

Preventing EAF'S Transformers Failures

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Introduction

Preventing EAF Transformer failures has been one of the most difficult problems in the steel industry. Herein is presented a methodology developed by AMIGE over 20 years to identify potential failure conditions in EAF Transformers and recommended practices on how to prevent them. This methodology has been applied in more than 50 EAF's systems, practical cases and results are discussed.

General

It is important to keep in mind that EAF transformers are exposed to more critical conditions than any distribution transformer, it includes the worst electrical and mechanical conditions expected in a power system, such; switching transients, harmonics, short circuits, induced currents additionally in many cases it includes frequent overloading conditions as a normal operating practices. This situation creates difficulties to extend the EAF transformer life as much as possible, the life expected in this type of applications is shorter than any other in the field. In some cases, any critical event may take from some weeks to few months to develop a major situation in EAF Transformer.

Preventing EAF transformer failures requires to consider several concepts at the same time in oil tests, operative counters and events of elements in power system.

Oil Tests

It requires complete and frequent oil tests, apply more rigid criteria's to review tests results looking also even for small changes, it means; fine tune the normal "limits" of all test results in order to identify the beginning of a "suspicious" condition. In order to prevent failures, the key concept is to watch tendencies.

If a small change on any oil characteristic or gas is found, it is important to look for all related variables in the power system that may involve this condition, include the revision of other tests that may show some of the involved characteristic. In case of do not have any change, do not extend the oil sample time.

The oil with inhibitor of oxidation requires to follow up the evolution of this variable because in case of any dielectric or thermal stress, the oil may keep all physical-chemical data in good or constant conditions. It may "consume" first the inhibitor of oxidation before show any possible change in other physical-chemical characteristic, after the inhibitor reaches low level, then it may show a sudden change of all physical-chemical data and may develop a critical situation I a short period of time.

Operative Counters

Keep records of operation of main elements in the power system; counters of all primary switches of the EAF transformer feeder, tap changes, and discharge counters of surge arresters.

Usually, if the system does not show any operation of discharge counters in surge arresters; it may indicate a protection problem instead of a good healthy condition.

Events of Elements in Power System

Record date of any important change or event related with all elements in the power system and use those events as "marks" in trending graphics of oil test results and operative counters. Those events will provide an important tool to "Look for" change of tendencies and find out any possible problem.

CASE 1 – STAGE A

This case has been part of a post mortem diagnostic after two EAF transformer failures in order to prevent a new failure in the third transformer in operation. Includes 3 stages, each related with an EAF transformer. Series reactor is oil filled.

Tag	Event Description
start	Start operation a new EAF transformer
sw1out	Removes out of operation the primary switch and start switch on/off with the yard switch with longer feeder cable.
Arrester	Surge arrester failure at primary side of
svc1out	Catastrophic failure of the SVC.
Reactor	Internal failures of the series reactor and repair on site.
Reactor PM	Degas series reactor
svc2in	Start operation of new SVC
EAF Fail	Failure of EAF transformer.

