INTEGRATED SERVICES

CASE STUDY
TRANSFORMER FAILURE ANALYSIS

WEIDMANN

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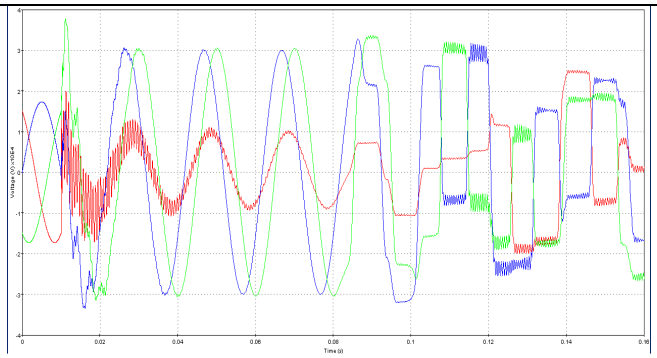
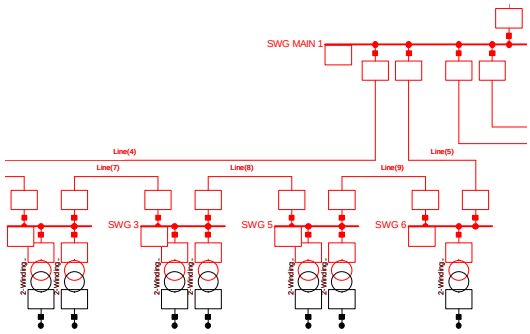
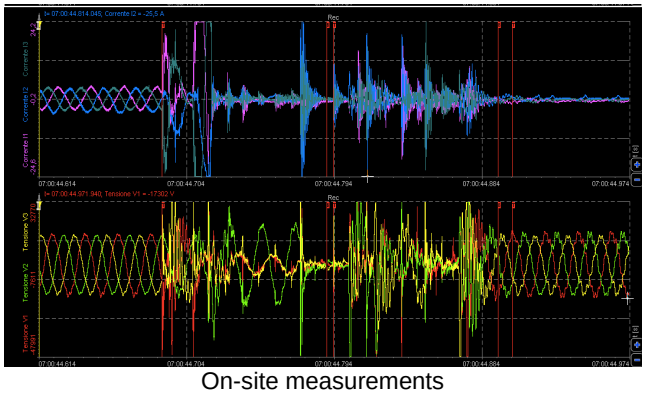


Simulation results



Simulation model



On-site measurements

Traces of high partial discharges

Dielectric tests

A photovoltaic plant connected to the HV network has experienced more than 30 transformer failures in less than 6 months. WEIDMANN was engaged to perform five different services:

a. Transformers inspection
b. On-site measurements
c. Network simulations
d. Transformer manufacturer audit
e. Dielectric and moisture tests

The study was carried out step by step, starting from the transformer inspection up to the tests carried out in Weidmann laboratories.

The results of all the different services showed beyond doubt that the root cause of the faults was a construction problem.

TRANSFORMER INSPECTION

The first step of the failure analysis was the inspection of some of the failed transformers.
The findings and the conclusions of the inspection were the following:

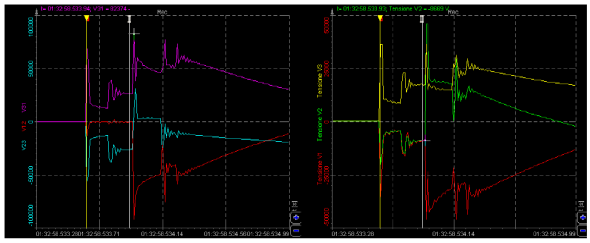
- From the analysed documentation, the transformers withstood very severe tests (PD + Chopped impulse + PD)
- High partial discharges traces on the failed transformers
- All the failed transformers show that the faults occurred between two windings (two-phase fault)
- Always at the same location
- Doubts regarding the method of assembly, gluing, impregnation, drying and storage

ON-SITE MEASUREMENTS

One month measurement campaign was carried out. The aim was to assess the harmonic content and to record the electromagnetic transients.
A very complex measurement system was installed that allow us to measure also very fast transients (bandwidth up to 300 kHz).

