Case Study 5-01-2005

Autotransformer's Degradation

In 2003, a bank of three single phase autotransformers, 500/230/13.8 kV, OA/FA/FA class, 146/194/243 MVA capacity, core type, was installed in a substation on the East Coast of the United States.

These transformers replaced three single phase units that were in operation since 1965. Thermal faults were detected on those units using a combination of Dissolved Gas Analysis and Acoustic Emission techniques in the connection between the winding lead and the high voltage bushing.

During the first months of 2005 and after two years in operation of the three identical transformers, Phase C started generating combustible gases, particularly Hydrogen. Even when the gas values were not excessive they were abnormal because the other two phases presented low values.

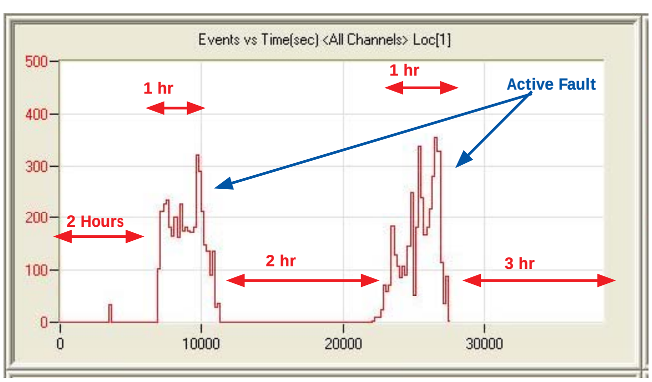
Due to the fact that the main gas was Hydrogen, all the DGA techniques indicated the existence of partial discharges, see Table 1.

Table 1 - Combustible gases values on Phase C at the moment of the AE test.

DATE	H2	CO	CO2	CH4	C2H6	C2H4	C2H2	TDCG
05/31/05	192	187	72	17	5	3	0	404

It was decided to perform an Acoustic Emission (AE) test to attempt to detect and/or locate the source of Hydrogen. This test was performed in May 2005 and the transformer was monitored continuously for five days using 20 acoustic sensors.

Figure 1 - Behavior of the acoustic activity detected on this unit.



During the AE monitoring, significant acoustic activity was detected, this activity presented the peculiarity of not being active all the time, as seen in Figure 1.

It can be seen that during the first 2 hours no acoustic activity was detected and suddenly there was a period of 1 hour and 13 minutes of significant activity. It was important to try to determine what was causing the changes in the amount of acoustic emission detected; therefore, the load current (monitored along with the AE) was analyzed.

It was noted that the amount of acoustic emission detected was higher when the load current was at its minimum value, see Figure 2. This behavior suggested that the fault was **ONLY** active when the voltage was at its maximum level. To confirm this hypothesis, we requested the voltage profile of the unit, for the period of time that it was monitored. This can be seen in Figure 3 and it shows that this assumption was correct.

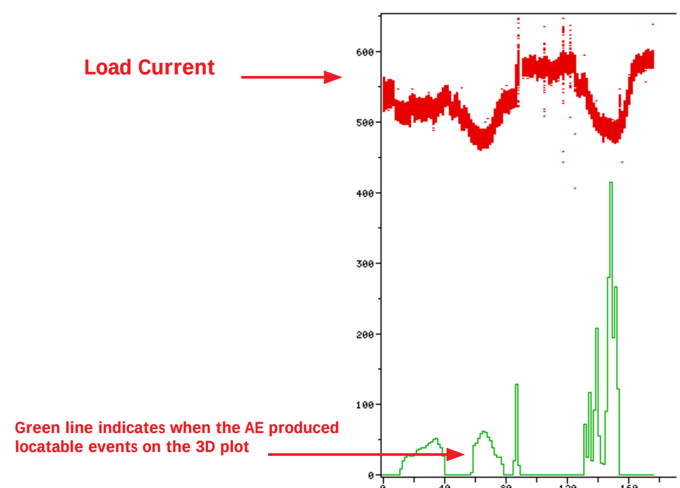


Figure 2 - Relation between load current (upper line) and AE (lower line).

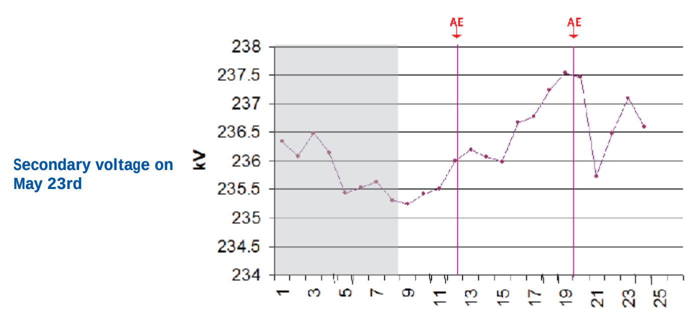


Figure 3 - Correlation between secondary voltage and time when the acoustic activity was detected

During all the AE monitoring time, the three-dimensional location algorithm was applied and as seen in Figure 4, where different locations were identified as the areas where the acoustic activity was concentrated. These areas correspond to the lower part of the core (Cluster 1) as well as the upper part of the core (Cluster 2).