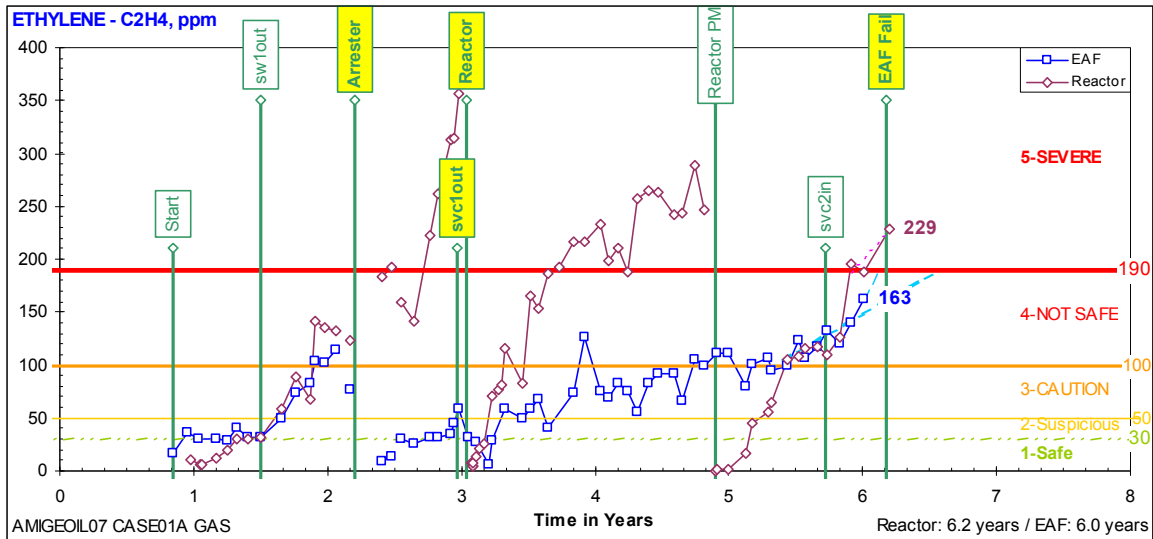


Figure 1. Oil tests results and main events in the power system becomes critical to identify source of problems.

System conditions

All physical-chemical tests were reporting “good” conditions. After removes primary switch.

Diagnostic

The Figure 1 shows the increment of tendency in the Ethylene, related with dielectric stress and some low-energy arcing conditions, after the primary switch “sw1out” is removed from operation. The longer cable of the yard switch provides more capacitance to ground and increases transients in the switching procedures disturbing both units; EAF transformer and series reactor. In other hand, the EAF transformer shows also a new increment of tendency after start operation of new SVC, “svc2in”

With this information is possible to identify two important concepts creating transients; switching transformer with the yard switch instead of primary switch and operation of new SVC.

CASE 1 – STAGE B

The spare transformer replaced the previous damaged Transformer and it fails after only 3 months of operation. This unit use to be in operation for over 17 years without any important problem. Time shows the transformer age.

Tag	Event Description
oil01	Oil reconditioning
Tout1	Spare transformer replaced by the previous stage in this case, new and larger transformer.
svc2in	Start operation of new SVC
Tin2	The spare transformer back in operation to replace the damaged transformer of previous stage in this case..
Tout2	Failure of EAF spare transformer after only 3 months of operation.

