ACS 1000 Transformer Failure Investigation

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ACS 1000 Transformer Failure

Objectives

- Learn what happened
- Explain why it happened
- Discuss solutions
- Suggest remedies so it does not happen again
- Prevention is the key to success

ACS 1000 VFD TRANSFORMER FAILURE

What happened?

- The plant experienced several transformer and VFD failures with the medium voltage drives supplied for Line 2 installation between November 1999 and January 2001.

ACS 1000 VFD transformer failures

- The equipment involved includes the following:

  -1000kVA - kiln bypass fan

  -3000kVA - pre-heater ID fan

  -4500kVA - raw mill ID fan

  -2250kVA - filter bag-house fan, which sustain damage to the electronic components

  - some of the smaller drives lost fuses and diodes (ACS600)

ACS 1000 VDF tranformer failures

ACS 1000 VFD transformer failures

ACS 1000 Transformer Failure

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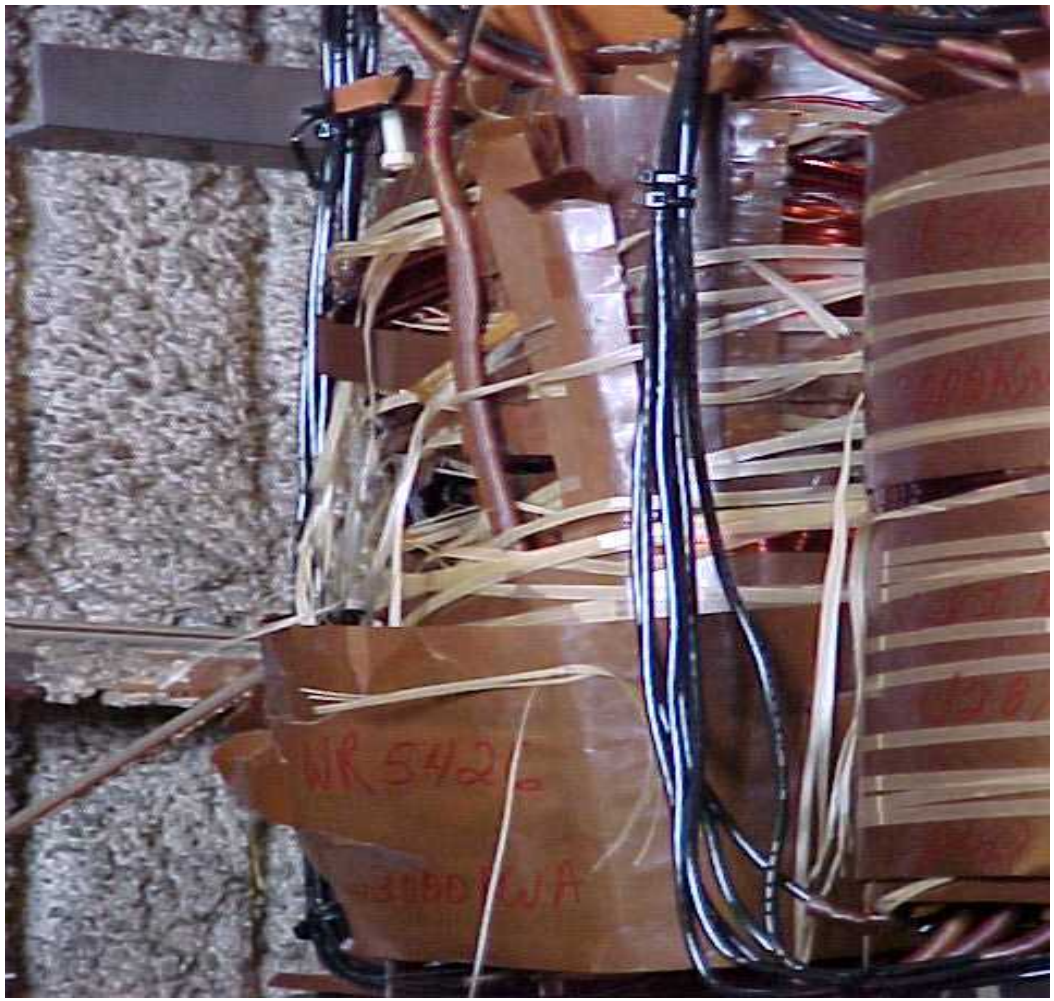

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Possible causes

- Physical design of the transformer for the application of non-linear load characteristics
- Impedance specification to limit the secondary current. (Commutating reactance)
- Electromagnetic forces withstand capability for core and windings
- Shape of the coils- rectangular or round
- Cooling and oil circulation between the coils

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What actually happened?

- Indications are that the windings did not fail turn to turn at first, which would be an indication of insulation failure due to an external surge
- The rectification process of the AC waveform itself subjects the windings to near short-circuit conditions every half cycle.
- All failures occurred on the Y winding connection of the secondary - ungrounded

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- The secondary windings deformed first as a result of the electromagnetic force which is proportional to I^2.
- The deformation of the windings also changes the mutual inductance of the windings, which in turn reduces the reactance component - a cascading effect to increase secondary current.
- Secondary of the transformer is not fused, the drive is a fuse-less design. It relies on the primary protection and the electronic protection supplied with the drive.

