RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

APR1400 Design Certification

Korea Electric Power Corporation / Korea Hydro & Nuclear Power Co., LTD

Docket No. 52-046

RAI No.:	**121-8050**
SRP Section:	**10.02 – Turbine Generator**
Application Section:	**10.02**
Date of RAI Issued:	**07/27/2015**

Question No. 10.02-1

GDC 4 requires, in part, that SSCs important to safety be “designed to accommodate the effects of and to be compatible with normal operation, maintenance, testing, and postulated accidents …” According to SRP 10.2, the requirements of GDC 4 are met, as it relates to T/G speed-load control, when for normal speed-load control, the speed governor action of the electrohydraulic control system fully cuts off steam at 103 percent of rated turbine speed by closing the control and intercept valves (CVs and IVs).

DCD Tier 2, Subsection 10.2.2.3.1.1 indicates that the active speed governor closes all CVs and IVs fully at 105 percent of the turbine normal operating speed. An acceleration limiter built into the microprocessor-based controller is activated during a high load rejection. The valves are fully closed below 105 percent.

The staff finds this as a deviation from SRP subsection 10.2.III, Item 2.B to meet the GDC 4 criteria, as related to T/G speed-load control.

The applicant is requested to provide an explanation and/or justification for this non-conformance with and deviation from the above SRP guidance.

Response

The value of 105 in the final sentence of Subsection 10.2.2.3.1.1 will be corrected to 103.

As indicated in the statement two sentences earlier, the "governor closes all CVs and IVs at approximately 103 percent of the turbine normal operating speed." DCD Table 10.2.2-3 shows the correct value of 103. The DCD will be revised to change the single erroneous occurrence of “below 105” to “at 103.”

Impact on DCD

DCD Subsection 10.2.2.3.1.1 will be revised as shown in the attached markup.

Impact on PRA

There is no impact on the PRA.

Impact on Technical Specifications

There is no impact on the Technical Specifications.

Impact on Technical/Topical/Environmental Report

There is no impact on any Technical, Topical and Environmental Reports.

10.2.2.3.1.1 Speed Control

The turbine speed is measured by three independent speed sensors. For overspeed protection, each module provides a binary output signal, which is normally energized, to the 2-out-of-3 tripping device.

For speed control, the three speed sensors provide signals for the turbine rotation rate. The three signals are input to three separate speed detection modules, each located on three separate I/O branches. Each of these modules has an onboard processor that converts the sensor input to a turbine rpm value. Independence of the three speed sensor signal branches is assured in that failure of the transmission of one branch of the signal does not affect the transmission of the signal in the other two branches. Each I/O branch is separately fused. Also, failure of a speed detection module (receiving one branch of the signal) does not affect the function of the remaining two speed detection modules from receiving their signals.

The speed control function of the turbine control and protection system's redundant controller provides speed control and acceleration functions for normal turbine operation. The speed error signal is derived by comparing the desired setpoint speed with the actual speed of the turbine. This error drives an algorithm that positions the control valves at the desired position. Acceleration rates can also be entered by the operator or calculated by the control system in the auto startup mode. A failure of one speed input generates an alarm. Failure of two or more speed inputs also generates an alarm and trips the turbine. The active speed governor closes all CVs and IVs fully at approximately 103 percent of the turbine normal operating speed. An acceleration limiter built into the microprocessor-based controller is activated during a high load rejection. The valves are fully closed ~~below 105~~ percent.

at 103

10.2.2.3.1.2 Load Control

Load control is used during normal operation to maintain power output steady. Control of all turbine control valves is done with redundant control processors. The load control function of the TGCS generates signals that are used to regulate the unit load. The signal outputs are based on maintaining the proper combination of speed error and load reference signals.