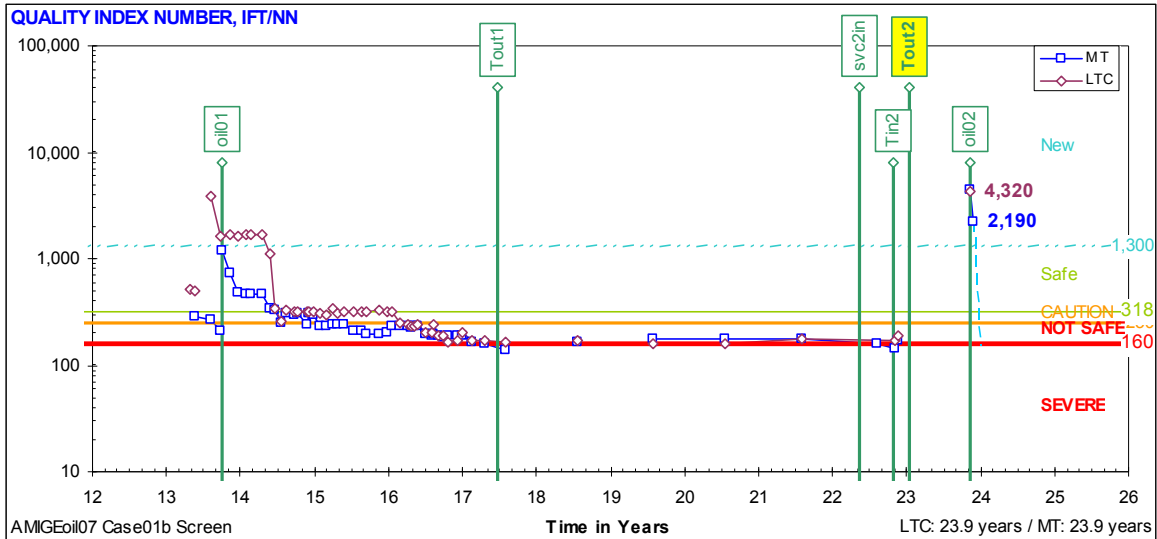


Figure 2. Low Quality of oil and an increment of dielectric stress, reduces transformer life.

System conditions

Only small amounts of Ethylene is shown (12ppm) without any other combustible gas.

Diagnostic

After the primary switch moved out of operation and the operation of the new SVC, the system shows important increment of electrical transients, when spare transformer return back in operation the second time with very quality of oil, it is not able to support the new dielectric stress and fails in short period of time.

Failure comes from high dielectric stress and low insulation capabilities due low quality of oil.

Solution

Due the evidence of dielectric stress, all actions must reduce transients; before start the operation of a new spare transformer;

- Reduce cable length between primary switch-and EAF transformer using a new breaker closer to transformers room,
- Add an RC circuit at EAF transformer terminals,
- Include a Pre-Insertion Resistor,
- Improve the surveillance of the system with an on-line monitor of dissolved gases and keep complete oil tests every month and operative counters every week; discharges of surge arresters, switches and taps changer.

CASE 1 – STAGE C

Finally, the last spare transformer rated at lower primary voltage –4.5% than systems condition and lower capacity replace the second damaged transformer of previous stage of this case. It starts to show important increment of moisture after 2 weeks of operation.

Tag	Event Description
dry	Oil reconditioning to remove moisture.
Vp-7.5%	Reduce primary EAF transformer voltage by 7.5%
Vp+4.5%	Increase primary EAF transformer voltage by 4.5%
EAFarr-20%	Reduce surge arrester size by 20% of primary EAF transformer protections.
SVCarr-30%	Reduce surge arrester size by 30% of SVC area.
Stops	Return back the first and largest transformer after repair of Case 1-Stage A.

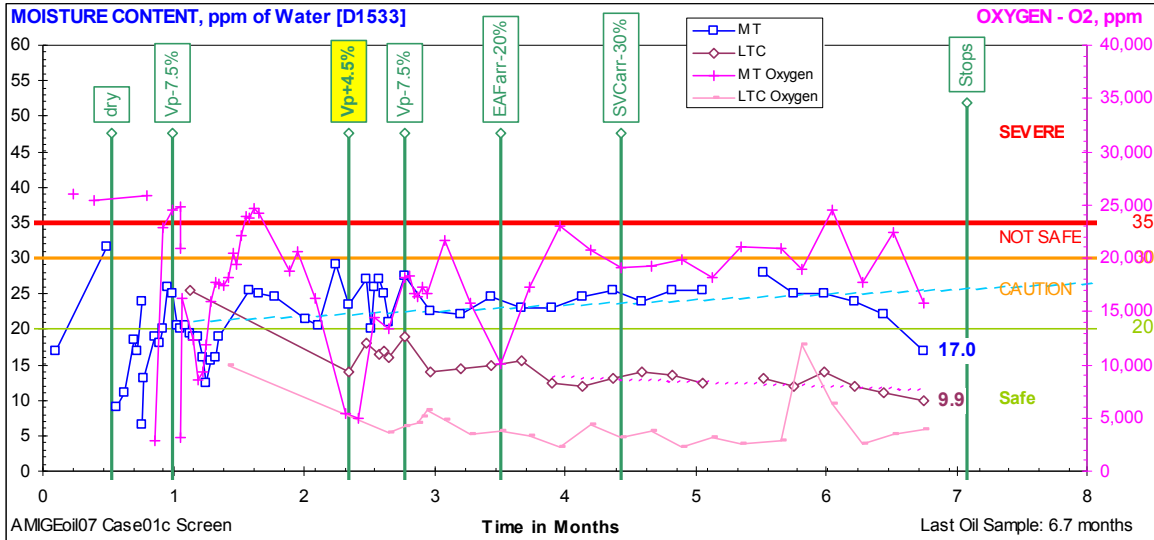


Figure 3. Thermal or dielectric stress may create oscillations of moisture and oxygen. The excess of moisture may become oxygen, and excess of oxygen may become moisture. The system stops oscillations after reduce dielectric stress.

