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Your ref: Docket No. 52-006
Our ref: DCP_NRC_002979

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Subject: AP1000 Response to Request for Additional Information (SRP 5)

Westinghouse is submitting a response to the NRC request for additional information (RAI) on SRP Section 5. This RAI response is submitted in support of the AP1000 Design Certification Amendment Application (Docket No. 52-006). The information included in this response is generic and is expected to apply to all COL applications referencing the AP1000 Design Certification and the AP1000 Design Certification Amendment Application.

Enclosure 1 provides the response for the following RAI(s):

RAI-SRP5.4.1-CQVB-01 R1

Questions or requests for additional information related to the content and preparation of this response should be directed to Westinghouse. Please send copies of such questions or requests to the prospective applicants for combined licenses referencing the AP1000 Design Certification. A representative for each applicant is included on the cc: list of this letter.

Very truly yours,

D.A. Lindgren/FCR

Robert Sisk, Manager
Licensing and Customer Interface
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/Enclosure

1. Response to Request for Additional Information on SRP Section 5

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NRO

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ENCLOSURE 1

Response to Request for Additional Information on SRP Section 5

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-SRP5.4.1-CQVB-01
Revision: 1

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 (Revision 1):

This response has been revised in its entirety from Revision 0.

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

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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. Overspeed protection will be set under the 120% overspeed value and as close to the operational limits of the equipment as achievable while still allowing for the avoidance of nuisance trips. Other protective features will be set following a similar philosophy; wide enough to avoid nuisance trips but well within the requirements of equipment protection.

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 estimated to be less than 120 percent of mechanical design flow. The total reactor coolant system flow is limited because the over-speeding RCP is drawing the majority of the reactor coolant flow from the steam generator channel head, thus the flow through the other RCP on that steam generator is reduced from its normal value. Also, the two RCPs on the other steam generator have lower than normal flow rates as a result of higher pressure in the reactor vessel generated from the higher flows produced by the over-speeding pump. The lower flows result because the operating point of the two pumps moves to a point on their head/flow curve corresponding to higher head and less flow. Therefore, there would be no damage to the reactor system components (reactor internals and fuel) since the reactor coolant flows through the reactor vessel would not exceed those included in the component design bases.

The steam generator on which the over-speeding pump is located could be subjected to an estimated flow rate in the range of 150 per cent of mechanical design flow. The steam generator components which could be impacted by this higher flow rate are the divider plate in the channel head and the tubes. The main load on the divider plate results from the pressure differential across the plate. The pressure difference across the divider plate as a result of this higher flow is estimated to be significantly less than the differential that results from a LOCA. Since the divider plate design was shown to be acceptable for a LOCA, its structural integrity should not be challenged by the flow rates resulting from an over-speeding RCP. The challenge to tube integrity is normally from flow-induced vibration (FIV). The high reactor coolant flow through the tubes is not expected to challenge the integrity of the tubes since FIV evaluations of the tubes indicate that the effects of primary side flow are negligible compared to secondary side (external) flow conditions. It is the two-phase flow external to the tubes that generates conditions which initiate tube vibration. Since there is no plant power production during heatup/cooldown operations, the secondary side of the steam generator will be water solid, substantially damping tube vibration as compared to the two-phase flow condition during power production.

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	$420 \geq T_{avg} > 200$
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.

Westinghouse believes that additions to the AP1000 DCD Tier 2 information are not necessary to address this issue.

Design Control Document (DCD) Revision:
None

PRA Revision:
None

Technical Report (TR) Revision:
None