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Other possible causes for failure

- It has been suggested that switching transients from the capacitor banks were the root cause of the failure. - not likely although repeated switching of shunt capacitors can give rise to over-voltages under certain conditions.
- A high secondary current is also likely a result of a diode failure because of forward current handling.
- Surge protection of the diode bridge and high DC bus voltage remain a potential weak link.

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- Re-energizing the transformer with a faulted winding
- Power system transients due to the breaker dropping out under load is to be expected in an industrial power system
- Switching transients of 1.8 to 2.0 per unit voltage are not desirable but are expected in an industrial power system.

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- Electrostatic shields provide adequate isolation between the primary and secondary steep waveforms such as a surge voltage

- Independent analysis of the mode of failure arrived to similar conclusions: - Sunbelt report, Van-Koy and BBX's reports ,etc.

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What has been done to date

- Interim transformers have been secured through ABB and installed temporarily until the new drive transformers arrive at the plant. These units remain in service at this time.
- Damaged drive parts have been replaced with spare parts. These were purchased by the plant.
- Three new transformers have been delivered to the plant: 2250kVA, 3000kVA and 4500kVA.

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- The 1000kVA powering the bypass fan was the first to fail. At the advise of ABB an available transformer was purchased by the plant from Monarch Cement.
- All the new transformers have been supplied also with surge arresters on the HV side. The original transformers did not have.

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- The priorities until now was to secure adequately designed replacement transformers.
- The next steps require fine tuning of the power distribution system.
- We require every ones participation.

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Outstanding issues with the drives

- Replace temporary transformers with new units.
- There were discrepancies with the impedance specifications and winding temperature class for all of the new transformers. These were only recently partially clarified.

  - Short circuit type test verification for the prototype coil design (VT /ABB to confirm)

  - Insulation class of the windings. ABB to confirm

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- A proposal from ABB to enhance the surge protection across the diode rectifier section of each drive remains on the table. ABB to confirm requirements

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- The plant is concerned that the 1000kVA transformer was designed with aluminum windings and want it replaced. Also it was designed for a higher temperature rise (65C) than the other units (55C). Also it has larger impedance than the other units - 8.84 vs 7.34. Supplied with 6kV arrester vs 3kV arresters for the new units.
- Spare parts for the ACS1000 drives. The plant depleted their resources.

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- Coordination of primary protection devices need to be revised for the electrical characteristics of the new transformers.

- Review of the drive control scheme and interface to the DCS. The drive must trip the contactor under normal operation.(ABB 80-100ms)

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- Concern remains with the smaller drives ACS600 and the design of the isolation transformers. These were were built by the same manufacturer as for the larger units.(PTI Industries)

- These units are fused and have slightly higher impedance values that that of the medium voltage drive transformers.

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- The secondary fuses have blown during the power system disturbance in December 2000. This is perhaps the reasons they have not failed.

- Also denotes a lack of selectivity in coordination with the primary protective devices. This has to be reviewed in detail.

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Other observations

- There was lack of information on the original transformers and actual test data. Transformer damage curves.
- Commissioning reports for the drives, protection device settings (preliminary and final settings), etc.

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Line 2 capacitor banks

- Requirement for having and also for switching the 800 and 1200kVAr capacitor whenever the 8000hp S-I motor is off line?
- If these are required the capacitor banks must be upgraded to include reactor de-tuned for 4.7th. This is the minimum requirement to mitigate harmonic effects from the utility. (IEEE)

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Utility contract

- What are the contractual power factor requirements at the 138kV for Line 1 and Line 2 ?

  - above 90, 92 or 95

  - firm demand or interruptible power contract?

  - what load factor?

  - coincidental billing?

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Preventative measures

- Power system analysis

  -short circuit duties at equipment

  -Load flow analysis

  -power factor - (displacement and actual)

  - selective co-ordination and protection. The incident on December 2000 indicates that a complete review is required. In particular with the SI motor

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Harmonic studies

- Modeling of harmonic sources
- Harmonic sensitivities and amplification factors
- Actual field measurements with the equipment operating - partial and full load. (measurements and spectrum analysis done at 138kV by the plant after Line 2 came on stream)
- First sign of harmonic amplification are blown fuses and capacitors.

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Switching transients

- EMTP -electromagnetic transient program and modeling can give an indication if there are dynamic over-voltages in excess.
- If these were a problem other equipment would have been also affected.
- Switching capacitor banks and virtual current chopping is more of a problem when a capacitor bank is de-energized. -

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Protection of fuse-less drives

- Special attention is required with the primary interrupting devices and power electronic devices. ABB has to provide damage curves for the diodes, protection IGCTs.
- Selection and coordination of primary fuse to protect the transformer winding, the diode and the electronic protection IGCT.

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- Similar attention is required for the ACS600 drives.

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Questions?

For additional clarifications/requirements please contact the presenter at

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