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Question No. 10.02-2

GDC 4 requires, in part, that SSCs important to safety be "appropriately protected against dynamic effects, including the effects of missiles …" According to SRP 10.2, the requirements of GDC 4 are met by the provision of an emergency turbine over-speed protection system (with suitable redundancy and diversity) to minimize the probability of generation of the turbine missiles. SRP, 10.2 further specifies that a mechanical overspeed trip device will actuate the control, stop, and intercept valves to close at approximately 111 percent of rated speed. The SRP also specifies that an independent and redundant backup electric overspeed trip device should actuate to close the control, stop, and intercept valves at approximately 112 percent of the turbine rated speed.

DCD Tier 2, Section 10.2.2.3 indicates there are the two electrical overspeed control systems: TCS (for normal conditions) and EOST (for emergency conditions). Both systems have dedicated triple-redundant speed sensors and are independent of each other, with separate processors and input/output modules. For each system, control signals are processed in redundant microprocessors, and these trip controllers are separate from each other.

While reviewing DCD Tier 2, Section 10.2, and the staff could not find any information on how these overspeed trips are performed and what components and subsystems are used in implementing these overspeed trip systems. Also missing is a description on how the turbine steam inlet valves and associated hydraulic fluid systems and solenoid valves function in tripping the turbine. Furthermore, there is no description on whether there are any fail-safe conditions.

In order to conform to the GDC 4 criteria, as it relates to minimizing the probability of generation of turbine missiles, the staff finds that the following additional information is needed to establish the redundancy, independency, and diversity, and single failure considerations of the TG overspeed protection systems EOST and the MOST.

The applicant is requested to:

1) Identify the turbine-generator control and overspeed protection systems

2) Provide electrical schematics and logic diagrams for the T/G control and overspeed protection systems, from the speed sensors to the Terminal Block, which is an interface between overspeed speed control and hydraulic/pneumatic fluid systems. Also, provide a detailed description of the overspeed Terminal Block and how it meets the single failure criteria described in SRP Section 10.2.III, Item 2A.

3) Provide a detailed functional performance description of the control and fluid systems in conjunction with the schematics in preventing the turbine overspeed. Further, describe how these overspeed systems conform to the above SRP guidance and meet the redundancy and independency considerations.

4) Address adequately with full justification how the APR1400 T/G subsystems and components meet the single failure considerations as described in SRP acceptance criteria Subsection10.2.II, Item 1.A.

5) Address the locations of the power sources for TGCS and EOST and whether they are isolated from and independent of each other.

Response

The APR1400 does not identify a specific turbine generator design. This will allow the COL applicant to select the optimum design from a plant safety and reliability perspective. Since continued evolution of turbine control and overspeed protection systems will occur over the several years before a COL applicant chooses a design, providing details such as schematics and detailed descriptions is undesirable. Some of the reasons are:

a) Inclusion of a generic schematic could imply that more modern solutions are excluded or deemed undesirable. The need to justify a deviation from DCD schematics could actually be a disincentive to selection of a more robust design.
b) The RAIs emphasize the importance of considering operational experience by referencing NUREG-1275. Providing schematics now would not address future lessons learned that will need to be considered by the time a COL applicant must demonstrate how his chosen design protects against generation of turbine missiles. The need to justify a deviation from the DCD could again be a disincentive.
c) Despite every effort to ensure it is a generic schematic, a schematic might imply or favor pre-approval of a certain Turbine Generator vendor (e.g., the acronym MOST could be viewed as vendor specific), thereby inadvertently limiting competition to select the most appropriate turbine or driving the COL applicant to select a design most closely matching the schematics in the DCD. This favored turbine could possibly be inferior in other areas of protection against turbine missiles (e.g., material properties).
d) Finally, any design details such as schematics provided as part of the DCD review cannot accurately represent an actual design that has not yet been selected by an unknown applicant. The intent of providing the functional requirements and COL items in the DCD is that any turbine design selected by the COL applicant will meet NRC guidance and expectations. NRC review and acceptance of generic schematics and logic would not be meaningful since the detailed information would not represent any actual system available

or ensure the system selected by the COL applicant satisfies NRC guidance for turbine protection at that time.