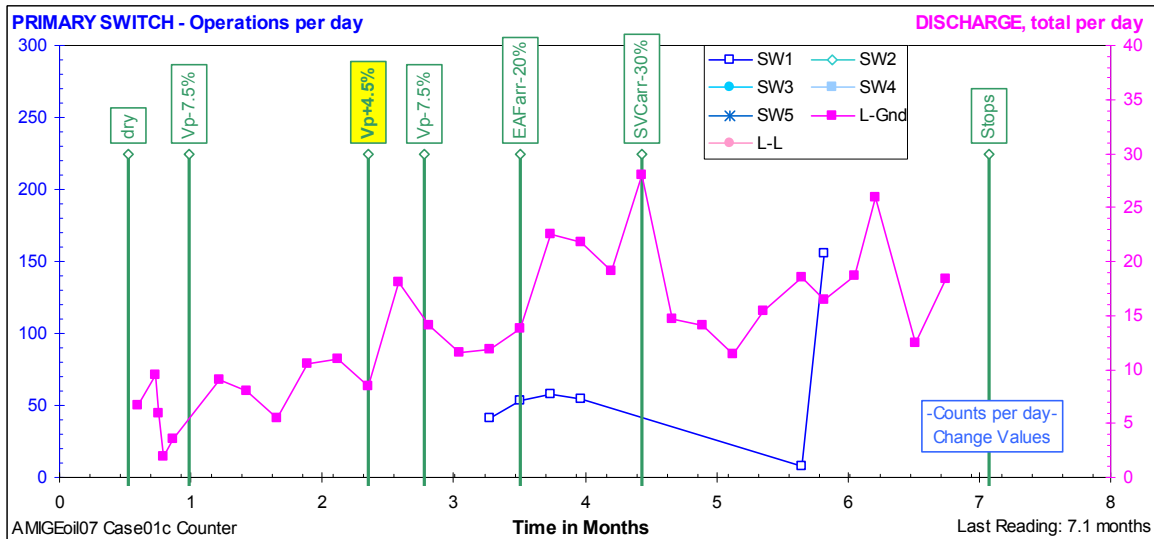


Figure 4 Increment of surge arresters discharges with increment of primary voltage.

System conditions

The transformer does not show any combustible gases and without evidence of any thermal concern. Surge arresters shows an increment of 100% discharges after rise primary voltage by 4.5%.

Diagnostic

If the system does not show evidence of any thermal concern then it still has some additional dielectric stress, may be created by the new SVC operation.

Solution

In order to reduce dielectric stress it has been implemented the following additional actions;

- Reduce size of surge arresters and relocate discharge counters for easy reading conditions, including when the system is on line and
- Keep primary voltage closer to rated voltage of EAF transformer.

CASE 2

This is a post mortem analysis after two failures of the same unit in order to provide diagnostic tools and prevent a third failure and verify the benefits of the previous actions. It has a small amount of oil tests with physical-chemical data in conditions, and reducing total amount of combustible gases.

Tag	Event Description
Fault01	Initial failure after only 8 heats of operation of a new EAF transformer.
Start02	Second start of operation after repair
Reactor01	Series reactor start operation.
Fault02	Second fault of EAF transformer.

