REVISED 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**
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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 – (Rev.1)

The APR1400 DCD specifies functional requirements for a turbine generator control system in lieu of describing an existing design. Providing a description of the control system architecture without detailed drawings will allow the COL applicant to select the optimum design from a plant safety and reliability perspective considering the latest regulatory and industry guidance. Since continued evolution of turbine control and overspeed protection systems will occur over the several years before a COL applicant chooses a design, providing schematics and detailed descriptions as part of the DCD is undesirable to avoid disincentives to the COL applicant choosing an improved design. The design, control architecture, and functional requirements described in the DCD will meet regulatory requirements and provide high assurance that the TGCS and overspeed protection systems will prevent damaging turbine overspeed events through redundancy, independence, separation, diversity, testability, etc. Specifically:

1) All overspeed trips are accomplished by spring-driven closure of the turbine steam valves (i.e., MSVs, ISVs, CVs, and IVs) by dumping hydraulic control oil pressure that holds the valves open during turbine operation. Three different subsystems that use different trip mechanisms respond to a potential overspeed condition, one is part of the normal TGCS while the other two make up the Emergency Trip System (ETS). The turbine-generator control and overspeed protection systems are:
   a. Normal control system – the TGCS uses three redundant speed sensor inputs to three redundant control processors with 2-out-of-3 voting to initiate a turbine trip. Upon sensing a turbine speed equal to greater than approximately 103%, the controllers actuate redundant relays that actuate fast-acting solenoid valves in each turbine steam valve actuator. Opening the solenoid valves results in the loss of EHC hydraulic pressure in the dump valve of the main steam valve mechanical actuator. This causes the main steam valve to rapidly close by spring force.

b. Mechanical overspeed trip system (MOTS) – A turbine shaft rotational speed in excess of approximately 110% results in the movement of mechanical linkages that actuate the mechanical trip valve in the turbine front standard to drain hydraulic control oil. A loss of electrical power to the manual emergency trip results in movement of a mechanical trip solenoid that similarly results in actuation of the mechanical linkage of the system and draining of hydraulic control oil. The loss of hydraulic oil pressure results in the loss of pressure in the main steam valve actuators, which causes them to close by spring force and isolate steam flow to the turbine.

c. Electrical overspeed trip system (EOTS) – three redundant magnetic speed sensors (independent and diverse from those of the TGCS) with 2-out-of-3 voting performed independently in a primary and a backup unit or loss of power open a valve in the turbine front standard to drain hydraulic control oil. The loss of hydraulic oil pressure results in the loss of pressure in the main steam turbine valve actuators, which causes them to close by spring force and isolate steam flow to the turbine.

The MOTS and EOTS are part of the ETS. See discussion of ETS below and Subsection 10.2.2.3.3 of DCD.

When the ETS is activated, it overrides all operating signals and trips all turbine steam valves. The extraction non-return valves also close by venting air through the relay dump valve, allowing spring force and steam pressure to cause them to close.

2) As noted above, in absence of a specific turbine design, the DCD specifies functional requirements and describes the overarching architecture in lieu of electrical schematics and logic diagrams. A COL item is established to ensure the COL applicant provides these details once a turbine design has been selected. To facilitate understanding of the functional requirements imposed by the DCD on selection of a turbine control and overspeed protection system, Figure 10.2.2-2 will be added to the DCD and is shown in the attached markup.

Similarly, since the overspeed protection terminal block is part of detailed design, functional requirements are identified to ensure the design specific selected by the COL applicant is satisfactory. The provisions to cope with any single failure are discussed in parts 3) and 4) below.

3) This part provides a detailed functional performance description of the TGCS and ETS, which is comprised of the MOTS and EOTS. How the design principles of redundancy, independence, diversity, etc. are met is discussed in part 4) below.

a. Redundant, in-series turbine steam valves are used on each line admitting steam to the high and low pressure turbines. These are the MSVs and CVs for the high pressure turbine, and the ISV and IVs for the low pressure turbines. Each of these valves fail closed (held open by hydraulic control oil pressure maintained by a closed dump valve).

b. Closure of the turbine steam valves is accomplished by draining hydraulic control oil holding the dump valves closed, allowing the springs to shut each steam valve.

c. Draining hydraulic control oil from the MSVs and ISVs is accomplished by activating any of the three overspeed trips discussed in part 1) above. Specifically:

i. Normal control system – receipt of a valid trip energizes the solenoid operated fast-acting valves, which drain off hydraulic control oil from each dump valve.