In view of the above and the staff's concerns that key attributes such as reliability, independence, and diversity be appropriately addressed, the following revisions will be made:

The paragraph prior to the beginning of Subsection 10.2.2.3.1.1 will be revised to read:

"The COL applicant shall identify how the functional requirements for the overspeed protection system are met and provide a schematic(s) of the TGCS and overspeed protection systems that show the entire system end-to-end and all discrete components and interfaces (e.g., sensors, power supplies, control devices, manual emergency trips, the device that eventually drains the hydraulic/air fluid from turbine control valves). The schematics and descriptive information provided once a turbine design is selected shall be sufficient to allow assessment of the TGCS and overspeed systems' ability to withstand a single failure without loss of function (i.e., redundancy), resistance to common cause failure (i.e., diversity as provided by electrical and mechanical overspeed trips), and resistance of propagation of a failure to another trip channel (i.e., independence) (COL 10.2(2))."

Subsection 10.2.5 Combined License Information item (2) will be similarly revised.

Impact on DCD

DCD Subsection 10.2.2.3.1, Subsection 10.2.5 Combined License Information item (2) and Table 1.8-2 will be revised as shown in the attached markup.

Impact on PRA

There is no impact on the PRA.

Impact on Technical Specifications

There is no impact on the Technical Specifications.

Impact on Technical/Topical/Environmental Report

There is no impact on any Technical, Topical and Environmental Reports.

b. Three redundant control processors

c. Redundant communication paths between processors within the TGCS

d. Redundant communication paths for each turbine and generator from the TGCS main control cabinet to the operator workstation

e. Redundant communication paths within the TGCS connecting to the plant control system

The TGCS is a microprocessor-based controller and provides the following turbine control functions through circuitry and hydraulics:

a. Automatic control of turbine speed and acceleration through the entire speed range

b. Automatic control of load and loading rate from no load to full load, with continuous load adjustment and discrete loading rates

c. Semi-automatic control of speed and load when it becomes necessary to take portions of the automatic control out of service while continuing to supply power to the system

d. Limiting of load in response to preset limits on operating parameters

e. Detection of dangerous or undesirable operating conditions, annunciation of detected conditions, and initiation of proper control response to such conditions

f. Monitoring of the status of the control system, including the power supplies and redundant control circuits

g. Testing of valves and controls

The COL applicant is to identify how the functional requirements for the overspeed protection system are met and provide a ~~schematic of the TGCS and protection systems from sensors through valve actuators~~ (COL 10.2(2)).

Insert (A) of next page

Insert (A)

schematic(s) of the TGCS and overspeed protection systems that show the entire system end-to-end and all discrete components and interfaces (e.g., sensors, power supplies, control devices, manual emergency trips, the device that eventually drains the hydraulic/air fluid from turbine control valves). The schematics and descriptive information provided once a turbine design is selected shall be sufficient to allow assessment of the TGCS and overspeed systems' ability to withstand a single failure without loss of function (i.e., redundancy), resistance to common cause failure (i.e., diversity as provided by electrical and mechanical overspeed trips), and resistance of propagation of a failure to another trip channel (i.e., independence)

Appropriate radiological controls can be applied to steam systems in the event that such leakage occurs. Discussions of the radiological aspects of primary-to-secondary leakage are presented in Chapter 11.

10.2.5 Combined License Information

COL 10.2(1) The COL applicant is to identify the turbine vendor and model.

COL 10.2(2) The COL applicant is to identify how the functional requirements for the overspeed protection system are met and provide a ~~schematic of the TGCS and protection systems from sensors through valve actuators~~.

Insert (A) of previous page

COL 10.2(3) The COL applicant is to provide a description of how the turbine missile probability analysis conforms with Subsection 10.2.3.6 to ensure that requirements for protection against turbine missiles (e.g., applicable material properties, method of calculating the fracture toughness properties per SRP Section 10.2.3 Acceptance Criteria, preservice inspections) will be met.

10.2.6 References

1. ASME Section VIII, Division 1, “Rules for Construction of Pressure Vessels,” the American Society of Mechanical Engineers, the 2013 Edition.