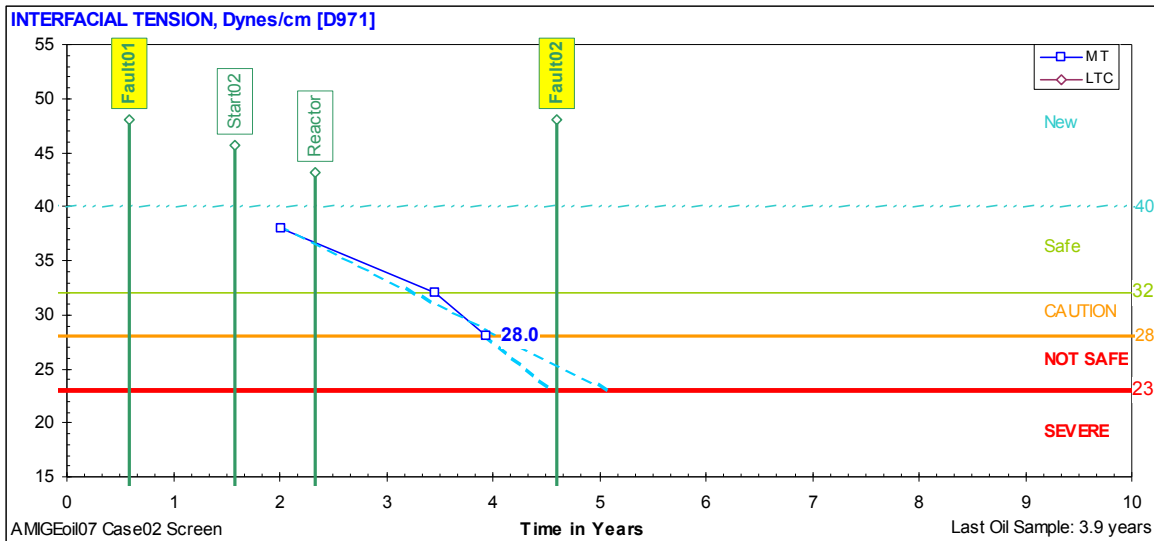


Figure 5. Interfacial tension is an important characteristic of oil in EAF transformer applications. Series reactor reduces the stress but the system and additional concerns.

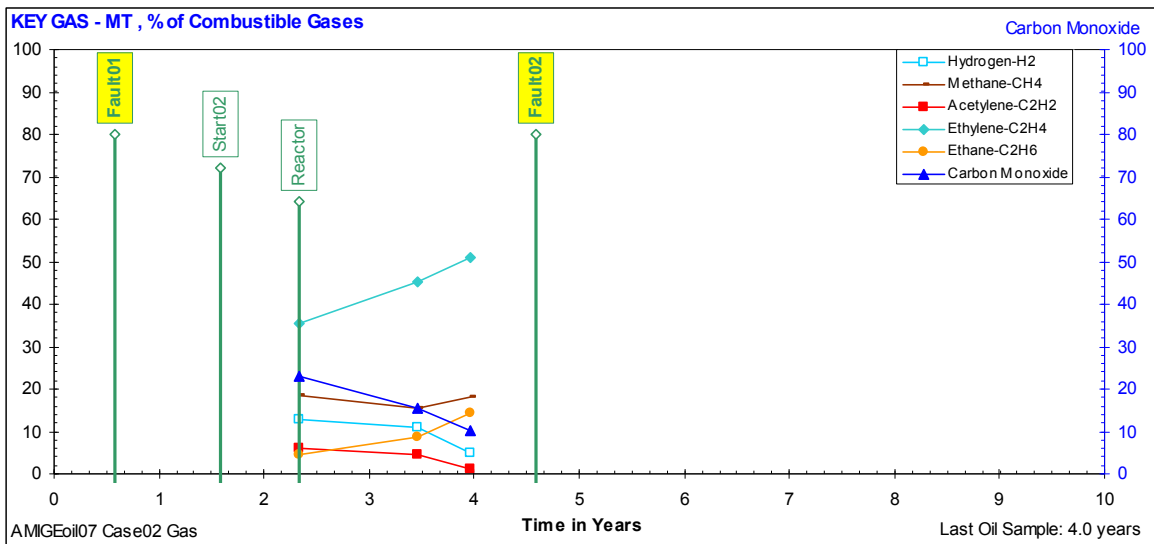


Figure 6. The total amount of combustible gases is reduced and the participation on each case shows different condition, mainly the Ethylene, related with dielectric stress.

