AP1000DCDFileNPEm Resource

From: DeBlasio, John J. [deblasjj@westinghouse.com]
Sent: Tuesday, June 29, 2010 5:16 PM
To: Buckberg, Perry; Jacobson, Jeffrey
Cc: Fecteau, Mark W.; Ziesing, Rolf F.; Sisk, Robert B.
Subject: RAI-SRP5 4 1-CQVB-01 Draft R1 6-29-10.doc
Attachments: RAI-SRP5 4 1-CQVB-01 Draft R1 6-29-10.doc

Attached is the Westinghouse draft response to the VFD RAI. Please perform a cursory review and indicate whether this response is a path to closure for this RAI. I need informal feedback by noon tomorrow to inform my upper management. He wants to know before meeting with Frank A on Thursday relative to open items. Your assistance in helping me provide the appropriate feedback would be greatly appreciated.

If you have any questions, please contact me at your earliest convenience.

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AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-SRP5.4.1-CQVB-01
Revision: ~~0~~Draft 6-25-10

Question:

Variable frequency drives, discussed in DCD section 5.4.1.2.1, are used for RCP startup and operation when the reactor trip breakers are open. There is no discussion of variable speed drive overspeed trips in the DCD, and there are no ITAAC for ensuring that such trips exist, are properly designed, are tested, and are operational. The variable frequency drives for the AP1000 RCPs are non-safety related and could potentially fail (or be mis-calibrated) in a way that would result in flow rates in the reactor coolant system in excess 104% best estimate analysis referenced in the DCD. Paragraph 5.1.4.4 of Revision 16 of the DCD states that the "Mechanical design flow is the conservatively high flow used as the basis for the mechanical design of the reactor vessel internals, fuel assemblies, and other system components. Mechanical design flow is established at 104 percent of best-estimate flow."

Is it possible for the variable frequency drives to fail or be mis-calibrated in a way that would result in reactor coolant system flow in excess of 104 percent? If so, please describe the provisions for ensuring that failure of the variable frequency drives will not cause a RCP overspeed condition in excess of the 104 percent best estimate flow rate?

The basis for the methodology should be incorporated into the AP1000, Tier 2 information.

Westinghouse Response:

In the AP1000 plant, VFDs are used to “soft-start” the RCPs during plant startup. This eliminates the large motor inrush currents associated with “line-starting” of the motors thereby reducing the footprint of the RCPs. Once rated RCP speed is achieved, the VFDs are bypassed and the RCPs are fed from grid power prior to the reactor trip circuit breakers being closed. During a plant shutdown, the reactor trip circuit breakers are opened and the RCP input power is transferred from grid power back to VFD control during plant shutdown. Because of its speed control capability, several VFD built-in protective functions are provided to prevent overspeed conditions.

Reactor coolant pump over-speed resulting from a possible failure of a variable frequency drive (VFD) does not present a safety issue for AP1000 plants located in the United States. The source of power to the reactor coolant pumps must be switched from the (VFD) to unit transformers (grid) before the reactor trip breakers are closed. This is ensured by adherence to Technical Specification 3.4.4, RCS Loops. Therefore, potential over-speed conditions resulting from a possible failure of the VFDs is limited to periods when the reactor is shutdown (all control rods are fully inserted in the core) and the reactor coolant system is either in a heatup or cooldown mode.

Given that the VFD software is not qualified as Class 1E, it is possible (although highly unlikely based on vendor operating experience with these drives) that multiple "smart" malfunctions could occur resulting in an over-speed flow condition. Multiple failures in a portion of the VFD control algorithms would have to occur such that the VFD-internal over-frequency, output over-voltage and volts/hertz protection would fail, but the VFD would continue to provide output power and increase output frequency.

The sole source VFD manufacturer (Siemens) asserts that the only viable scenario for a true overspeed condition to be initiated and maintained by the VFD requires massive internal control/feedback failures to be encountered. VFD standard internal protection mechanisms will trip the output of the drive when control algorithm errors have been detected or when drive output power protection setpoints have been exceeded.

- VFD software-based protection includes torque limit, current overload, overspeed, overvoltage and volts/hertz protection.
- VFD hardware-based protection includes instantaneous overcurrent circuit via a direct connection to phase current feedback.
- Each VFD contains eighteen power cells (comprised of the switching devices that convert DC voltage to variable frequency AC voltage) which have independent protection features to trip the VFD due to component or control failure. These include input fuses, individual switching device firmware-based protection, input overcurrent monitor/trip, out of saturation detection for switching devices, DC bus over/under voltage and overtemperature.
- Diverse non-1E overspeed, overvoltage, and overcurrent protection is provided by a microprocessor-based motor protection relay in each of the series pair of Class 1E RCP trip switchgear cabinets.

The reactor internals, fuel, and other system components, however, are designed to comply with Level B service limits for transient conditions up to 120 percent of mechanical design flow. Even in the extreme case of one RCP running at twice its normal speed, the total RCS flow rate is less than 120 percent of mechanical design flow. Therefore, there would be no damage to the RCS components (reactor internals, fuel, steam generator tubes) since the flow conditions would not exceed those included in the component design basis.

The only time a reactor overspeed condition could effect a positive reactivity insertion to challenge reactor criticality is during Mode 3 operation. The administrative limits for Mode 3 are $K_{eff} \leq 0.99$ and $T_{avg} > 420$ °F. Table 1 shows the administrative limits for the modes of operation for the AP1000 (taken from Chapter 16 of the AP1000 DCD).

MODES	TITLE	REACTIVITY CONDITION (K_{eff})	% RATED THERMAL POWER[(a)]	AVERAGE REACTOR COOLANT TEMPERATURE (°F)
1	Power Operation	≥ 0.99	> 5	NA
2	Startup	≥ 0.99	≤ 5	NA
3	Hot Standby	< 0.99	NA	> 420
4	Safe Shutdown[(b)]	< 0.99	NA	420 ≥ T_{avg} > 200
5	Cold Shutdown[(b)]	< 0.99	NA	≤ 200
6	Refueling[(c)]	NA	NA	NA

(a) Excluding decay heat.

(b) All reactor vessel head closure bolts fully tensioned.

(c) One or more reactor vessel head closure bolts less than fully tensioned.

The feedwater temperature is approximately 440 °F. Assuming a conservative moderator temperature coefficient of 5.0 pcm/°F, the RCS average temperature would have to be reduced approximately 200 °F to insert enough positive reactivity to make the reactor critical. In mode 3 at approximately 550 °F this would require the RCS temperature to be reduced to approximately 350 °F. This is a lower temperature than the secondary side of the Steam Generator. Based on this information, it is highly improbable that an RCP overspeed transient could result in an adverse reactivity excursion that would challenge the limits of the RCS.

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Therefore, the potential over-speed of a reactor coolant pump from a VFD failure is not a safety issue for the AP1000 plants in the US. The current design of the VFDs, reactor coolant pumps, and protection against pump overspeed when operating on the VFDs is the same as in the certified AP1000 design of DCD Revision 15.

Design Control Document (DCD) Revision:
None

PRA Revision:
None

Technical Report (TR) Revision:
None