2. IEEE Standard C50.13-2014, “IEEE Standard for Cylindrical - Rotor, 50 Hz and 60 Hz Synchronous Generators Rated 10 MVA and Above,” Institute of Electrical and Electronics Engineers, 2014.

3. ASTM A470, “Standard Specification for Vacuum-Treated Carbon and Alloy Steel Forgings for Turbine Rotors and Shafts,” American Society for Testing and Materials, 2010.

4. ASTM A370, “Standard Test Methods and Definitions for Mechanical Testing of Steel Products,” American Society for Testing and Materials, 2014.

Table 1.8-2 (16 of 29)

Item No.	Description
COL 9.5(7)	The COL applicant is to provide the fire brigade radio systems.
COL 9.5(8)	The COL applicant is to provide the LAN and VPN system.
COL 9.5(9)	The COL applicant is to provide the emergency offsite communication system including dedication hotline, local law enforcement radio equipment, and wireless communication system.
COL 9.5(10)	The COL applicant is to specify that adequate and acceptable sources of fuel oil are available, including the means of transporting and recharging the fuel storage tank, following a design basis accident.
COL 9.5(11)	The COL applicant is to provide a description of the offsite communication system that interfaces with the onsite communication system, including type of connectivity, radio frequency, normal and backup power supplies, and plant security system interface.
COL 9.5(12)	The COL applicant is to provide the security radio system that consists of a base unit, mobile units, and portable units.
COL 9.5(13)	The COL applicant is to provide the local law enforcement communications including dedicated conventional telephone and radio-transmitted two-way communication system.
COL 9.5(14)	The COL applicant is to provide electric power for the security lighting system.
COL 9.5(15)	The COL applicant is to provide the system design information of AAC GTG building HVAC system including flow diagram, if the AAC GTG building requires the HVAC system.
COL 10.2(1)	The COL applicant is to identify the turbine vendor and model.
COL 10.2(2)	The COL applicant is to identify how the functional requirements for the overspeed protection system are met and provide a ~~schematic of the TGCS and protection systems from sensors through valve actuators~~. Insert (A) of previous page
COL 10.2(3)	The COL applicant is to provide a description of how the turbine missile probability analysis conforms with Subsection 10.2.3.6 to ensure that requirements for protection against turbine missiles (e.g., applicable material properties, method of calculating the fracture toughness properties per SRP Section 10.2.3 Acceptance Criteria, preservice inspections) will be met.
COL 10.3(1)	The COL applicant is to provide operating and maintenance procedures including adequate precautions to prevent water (steam) hammer and relief valve discharge loads and water entrainment effects in accordance with NUREG–0927 and a milestone schedule for implementation of the procedure.
COL 10.3(2)	The COL applicant is to establish operational procedures and maintenance programs as related to leak detection and contamination control.
COL 10.3(3)	The COL applicant is to provide a description of the FAC monitoring program for carbon steel portions of the steam and power conversion systems that contain water or wet steam and are susceptible to erosion-corrosion damage. The description is to address consistency with GL 89-08 and NSAC-202L-R3 and provide a milestone schedule for implementation of the program.

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Application Section:	**10.02**
Date of RAI Issued:	**07/27/2015**

Question No. 10.02-3

GDC 4 requires, in part, that SSCs important to safety be “appropriately protected against dynamic effects, including the effects of missiles …” According to SRP 10.2, the requirements of GDC 4 are met by the provision of an emergency turbine over-speed protection system (with suitable redundancy and diversity) to minimize the probability of generation of the turbine missiles. The SRP also indicates that the applicant should include in-depth defense and diverse protection means to preclude unsafe turbine overspeed conditions.

DCD Tier 2, Section 10.2.2.3 describes various control systems for the APR1400 TG system for normal and abnormal operating conditions, including normal control and emergency protection systems to protect the turbine from overspeed. The DCD further describes the automatic turbine startup and shutdown (ATS) in that it receives commands from the operator using the operator interface or from a plant computer through a data link.