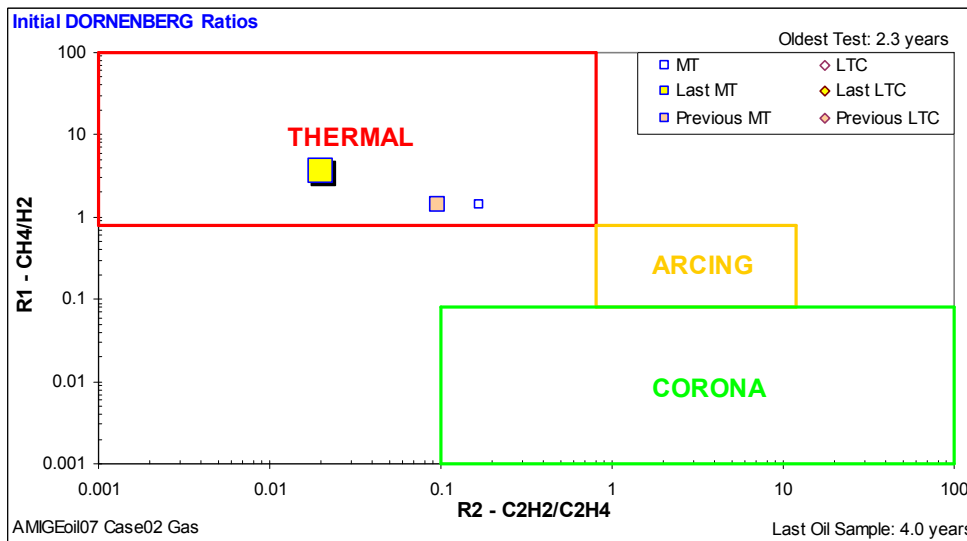


Figure 7. Symptom moves from arcing to thermal conditions.

System conditions

Small amount of oil tests with physical-chemical data in conditions, and reducing total amount of combustible gases. The electrode regulator is cable based with low response speed and keeps large current conditions more than normal.

Diagnostic

The system has been exposed to large thermal or dielectric stress due the fast reduction of Interfacial tension. The use of series reactor reduces some of the transformer stress, but in this case it did not eliminate all this condition. Usually if symptom moves to a different condition, it indicates the possible evolution of the internal phenomena or new situation is present. In this case it is possible to see the presence of dielectric and some of the initial thermal concerns.

Solution

- Recondition the oil to rise interfacial tension,
- Reduce surge arrester size,
- Change to hydraulic and faster electrode system and
- Keep complete oil test every month.

CASE 3

This case shows a primary breaker failure and its EAF transformer was close to a critical situation, it is the intention to prevent an additional failure of primary breaker and the damage of EAF transformer.

Tag	Event Description
+disch	Starts important increment of discharges of surge arrester at primary EAF transformer side.
S01	Damage of primary switch
S02	Poles synchronization of primary switch

