.

KEYWORDS

Online monitoring, Diagnosis, Prognosis, Predictive Maintenance, Transformer

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1.0 - INTRODUCTION

Every three years Braskem’s industrial plants, in Mauá and Cubatão, interrupt their activities for inspection and general maintenance of their facilities. Equipment and structures are inspected, in addition to the electric power conditions, which receive special attention with specific activities, mainly at the power substation.

Since electric power is a crucial input for factory production, it is crucial that all assets in the substation are working perfectly. Therefore, each detail of the system is analyzed, such as maneuver equipment (circuit breakers and disconnect switches), insulators (CTs and PTs) and especially the power transformer.

Both substations have only one transformer which cannot have any inconsistency because this may bring great loss to the company.

The actions of Braskem technical and maintenance teams aim at keeping employees safe, reaching the highest possible asset performance level and also keeping power supply uninterrupted to meet the demands of a constant growth in production.

Therefore, from 2011 on, both units started to operate under online transformer monitoring, so predictive analyses could be performed and power reliability could be increased.

Fig. 1 IF Braskem Cubatão/SP - 88 / 13.8 kV, 15 MVA Transformer

Fig. 2 IF Braskem Cubatão/SP - 88 / 13.8 kV, 35 MVA Transformer

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 3 shows those data for OLTC transformers in power plants. According to those statistic data, the OLTC is the main cause of transformer failure, followed by the active part and the bushings.

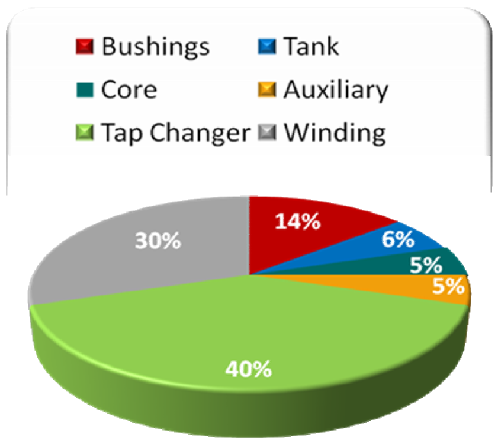

Fig. 3 Statistics of the causes of OLTC transformer downtime [1].

Based on this and on the need to increase operational reliability of the assets the variables to be monitored were selected, in addition to the data processing functions needed so the measured variables were transformed into useful information for transformer diagnosis and prognosis.

That 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
OLTC:	Voltage Regulator:	Automatic voltage regulation
		Power supply quality
	Torque Monitor	Activation mechanism effort

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

All data obtained by the sensors installed directly on the transformer are sent to the server located in Braskem's own plant and then, after they are processed, are made available online on the computer display. Through the intranet, any authorized terminal can access the system.

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.

Engineering Model	Diagnoses and Prognoses
Isolation service life	Remaining Isolation service life
	Isolation service life trend (% / day)
	Remaining isolation service life (years)
Temperature final gradient forecast	Future hot spot temperature after stabilization
	Time to reach alarm temperature
	Time to reach shutdown temperature
Gases dissolved in oil	Gas in oil evolution trend (mainly H_2)
	Alarms per evolution trend and high or very high gas concentrations
Chromatography / Physicochemical	Gas chromatography test offline reports
	Physicochemical test offline reports
Moisture in oil and on paper	Transformer sealing - expansion tank rubber bag rupture
	Water content in oil (ppm)
	Trend in water content evolution (ppm / day)
	Water content in the paper (% dry mass)
	Acceleration factor of insulation life loss through hydrolysis
Bubble formation temperature	Bubble formation temperature
	Free water formation temperature
Cooling efficiency	Top oil calculated temperature
	Difference between measured and calculated temperatures
	Cooling system efficiency
Torque and changer motor operation time	Maximum torque of the motor in each region of the switching
	OLTC mechanism operation time
	Alarms per torque values and out-of-standard operation time
OLTC maintenance assistant	Commuter operation number
	Switched current sum
	OLTC operation time
	Forecast of remaining time before OLTC maintenance
	Early OLTC mainstenance warnings
Forced ventilation maintenance wizard	Ventilation group operation time, total and after the last maintenance.
	Forecast of the remaining time before ventilation maintenance.

Engineering Model	Diagnoses and Prognoses
	Early Ventilation maintenance warnings

Therefore, the raw data from sensors allow the obtention of useful information for diagnoses and prognoses of the transformer status [2], [3].

5.0 - MONITORING SYSTEM ARCHITECTURE

Braskem's transformer monitoring system architecture is shown in figure 4.