While reviewing DCD Tier 2, Section 10.2, the staff could not find any reference to or description of the manual turbine trip feature for the APR1400 turbine. The staff considers the manual turbine trip system as one of the diverse turbine protection systems under all modes of plant operations.

The applicant is requested to provide detailed information regarding a manual control and/or manual turbine trip system for the APR1400 TG system. Also requested is the inclusion of any hard wiring from the main control room (MCR) to the T/G unit, including a push button at the turbine pedestal.

Response

DCD Section 10.2 includes a requirement for a manual turbine trip. The use of the word “manual” is not used, instead “Emergency Trip” will be found in the DCD. The "Emergency Trip" is available from the control room and at the turbine front standard (see page 10.2-17, item a and 10.2-18, item g, respectively). The list beginning on page 10.2-17 will be clarified by revising item a to read "Manual emergency trip in control room" and item g to read "Manual emergency trip at front standard." Consistent with the discussion in the response to RAI 10.02-4 and 5, details of the manual trip (e.g., hard wiring) cannot be provided until a COL applicant selects a turbine design. To ensure that the manual trip is independent and as diverse as possible, the following will be added to the last paragraph of Subsection 10.2.2.3.3: "The manual emergency trip shall be designed such that no single failure (e.g., push button) will prevent a manual trip and that failure of the ETS to initiate an automatic trip does not prevent a successful manual trip. The physical implementation (e.g., hard wiring) shall be included in the schematic required by COL Item 10.2(2)."

Impact on DCD

DCD Subsection 10.2.2.3.3 will be revised as shown in the attached markup.

Impact on PRA

There is no impact on the PRA.

Impact on Technical Specifications

There is no impact on the Technical Specifications.

Impact on Technical/Topical/Environmental Report

There is no impact on any Technical, Topical and Environmental Reports.

demand. A redundant electrical signal transmission sends valid trip signals from the control and protection cabinet to redundant trip devices, which consist of an electronic solenoid valve and a mechanical solenoid valve in the turbine front standard.

The following requirements are met by the ETS:

a. Each trip input is applied to a triple redundant protection module. 2-out-of-3 majority voting is conducted within the protection system where possible to prevent spurious turbine trips and enhance protection system operation on an actual turbine trip.

b. Electromechanical trip devices triggered by the hydraulic solenoid valves using the electronic protection system are testable online using the appropriate lockout devices. The redundant trip systems in this area protect the turbine while one system is being tested. The entire protection system, from signal input to actual trip device, has online test capabilities.

c. Electrically signaled trips are initiated by contact closures. The loss of trip system power is annunciated.

d. Contacts representing the actuation of any trip function or alarm device are available for computer monitoring or annunciation.

The turbine includes instrumentation for a trip on excess vibration and a remote trip input signal from the plant control system on a reactor trip.

The trip and monitoring system initiates appropriate action on abnormal operating conditions and indicates the existence of these conditions to the operator.

The ETS closes the MSVs, CVs, ISVs, and IVs to shut down the turbine on the following signals:

Manual emergency

a. ~~Emergency~~ trip in control room

b. Moisture separator high level

c. High condenser pressure

d. Low turbine lube oil pressure

e. LP turbine exhaust hood high temperature

f. Thrust bearing wear

g. ~~Emergency~~ Manual emergency trip at front standard

h. Loss of stator coolant

i. Low hydraulic fluid pressure

j. Selected generator trips

k. Loss of TGCS electrical power

l. Excessive turbine shaft vibration

m. Loss of two speed signals – either two normal speed control or two emergency

n. Abnormal shell and rotor differential expansion or rotor expansion

When the ETS is activated, it overrides all operating signals and trips the MSVs, CVs, ISVs, and IVs.

Insert:

The manual emergency trip shall be designed such that no single failure (e.g., push button) will prevent a manual trip and that failure of the ETS to initiate an automatic trip does not prevent a successful manual trip. The physical implementation (e.g., hard wiring) shall be included in the schematic required by COL item 10.2(2).

