

Coil Protection Planning

Hutch Neilson, May 29, 2008

The purpose of this document is to provide a strawman plans for coil protection. The coil protection peer review of 2/22/08 identified some possible gaps in the planning, which were documented in chits, specifically Nos. 1, 5, 6, 8, 13, 14. Issues are:

- Establishing coil operating limits and protection responses.
- Identifying failure modes and mitigation measures.
- Establishing sensor requirements (thermocouples, voltage leads, etc.)
- Establishing local I&C signal conditioning / signal processing requirements & responsibilities.

For all of the above, how far should we go beyond minimum Day 1 requirements? It may be wise to do the analysis needed to establish outer limits of the operating envelope now while the information and models are still fresh, even if the hardware implementation is postponed to upgrades.

This subject was addressed by Wayne Reiersen in a memo, "Coil Protection," (Feb. 22, 2007), which provides a good planning foundation, especially for Day 1 protection needs.

Proposed Plan

Chit 1. Document Coil Protection Requirements

Chit 6. Combination of measurements recommended for overheating protection

Chit 8. Provide voltage sensor leads to support pre-shot resistance measurements

- Instantaneous overcurrent protection limits
 - WBS 14/13 to specify for Day 1 and upgradeWBS 163 will compile this information (Harris). Mike Kalish will support for WBS 13 scope. Harris for WBS 14.
Needs a recommended level that can't be exceeded.
Strawman (Phil): 110% peak current, subject to WBS 13/14 confirmation that it is safe w.r.t. struct. allowables.? Use the 2T scenario. Raki's accuracy has to be kept in mind.
Wayne: assumption was that operators would proceed cautiously. Real operation will deviate from reference scenarios. Ramifications unknown, e.g. different ratios in A:B:C coils.
WBS 4 to implement in hardware
- Pre-shot temperature permissive
 - Resistance method
 - WBS 14/13 to specify maximum acceptable pre-shot resistance.
 - WBS 14/13 to provide voltage sensor leads on coil terminals.
 - What is the maximum LN2 temperature? Cole: Will do.
 - What temperature accuracy is needed? Needed from coil designers:

- Maximum pre-shot temperature, -→ Really, maximum resistance
 - Document design assumptions regarding voltage leads, connection, termination, location, etc. Phil will get details from C-Mod.
 - Mike Cole: voltage taps are not currently in the design. Raki: recommendation was made at a peer review.
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 - WBS 4 to implement in hardware
- Temperature method
 - WBS 14 to define permissive based on suitable combination of outlet temperature, inlet-outlet temperature difference, shell temperature.
 - WBS 13 to define permissive based on suitable combination of outlet temperature, inlet-outlet temperature difference, coil/structure temperature.
 - Coil protection: document safe inlet-outlet temperature difference, and expected time-dependent trends after a pulse.
 - Trim coils: t.b.d
 - Provide concept design for TF coil local I&C (Kalish). Document in coil protection plan.
 - WBS TBD (14/13 or 5?) to implement in hardware.
- Coil overheating / Timed overcurrent protection limits
 - WBS 14 / 13 specify for Day 1 and upgrade
 - WBS 4 to implement in hardware (simple algorithm may be OK for Day 1)

Coil protection will document the I^2t limit of the coils.
 Time constant for cooldown needs to be documented
 Coils are inertially cooled. Not relying on flow to prevent overheating. LN2 is designed not to flash if it goes to the temperature of the coil.
 Fred is worried about protecting the fittings, etc. in the LN system- needs pressure relief.
- Instantaneous structural protection limits.
 - WBS 14 / 82 to specify safe current operating limits based on stresses (and other considerations if applicable). Information to be used by WBS 4 in designing a coil protection calculator, which would be an upgrade.
 Raki would like the equations needed for a coil protection calculator. **But this is too big a job to do now.**
 - Coil protection document should include a list of caveats and future analysis needed.
- Other coil protection conditions
 - Cryostat temperature or pressure: inhibit / trip?
 - Cryosystem operating parameters: flows, pressures, temperatures: inhibit / trip?

Chit 5. Document Coil Structural Protection Requirements

- Instantaneous structural protection limits.

- WBS 14 / 82 to specify safe current operating limits based on stresses (and other considerations if applicable). Information to be used by WBS 4 in designing a coil protection calculator, which would be an upgrade.
- Confirm that current levels permitted by temperature do not violate structural limits, and vice versa.

Chis 13 & 14. Coil FMECA's required

- Identify all single-point failures and effects.
- Identify all mitigation measures, including those involving the coil protection system.
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