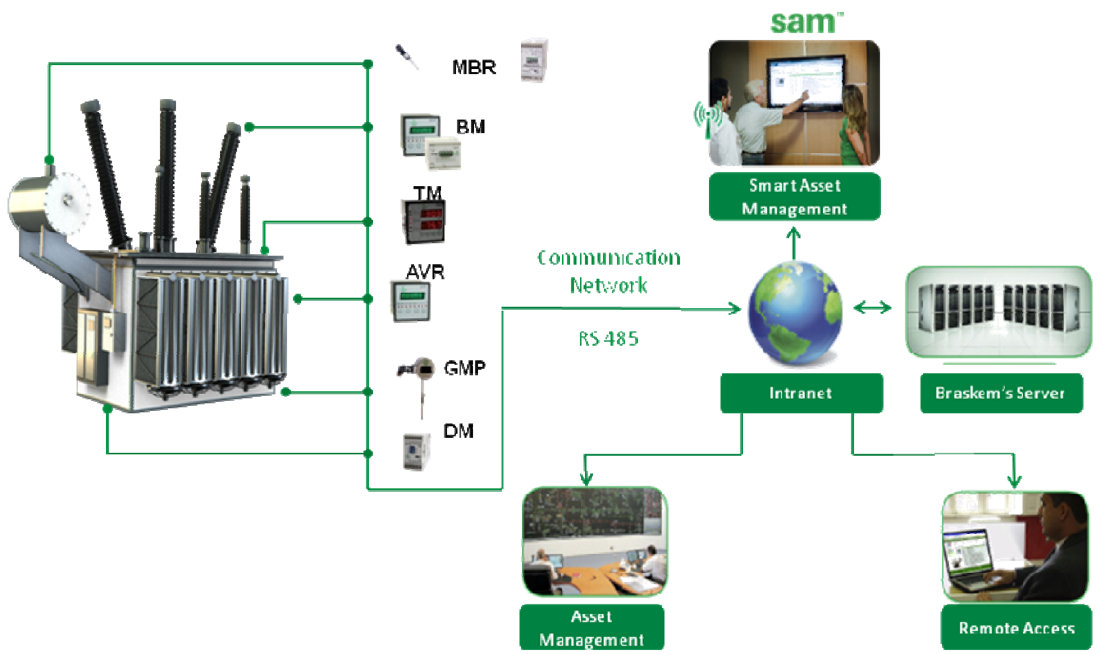

Fig. 4 Transformer monitoring system architecture

Fig. 5 Pt100 to measure oil temperature

Fig. 6 Gas and Moisture Monitor to measure gas dissolved in insulating oil.

Fig. 7 Temperature, Torque, Bushing and Relay 90 Monitors.

Fig. 8 Server with the online monitoring software in the control room

6.0 - RESULTS OBTAINED

Several results were obtained wiht the installation and operation of the monitoring system we have just described, and the following goals were reached:

- Online diagnosis of the transformer status;
- Plant availability;
- Alarm and alert are noticed and operators act according to standards and procedures applicable to the normal and contingent operation conditiosn;
- Predictive maintenance, operation and planning actions;
- Action and communication standardization at the maintenance area;
- Identification of optimization opportunities in the efficiency of the assets;
- Effective maintenance management through periodic performance and asset state reports;
- Reduction of the risk of catastrophic failure, with the detection of defect onset [4], [5] - an increase from 30% to 72% in failure prediction;
- Consequently, increase in plant personnel safety, both for the equipment and for the facility;
- Extension of the service life of the equipment by quick detection of accelerated aging;
- Preservation of the corporate image by reducing risks of accidents;
- Preparation of the equipment for application of the Reliability-Centered Maintenance (RCM) philosophy;
- Best Insurance Premiums

Since of the beginning of the system operation, Braskem’s plants have been taking advantage of the diagnoses and prognoses, and this guarantees that the plastic production would never need to be interrupted unnecessarily.

2011 - Detection of incipient failure after preventive maintenance

During general planned plant downtime the OLTC went through a complete preventive overhaul. Soon after, by monitoring the motor torque at each TAP command operation, a defect was detected: from TAP 6 to TAP 7, at Mauá Substation in São Paulo, the mechanism needed two commands to complete the operation.