ii. MOTS – movement of mechanical linkages repositions the mechanical trip valve, draining hydraulic control oil. A trip can occur for any of the following reasons:

a) Mechanical (i.e., rotating inertia increasing due to rising rotational speed) turbine trip that moves the trip linkages

b) Manual trip activation at the turbine front standard by de-energizing a solenoid that moves the trip linkages

c) Emergency manual trip activation from the control room by de-energizing a solenoid that moves the trip linkages

iii. EOTS – trip signals are processed by both a primary and backup unit to determine trip validity based on 2 of 3 voting, either of which then opens the master trip valve. This allows the master trip valve to reposition due to spring force, draining hydraulic control oil.

d. Draining hydraulic control oil from the CVs and IVs is accomplished when draining of hydraulic control oil pressure described in c. above also allows a spring to reposition a valve, which drains hydraulic control oil from the separate CV/IV header.

e. An extraction relay dump valve under normal operating conditions aligns the incoming instrument air supply to the operators of air-assisted, spring-closed, non-return valves in the higher-pressure extraction lines to hold them open. The non-return check valves close rapidly on turbine trip when the extraction relay dump valve vents air. Their typical characteristics and closure times are provided in Table 10.2.2-2, but the number of valves, required close time, and detailed design will be in accordance with the turbine manufacturer's requirements and the requirements of ANSI/ASME TDP-1-1998. Although held open by air, the valve closes as a non-actuated swing check valve. The design allows periodic trip confirmation.

f. The balance of the hydraulic control oil system must fulfill the following requirements:

i. Drains - Control oil from the valve actuators is collected in two stainless steel drain headers. There is one header for the MSVs (ISVs for low pressure turbines) and one for the CVs (IVs). These two headers drain to the hydraulic power unit reservoir through a common drain line. The drain headers are sized to handle the maximum hydraulic control oil flow requirements, maintaining the required valve stroke times, and are sloped to drain to the reservoir.

ii. Failure of the hydraulic piping between the trip block and the valve actuator, or between the hydraulic fluid tank and the valve actuator will cause a loss of fluid pressure, which closes the turbine steam valves.

iii. The hydraulic fluid in the trip and overspeed protection control headers is independent of the bearing lubrication system to minimize the potential for contamination of the fluid.

4) The fundamental design principles are met as follows:

a. Diversity –

i. A purely mechanical overspeed trip is available in conjunction with the normal

control and electrical overspeed trips. The mechanical trip valve does not depend on availability of electric power (power is required to keep the mechanical trip solenoid valve energized to prevent the manual trip valve from draining hydraulic control oil).

ii. The TGCS and EOTS use diverse speed inputs, determine trip validity using different technology, have different set points, and actuate to drain hydraulic control oil, to eliminate common cause failures from rendering the trip functions inoperable. The MOTS senses speed via physical repositioning of an eccentric weight, rather than counting rotations per unit time.

b. Separation

i. The ETS valves are located in the turbine front standard out of the way of turbine missiles and high pressure steam lines, whereas the TGCS solenoid-operated fast-acting valves are part of the main steam valve actuators.

ii. The TGCS overspeed trip controllers and the EOTS primary and backup processors are located in different instrument cabinets.

iii. Hydraulic control oil drain headers for MSVs and CVs and for ISVs and IVs are separate and separated on opposite sides of the turbines.

c. Redundancy –

i. Each turbine steam inlet line has two valves (e.g., MSV and CV for high pressure turbine); closure of any one in each pair isolates that line.

ii. Failure of any one component in overspeed protection systems will not prevent a turbine trip.

d. Independence –

i. The normal control overspeed system, EOTS, and MOTS each determine turbine speed using independent means: normal speed sensors using a technology other than magnetic, passive magnetic speed sensors, and rotational acceleration (“centrifugal force”).

ii. A failure of one of the overspeed protection systems will not propagate to the others because they are electrically isolated and physically separated.

iii. Closure or lack of closure of one of the series turbine steam valves (e.g., MSV and CV) will not prevent the other valve from closing within its timing requirements to prevent overspeed.

e. Single failure criterion – single failures are addressed through redundancy and independence, but additionally:

i. No single failure will cause a turbine to overspeed. This feature is desirable since the best way to protect for an overspeed is to designate TGCS features that assure no single failure can initiate the transient.