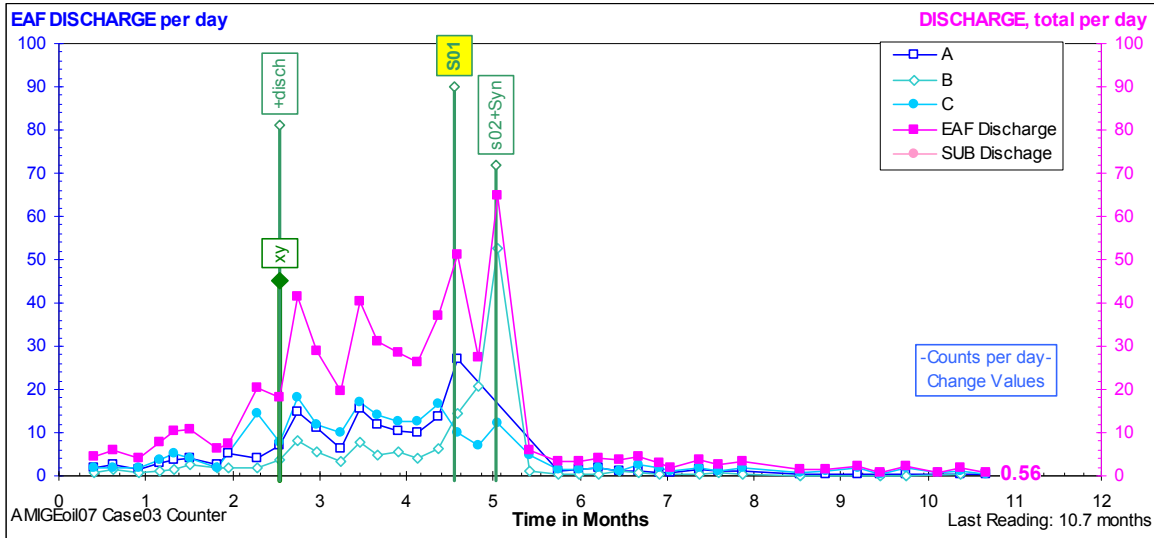


Figure 8.

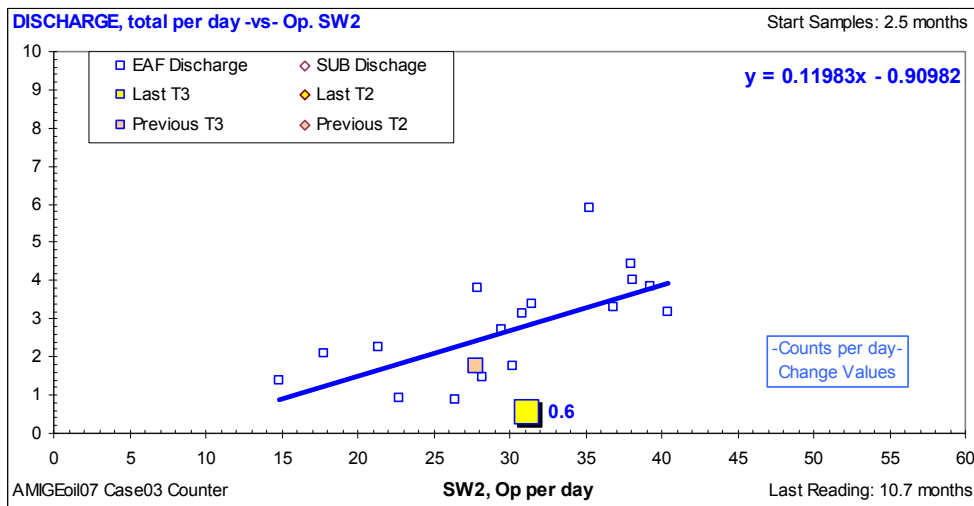


Figure 9.

System conditions

All combustible gases are in very high levels. Tap changes per day is over 300 operations, over 10 times more than primary switch.

Diagnostic

It was found close to 2 times more surge arresters discharges per primary switch than tap changes, it means; the system is more sensitive to switching transients than tap changes, it requires an accurate operation of primary switch.

Solution

- Keep poles synchronization of primary breaker lower than 3ms, between the first and last pole to close or open.

Summary

Preventing EAF transformer failures requires review tendencies of complete oil test, gas-in-oil and physical-chemical data, in frequent basis and records of operative counters and related events of main elements in the power system in combination with the understanding of the system behavior at any moment and inherent information of oil test results. Do not wait for large changes, it may become too late. Usually more than one month in a EAF transformer is too much time.