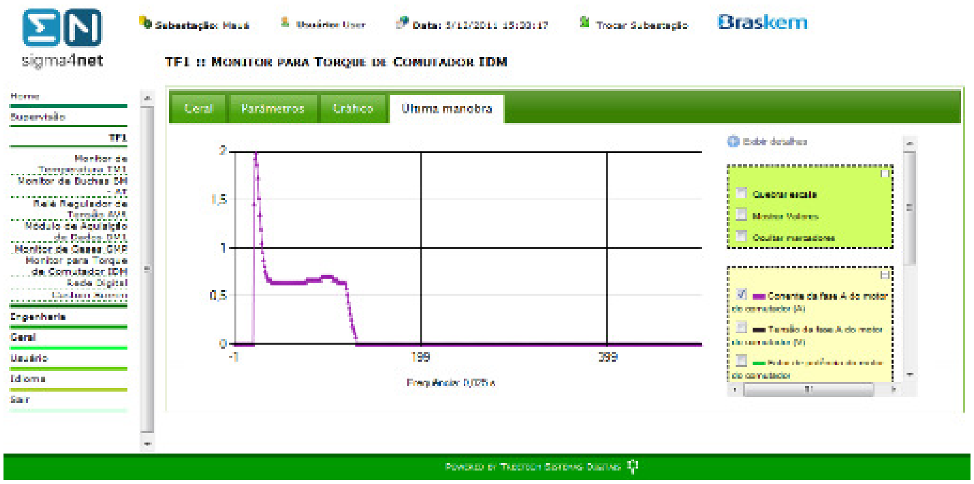

Fig. 9 Motor Oscillography during TAP change.

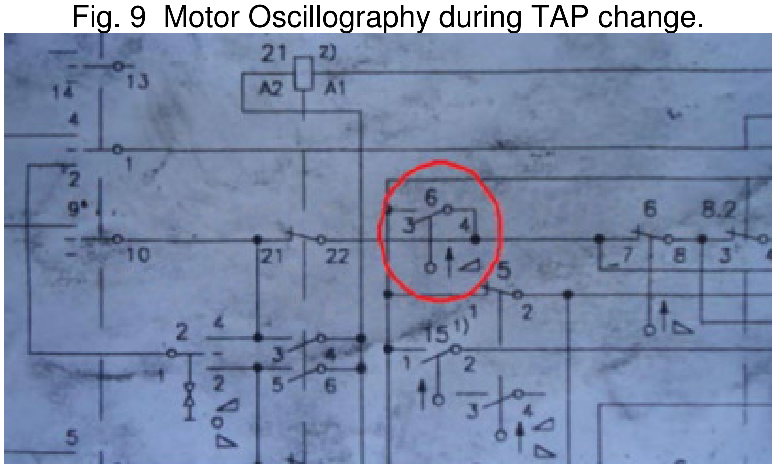
Fig. 10 OLTC operation electric project

The excessive number of operations and consequent OLTC wear may cause it to break and even explode.

The technician in charge of the OLTC returned to the plant and found out that one of the parts of the points 03 and 04 was damaged. The defect was detected when it was still incipient and did not cause any other significant operational complications for Braskem.

2012 - Availability of the plant even with failure

During a visual routine inspection at the Mauá substation - São Paulo, an oil leakage was detected in one of the 88kV condensive bushings of the main transformer. Braskem's whole polypropylene production was concentrated at the plant, and it was not possible to shut down the plant to correct the defect.

With the loss of insulating oil, the dielectric insulation of the bushing is also lost.

Through online monitoring of the capacitance and tangent delta of the bushing above, Braskem can monitor the evolution of the criticality and risk of the operating transformer.