f. Fail safe –

i. Upon loss of power, valves transition to positions where hydraulic control oil is drained, tripping shut all turbine steam valves.

ii. If a speed sensor fails, it is removed from the voting logic, leaving two out of two trip logic. If two speed sensors fail, a turbine trip is initiated.

iii. Relays that provide the interface between the TGCS and the EOTS controllers and the valves of the hydraulic control and protection systems fail in a failsafe position on a loss of power.

g. Testability –
   i. Test valves and relays are provided to allow any turbine steam valve to be tested during operation.
   ii. Overspeed sensors, controllers, and trips are fully testable during normal operation.
   iii. To avoid the possibility that a test alignment error could block a trip and due its simplicity, the mechanical overspeed protection trip is not provided a means to test during operation. Instead, the turbine manual switches and associated linkages are tested during refueling outages prior to turbine start-ups or if maintenance work could have affected functionality.

5) The normal overspeed and EOTS controllers and relays are installed in separate cabinets; electric power for each is supplied by two AC sources for redundancy with a 120V AC single-phase station source and a vital control bus from a UPS or other reliable source.

These requirements, when implemented in a design selected by the COL applicant, address the issues and problems with overspeed protection systems identified in NUREG-1275, assure that the acceptance criteria in SRP 10.2.II are met, and provide the information identified in SRP 10.2.III. Use of COL action items is explicitly recognized in SRP 10.2.III, subject to review of the appropriateness of such.

In view of the above and the staff's concerns that key attributes such as reliability, independence, and diversity be appropriately addressed, additional information will be provided to more clearly identify the functional requirements that must be met. To do so, 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 is to identify how the functional requirements as described in Subsection 10.2.2.3.2 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 and separation) (COL 10.2(2))."

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

Impact on DCD

DCD Subsection 10.1.1, Section 10.2, Subsection 10.2.1.2, Subsection 10.2.2, Subsection

10.2.3.5, Subsection 10.2.5 Combined License Information item (2), Table 10.2.2-2, Figure 10.2.2-1, Figure 10.2.2-2 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.

ACRONYM AND ABBREVIATION LIST

ABD	Abnormal Blow Down
AC	Alternating Current
AFAS	Auxiliary Feedwater Actuation Signal
AFW	Auxiliary Feedwater
AFWS	Auxiliary Feedwater System
AFWST	Auxiliary Feedwater Storage Tank
ALARA	As Low As Reasonably Achievable
AOO	Anticipated Operational Occurrence
AOV	Air Operated Valve
ATS	Automatic Turbine Startup
ATWS	Anticipated Transients Without Scram
AVT	All Volatile Treatment
BDS	Blowdown Subsystem
BTP	Branch Technical Position
CBD	Continuous Blowdown
CBV	Cation Bed ion exchanger Vessel
COL	Combined License
CP	Condensate Polishing
CV	Control Valve
Cv	Charpy V-notch
CW	Circulating Water
CWS	Circulating Water System
DBA	Design Basis Accident
DBE	Design Basis Event
DC	Direct Current
DPS	Diverse Protection System
EBD	Emergency Blowdown
~~EOST~~ EOTS	Electrical Overspeed Trip System
ESFAS	Engineered Safety Feature Actuation System

ETS	Emergency Trip System
FAC	Flow-Accelerated Corrosion
FATT	Fracture Appearance Transition Temperature
FLB	Feedwater Line Break
FWCS	Feedwater Control System
GDC	General Design Criterion
HCBD	High Capacity Blowdown
HEI	Heat Exchange Institute
HP	High Pressure
IEEE	Institute of Electrical and Electronics Engineers
ISV	Intermediate Stop Valve
IV	Intercept Valve
LP	Low Pressure
LOOP	Loss of Offsite Power
LCP	Local Control Panel
MBV	Mixed Bed ion exchanger Vessel
MCR	Main Control Room
MFIV	Main Feedwater Isolation Valve
~~MOST~~ MOTS	Mechanical Overspeed Trip System
MSADV	Main Steam Atmospheric Dump Valve
MSADVIV	MSADV Isolation Valve
MSGTR	Multiple Steam Generator Tube Rupture
MSIS	Main Steam Isolation Signal
MSIV	Main Steam Isolation Valve
MSIVBV	Main Steam Isolation Valve Bypass Valve
MSLB	Main Steam Line Break
MSR	Moisture Separator Reheater
MSS	Main Steam System
MSSV	Main Steam Safety Valve
MSV	Main Stop Valve
MSVH	Main Steam Valve House

steam generators for removal of residual heat from the reactor core. The AFWS is described in Subsection 10.4.7.