Using the grading system to determine the intensity of the fault [1], "C" grades were given to both clusters and an overall grade "C" was given to the transformer (due to the low TDCG value). Based on these grades, a follow up was recommended.

A Hydran installed on this unit increased from 139 ppm to 209 ppm during the monitoring period.

A technical report indicating the severity of the fault was sent to the electrical utility and they sent it to the transformer manufacturer who, not having enough experience with the acoustic emission technique, concluded that these results could not be trusted and recommended to perform a partial discharge test on the field using an electrical method.

The electrical test requires the transformer to be taken out of service in order to install sensors on the bushings and take the unit out of service again in order to remove the sensors once the test was completed (disadvantage of this technique). Personnel from the electrical utility indicated that this was practically impossible because it was a period of maximum demand on the system.

With the electrical utility was trying to schedule an outage to comply with the manufacturer's recommendations, the transformer failed catastrophically in July, 2005 (only 40 days after the acoustic emission test was performed).

Once the unit failed, an internal inspection was performed and it was possible to verify the accuracy of the predicted location, see Figure 5, by detecting significant degradation on the core (upper and lower sections).

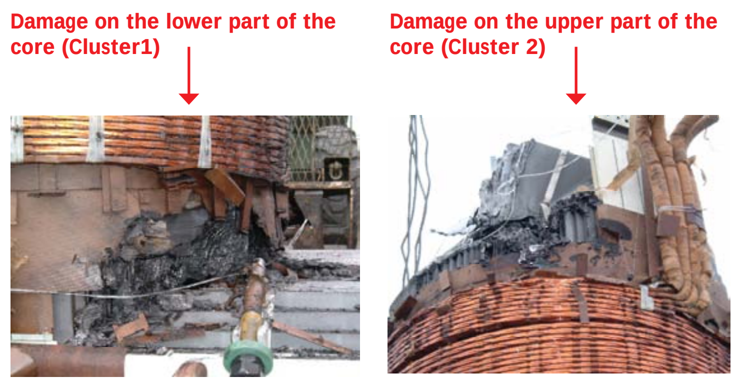


Figure 5 - Core Degradation

Fault investigations concluded that the catastrophic failure was due to excessive overheating and eventual melting of the silicone steel core laminations. It is suspected that particles coming from the defective core were slowly depositing on the tertiary winding and this eventually caused the fault of the unit.

It is important to mention that if this test would have been done with fewer sensors or for a shorter period of time the fault might have not been detected.

Installing an Acoustic On-line Monitoring System at the end of this test could have prevented the failure of the autotransformer by detecting an increment on the intensity of the acoustic activity coming from the faulted areas.

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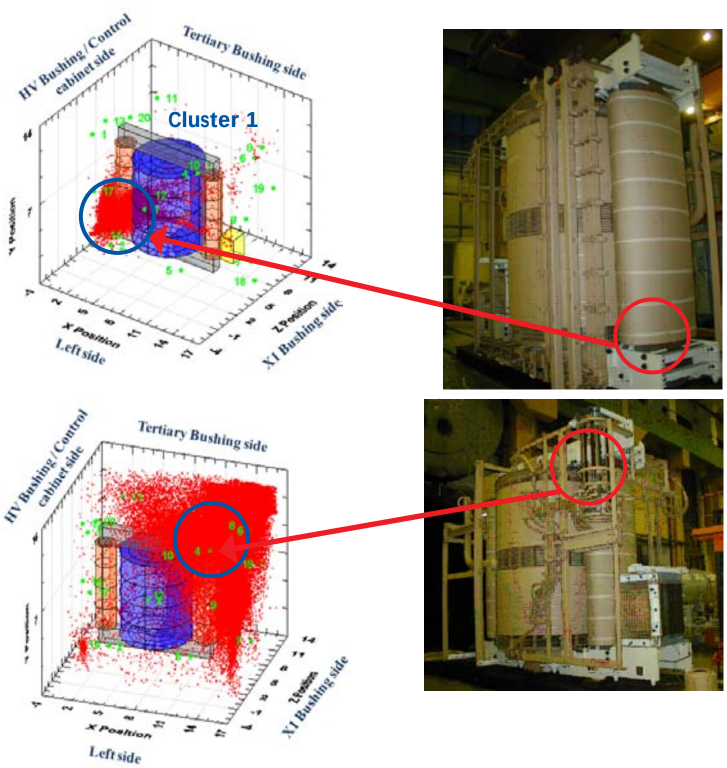

Figure 4 - Predicted location of the faults using the three-dimensional algorithm and its relative location on the transformer.

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