10.2.2.3.4 Inspection and Testing

The overspeed trip circuits and devices are tested remotely at or above the rated speed by means of controls in the main control room and can also be tested with the turbine not in operation. Operation of the overspeed protection devices under controlled speed conditions is checked at startup and after each refueling or major maintenance outage. In some cases, operation of the overspeed protection devices can be tested just prior to shutdown. This eliminates the need to test overspeed protection devices during the

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Application Section:	**10.02**
Date of RAI Issued:	**07/27/2015**

Question No. 10.02-4

In consideration to meet the GDC 4 requirements, as related to single failure criteria for the turbine control and the turbine hydraulic fluid systems, SRP Section 10.2 and NUREG-1275, "Operating experience feedback report," provides guidance to avoid the single failure impacts on the T/G operation. The turbine trip-block provides an interface between the turbine speed control systems and the turbine valve control fluid systems.

While reviewing the DCD Tier 2, Section 10.2, the staff could not find any description of the turbine trip-block, which is an interface between the turbine control systems and the turbine steam inlet valves (i.e., MSVs, CVs, ISVs, and IVs) and associated fluid systems.

The applicant is requested to provide adequate details of this turbine trip-block and its configuration, considering the full "end-to-end," from the T/G input speed sensors to the device that eventually drains the hydraulic/air fluid from turbine steam inlet valves. In case the APR1400 uses a single trip-block for turbine overspeed control, the applicant is requested to provide:

1) The single failure criteria for the turbine overspeed protection system

2) Justification on how this satisfies the requirement for redundancy and diversity

3) Justification on how this meets the SRP guidance in SRP Subsection 10.2.III.A and the NUREG-1275 recommendation to avoid single failures in the controls and hydraulic fluid systems

Further, the staff requests that the applicant to provide detailed schematics depicting the turbine-trip block, logic diagrams between the turbine speed sensors to the turbine trip-block and fluid flow paths between the turbine steam admission valves and the fluid tank.

Response

See the response to RAI Question 10.02-2

Impact on DCD

DCD Subsection 10.2.2.3.1, Subsection 10.2.5 Combined License Information item (2) and Table 1.8-2 will be revised as shown in the response to RAI Question 10.02-2.

Impact on PRA

There is no impact on the PRA.

Impact on Technical Specifications

There is no impact on the Technical Specifications.

Impact on Technical/Topical/Environmental Report

There is no impact on any Technical, Topical and Environmental Reports.

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Question No. 10.02-5

In consideration of GDC 4 requirements as to prevent vulnerabilities to avoid common mode and common cause failures (CCF) of the turbine overspeed systems to function properly, SRP and NUREG-1275 provide guidance to meet the industry experience.

While reviewing DCD Tier 2, Section 10.2, the staff could not find any details regarding the design and testing requirements to minimize or eliminate the common cause failures (CCF) in the hydraulic and air systems associated with the T/G control and protection systems, including the TG steam admission and extraction non-return valves.

The applicant is requested to address the details of the following air/hydraulic systems as they relate to turbine overspeed:

1) The electrical and fluid flow paths, shared components, failure modes, and CCF vulnerabilities.

2) A description on reliable operation of the hydraulic/air systems as associated with preventing turbine overspeed conditions.

The description of the turbine overspeed protection and fluid systems should clearly indicate what parts are shared. For example, shared air and hydraulic dump lines and components such as trip blocks, dump valves and fluid reservoirs should be described in the DCD. For clarity, the response should include schematic diagrams that show the control fluid flow paths, piping and valves being actuated (i.e., turbine stop, control, reheat stop, intercept, and extraction non-return valves).

Response

See the response to RAI Question 10.02-2

Impact on DCD

DCD Subsection 10.2.2.3.1, Subsection 10.2.5 Combined License Information item (2) and Table 1.8-2 will be revised as shown in the response to RAI Question 10.02-2.

Impact on PRA

There is no impact on the PRA.

Impact on Technical Specifications

There is no impact on the Technical Specifications.

Impact on Technical/Topical/Environmental Report

There is no impact on any Technical, Topical and Environmental Reports.