Turbine Overspeed Protection

The turbine generator control system (TGCS) provides automatic control of turbine speed and acceleration through the entire speed range. The speed control function serves as the first line of defense against turbine overspeed. If the speed control function fails to protect the turbine overspeed, the overspeed protection system is activated. The overspeed protection system consists of two major subsystems:

a. Mechanical overspeed trip ~~(MOST)~~ system (MOTS) in the front standard

b. Electrical overspeed trip ~~(EOST)~~ system (EOTS)

The MOST is the emergency overspeed protection that acts to bring the turbine to a safe shutdown condition upon reaching a setpoint that is approximately 110 percent of the rated speed. The EOST system consists of two speed calculating modules: primary and backup. Each module uses the three ~~binary~~ signals from the speed conditioning units to the 2-out-of-3 tripping device~~ in the common safety system~~. Each setpoint is 111.5 percent of the rated speed. Turbine overspeed protection is described in Subsection 10.2.2.3.2.

Turbine Missile Protection

The design of the turbine rotor minimizes the probability that the turbine rotor will generate turbine missiles (see Subsection 10.2.3). Turbine missile protection is designed and controlled to minimize the potential for turbine missile generation (see Subsection 3.5.1.3).

The APR1400 plant design has a favorable orientation of the T/G to avoid potential impact on safety-related structures, systems, and components (SSCs). The orientation of the T/G, as shown in Figure 1.2 and Figure 3.5-1, is found to be favorable when considering its location relative to essential safety-related SSCs. These layout drawings show the general arrangement of the T/G and associated equipment in relation to essential safety-related SSC. Failure of the T/G equipment does not preclude safe shutdown of the reactor (see Subsection 10.2.4).

10.2 Turbine Generator

The T/G specification will address the following criteria, as identified in Subsection 10.2.5 COL Items and as verified by ITAAC. By establishing functional requirements, COL items, and ITAAC, instead of specifying a specific design in the DCD, assurance is provided that each APR1400 will be equipped with the design that best meets reliability and then current regulatory expectations for the T/G, the TGCS, and the overspeed protection system.

10.2.1 Design Bases

10.2.1.1 Safety Design Bases

The T/G system does not perform nor support any safety-related function and therefore has no safety design basis. Classification of the T/G system in regard to the seismic and safety and quality group is provided in Table 3.2-1 of Section 3.2.

However, because it is possible for the T/G system to generate high-energy missiles that could damage essential safety-related structures, systems, and components (SSCs), it is designed and controlled to minimize the potential for turbine missile generation. The T/G system is designed to meet the requirements of General Design Criterion (GDC) 4 as related to the protection of SSCs from the effects of turbine missiles described in Subsection 3.5.1.3.

10.2.1.2 Non-Safety Power Generation Design Bases

The T/G converts the energy of the steam produced in the SGs into rotational energy and then into electrical energy. The principal design features of the T/G are as follows:

a. The T/G is designed for base load operation and has load following capability.

b. The T/G load change characteristics are compatible with the plant control system, which coordinates the T/G and reactor operations.

c. The main turbine system is designed for electric power production consistent with the capability of the reactor and the reactor coolant system.

d. The T/G is designed to be monitored and controlled automatically by the TGCS at normal or abnormal conditions, as described in Subsection 10.2.2.3. The TGCS

overspeed

includes redundant, diverse, and independent mechanical and electrical trip devices that trip the turbine at approximately 110 percent and 111.5 percent of the rated speed of T/G, respectively. The maximum expected overspeed of the turbine does not exceed 115 percent of the rated speed. The design overspeed of the T/G is at least 5 percent above the maximum expected overspeed resulting from a loss of load.

e. The main stop valves (MSVs), control valves (CVs), intermediate stop valves (ISVs), intercept valves (IVs), non-return valves, overspeed protection system, and other protection devices are designed to allow regular online testing of each protection device with minimum effect on the online turbine operation.

f. The T/G system is designed so that the single failure of any component or subsystem does not disable the turbine overspeed trip function.

g. The T/G system provides the proper drainage of related piping and components to prevent water induction to the inside the turbine.

h. The MSRs, MSR drain tanks, pressure vessels, and piping in the T/G auxiliary systems are designed to the requirements of ASME Section VIII (Reference 1). The other parts of the T/G are designed to the T/G manufacturer's standards.

i. Generator rating, temperature rise, and class of insulation are in accordance with Institute of Electrical and Electronics Engineers (IEEE) Standard C50.13 (Reference 2).

j. The T/G is designed to trip automatically under abnormal conditions.