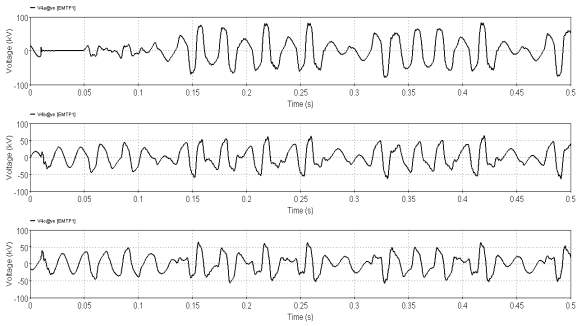
The main conclusions are below reported:

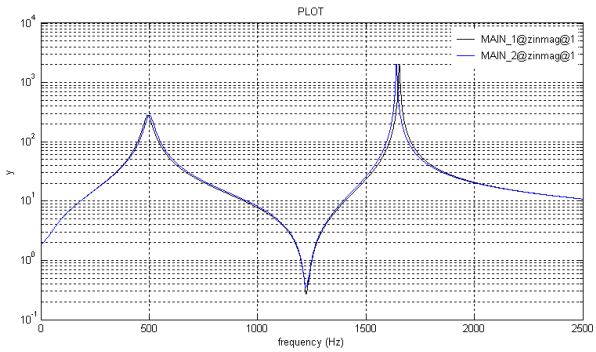
- Vacuum circuit-breaker operations provoke dangerous dielectric stresses, during opening and closing as well
- No other dangerous overvoltages were measured



NETWORK SIMULATIONS

Network studies, with the aim of find out eventual weak points of the network and to find mitigation alternatives, were carried out.





The simulations show:

- The electric network configuration gives good performance regarding the overvoltage damping
- Only very unlikely faults (e.g. cutting one conductor after a single-phase fault) can provoke dangerous ferroresonance conditions
- Based on the simulations and measurements carried out, no dangerous slow-front overvoltages were seen

Therefore, the conclusion of the on-site measurements and the network simulation is the following:

- Based on the above, it strengthens the thesis of a defect in the transformer

TRANSFORMER MANUFACTURER AUDIT

The audit covered the following points:

- Review of the manufacturing process (drying, assembly, etc.)
- Factory environment cleanliness
- Storage and handling of insulation material

Conclusions:

- The assembly of the active parts was clean and properly treated
- The handling of the insulation material in windings and assembly procedure was proper
- Cutting the insulation material and copper in the same machine could lead to contamination of metal particles
- The application of glue in the assembly of the separators should be done by adding as less glue as possible. Glue drops on the pressboard have the risk of voids which are not impregnable with oil

DIELECTRIC AND WATER CONTENT TESTS

The following tests were performed on samples taken from 2 different "laminated barriers".

1) Water content

Water content from 2 "laminated barriers" taken from 3 different areas were investigated

2) Dielectric test

Three different dielectric tests were performed on all the samples :

The samples were put between electrodes (Test 1 and 3: glue lines parallel to equipotential lines; Test 2 perpendicular to equipotential lines)

Description of tests 1 and 2:

Initial voltage of 20 kV (Test 1) and 5 kV (test 2) applied for 10 minutes; voltage increased by steps of 5 kV (test 1) and 2.5 kV (test 2); an application time of 1 minute at each voltage step with Partial Discharges measurements.

Partial Discharge inception (<2 pC as well as ≥ 2 pC) as well as breakdown voltage were reported.

Table 1: results of test 1

Test 1	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
PD≤2pC	80 kV	70 kV	65 kV	55 kV	90 kV
PD≤2pC	105 kV	115 kV	100 kV	90 kV	90 kV
Breakdown	110 kV	120 kV	110 kV	100 kV	120 kV

Table 2: results of test 2

Test 2	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
PD≤2pC	27.5 kV	25 kV	25 kV	22.5 kV	25 kV
PD≤2pC	30 kV	25 kV	25 kV	22.5 kV	25 kV
Breakdown	30 kV	30 kV	27.5 kV	25 kV	32.5 kV

Description of test 3:

For the whole testing time a constant voltage of 30 kV (1 kV/mm) was applied.

Each test sample was submitted to 2 stages:

- 1st stage: 8 hours test at room temperature (about 23°C)
- 2nd stage: 16 hours test; immediately after the voltage was applied an "indirect" heating system started to heat up the oil. The final temperature of 75°C was reached after about 2 hours.

Table 3: results of test 3

Test 3: 1st day	hour 1	hour 2	hour 3	hour 4-8
30 kV for 8 hours; Temp: constant (23 °C)	no PD were observed over the whole testing time			
Test 3: 2 nd day	hour 1	hour 2	hour 3	hour 4
30 kV for 8 hours; Temperature: starting at 23°C; heating up to 75 °C (75 °C reached after 2 hours)	no PD	2 pC	2 pC	Breakdown

CONCLUSIONS

- It results form dielectric tests that the tested material was of poor dielectric quality
- The water content of the pressboard measured during these investigations (4 to up 7 %) showed too much high values for a dried transformer ready to be put into operation
- Based on the above, review of the transformer manufacturing process was put in place

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