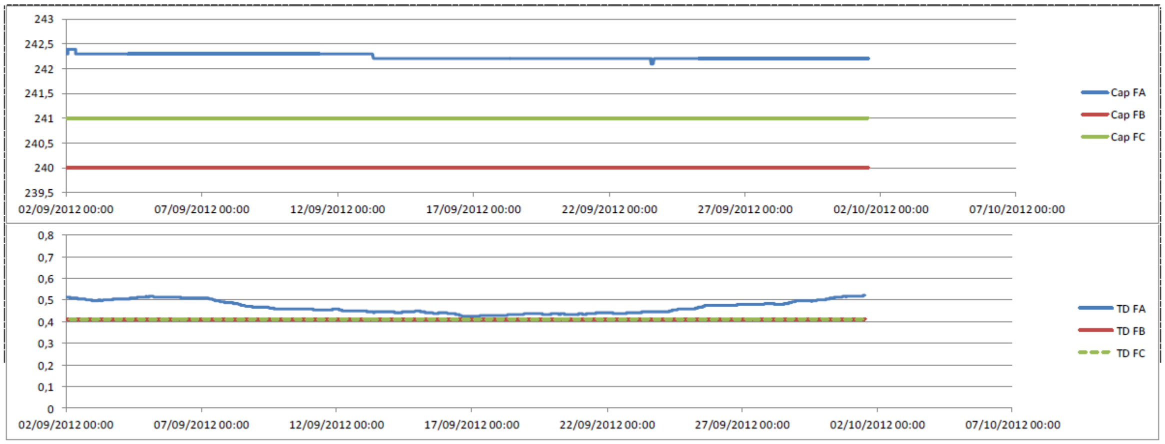

Fig. 11 Graph showing bushing behavior during the leakage.

Plant output continued to be normal, for the readings did not present any evidence of explosion, so Braskem operated normally for almost two months until the ideal moment to stop the substation to repair the bushing presented itself.

2013 - Drying oil at the right time

The excess of water in the insulating oil of the transformer causes widely known negative effects, such as the reduction of the dielectric rigidity and migration of water to the insulating paper, with the risk of forming bubbles and causing accelerated aging in the presence of high temperatures; this places at risk the equipment's service life and integrity [6].

The monitoring system detected the presence of water out of the established standards and sounded an alarm that told the maintenance team of Braskem Cubatão / São Paulo the oil needed to be dried off.

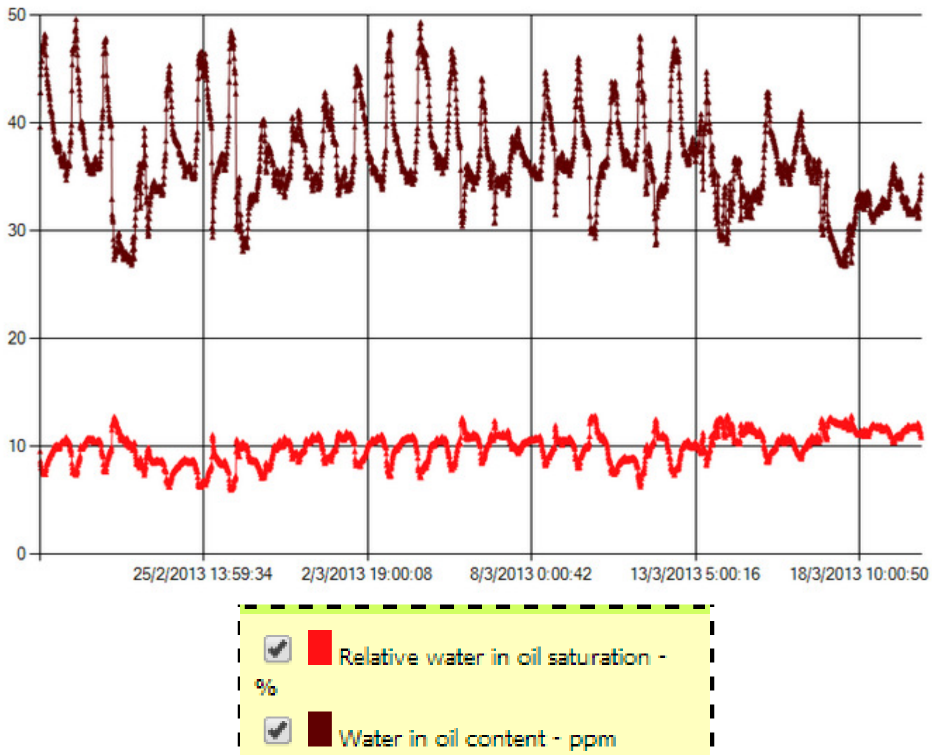

Fig. 12 Graphic of the moisture along time - the limit of 13ppm was reached.

In time, Braskem hired the specialized service and treated the insulating oil so there were no restrictions in operation.

The actions were taken at the right time, they could be planned beforehand, and not as many resources had to be used. Through the software, the quality of the service was also proven.

7.0 - CONCLUSION

Considering the importance of electric power for Braskem's output, the installation of an online monitoring system in their power transformers is an indispensable measure for the increase of the reliability and to guarantee the availability of the plant.

Using the predictive philosophy also transforms maintenance action planning, making it more efficient and effective, respecting the demands by the Braskem group and causing minimal operational and financial disturbance.

The benefits already obtained have justified the application of the system from the financial point of view, so the extension of this system to other Braskem units is being planned as well as to new electric assets, such as circuit breakers, disconnect switches and dry transformers.

8.0 - REFERENCES

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