10.2.2 Description

10.2.2.1 General Description

The T/G system consists of an 1,800 rpm turbine, two sets of MSRs, generator, exciter, controls, and associated subsystems.

The TGCS uses a digital monitoring and control system that controls the turbine speed, load, and flow for startup and normal operations. The control system operates the turbine MSVs, CVs, ISVs, and IVs. T/G supervisory instrumentation is provided for operational analysis and malfunction diagnosis.

The extraction steam piping is constructed of low-alloy steel such as Cr-Mo steel or equivalent material for erosion and corrosion resistance. The source of the extraction steam for feedwater heating at each stage is presented in Table 10.2.2-1.

Upon loss of load, the steam contained in piping downstream of the ~~extractions~~ extraction lines can flow back into the turbine across the remaining turbine stages and into the condenser. Associated condensate can flash to steam under this condition and contribute to the backflow of steam or can be entrained with the steam flow and damage the turbines. Non-return check valves are employed to minimize the potential for these conditions to contribute to the turbine overspeed. These valves are periodically tested.

The T/G foundation is a reinforced concrete structure. The T/G foundation and equipment anchorage are designed to the same seismic design requirement as the turbine building. Additional information on seismic design requirements is provided in Section 3.7.

10.2.2.2 Component Description

The T/G will consist of a double-flow high-pressure (HP) turbine, three double-flow low-pressure (LP) turbines, and a direct-coupled generator in tandem. Details of the design will depend on the unit selected by the COL applicant. The COL applicant is to identify the turbine vendor and model (COL 10.2(1)).

The typical valve and piping arrangements are shown in Figure 10.2.2-1. Two MSRs with two stages of reheating are located on each side of the T/G centerline. The single direct-driven generator is water-cooled and rated 1,425 MWe. T/G accessories include the bearing lubrication oil system, TGCS, turbine hydraulic system, turning gear, hydrogen gas control system, seal oil system, stator cooling water system, etc.

10.2.2.2.1 Main Stop Valves and Control Valves

The flow of main steam is directed from the SGs to the HP turbine through four MSVs and four CVs. Each main stop valve is in series with a control valve.

MSVs are designed to incorporate a steam strainer to limit foreign material from entering the control valves and turbine. The primary function is to quickly shut off steam flow to the HP turbine under emergency conditions. MSVs are hydraulically operated in an open-closed mode by the turbine overspeed protection system in response to turbine trip signals.

CVs are designed to provide steam flow throttling and shut-off that is adequate for turbine speed control. The primary function of the CVs is to control steam flow to the turbine in response to the TGCS. CVs are closed under trip conditions.

MSVs and CVs are hydraulically operated by a high-pressure fire-resistant fluid supplied through a servo valve. ~~Valve~~ Typical valve characteristics and closure times are provided in Table 10.2.2-2. Each valve will have an actuator consisting of a spring, housing assembly, and control package. The control package contains the hydraulic cylinder, operating piston, ~~disk~~ dump valve, solenoid-operated trip line test valve, shutoff valve, and servo-valve. The actuator shall be designed to allow the valves to close rapidly on turbine trip. If the hydraulic system fails, the hydraulic pressure will drop, and the valve will be closed by the spring force.

10.2.2.2.2 High-Pressure Turbine

The HP turbine receives steam through four steam lines. The steam is expanded axially across several stages of stationary and moving blades. These stages consist of a blade-attached wheel and diaphragm structure. Extraction steam from the HP turbine at three locations is supplied to the fifth, sixth, and seventh stages of feedwater heaters, as described in Table 10.2.2-1. After expanding through the HP turbine, the exhaust steam passes through the MSRs.

10.2.2.2.3 Moisture Separator Reheaters

The moisture in the HP turbine exhaust steam is separated and reheated by two sets of external MSRs. The MSRs are located on each side of the T/G centerline. Extraction from the HP turbine and main steam from the equalization header are supplied to the first and second stages of the reheater tube bundle in each reheater.

The MSRs use multiple banks of chevron-skip vanes for moisture removal. The moisture is removed by the external moisture separator.

Condensed steam in the reheater, which is drained to the reheat drain tank, flows into the shellside of the fifth, sixth, and seventh feedwater heaters and cascades to the deaerator.

10.2.2.2.4 Intermediate Stop Valves and Intercept Valves

Hydraulically operated ISVs and IVs are provided in each hot reheat line upstream of the LP turbine inlet. Each intermediate stop valve is in series with an intercept valve.

Upon loss of load, the IVs first close and then throttle steam to the LP turbine to control speed. The ISVs and IVs close on a turbine trip. The ISVs and IVs are designed to close rapidly to control turbine overspeed. ~~Valve~~ Typical valve characteristics and closure times are provided in Table 10.2.2-2.

10.2.2.2.5 Low-Pressure Turbine

Each LP turbine receives steam from the MSRs through two hot reheat lines. The steam expands axially across several stages of stationary and moving blades.

The steam then passes through the LP turbines, each with extraction points for the LP stages of feedwater heating, and exhausts into the main condenser. Extraction steam from the LP turbines supplies the first stages of feedwater heating.

Condensate moisture from the moving blade at the latter stages is removed along the moisture groove. Drainage holes are drilled through the diaphragm rings to remove the moisture generated from the diaphragm rings located in high wet zones.

10.2.2.2.6 Extraction Non-Return Check Valve

Typical non-return

Non-return check valves are installed on extraction lines as shown in Figure 10.2.2-1. Valves in the higher-pressure extraction lines are power-assisted, spring-closed, non-return check valves. The ~~power-assisted,~~ spring-closed actuators are designed to overcome friction and allow the valves to close rapidly on turbine trip. These non-return check valves are capable of closing within a time period to maintain stable turbine speeds in the event of a T/G system trip. ~~Non-return~~ check valve characteristics and closure times are provided in Table 10.2.2-2. The two low-pressure heaters and their associated extraction lines are located in the condenser neck. The no. 3 heaters are installed horizontally in the heater bay. Because of the low energy levels of the entrained fluid in the two lowest-pressure heaters, no. 2 heaters are provided with anti-flash baffle plates located inside the heaters.

10.2.2.2.7 Generator

The generator is a direct-driven, three-phase, 60 Hz, 1,800 rpm, four-pole synchronous generator with a water-cooled armature winding and hydrogen-cooled rotor. Generator rating, temperature rise, and class of insulation are in accordance with IEEE Standard C50.13.

The generator rotor is manufactured from forged components and includes layers of field windings embedded in milled slots. The windings are held radially by slot wedges at the rotor outside diameter. The wedge material maintains its mechanical properties at elevated temperatures. The magnetic field is generated by direct current (DC) power, which is fed to the windings through collector rings located outboard of the main generator bearings.

The generator rotor will be machined from a single, solid steel forging. Detailed examinations include:

a. Material property checks on test specimens taken from the forging

b. Magnetic particle and ultrasonic examination

10.2.2.2.9 Generator Exciter

The excitation system regulates the generator terminal voltage. This system is a static bus-fed type and consists of a 3-phase full-wave rectifier, excitation transformer, and AC/DC bus duct. Excitation power can be obtained from an excitation transformer, which is connected directly to the generator terminals. The excitation system, generator field, and excitation transformer are connected by the AC/DC bus duct to each other.

The secondary side of the excitation transformer is connected to the 3-phase full-wave rectifier. The 3-phase full-wave rectifier uses a thyristor, which is a semiconductor device for power conversion from AC to DC.

10.2.2.3 Control and Protection

10.2.2.3.1 Normal Control

The TGCS is a digital monitoring and control system that controls turbine speed, load, and flow for startup and normal operations. The TGCS operates the turbine MSVs, CVs, ISVs, and IVs. T/G supervisory instrumentation is provided for operational analysis and malfunction diagnosis.

The TGCS combines the capabilities of redundant digital processing and high-pressure hydraulics to regulate steam flow through the turbine. Valve-opening actuation is provided by a hydraulic system that is independent of the bearing lubrication system. Valve-closing actuation is provided by springs and steam forces in the event of a reduction in or relief of fluid pressure. The system is designed so that loss of fluid pressure, for any reason, leads to valve closing and a consequent turbine trip.

Electric power for the TGCS [and protection system] is supplied by two AC sources for redundancy with a ~~120 Vac~~ [120V AC] single-phase station source and a vital control bus [from uninterruptible power source(UPS) or other reliable source].

The TGCS contains the following components:

a. Three redundant speed inputs

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

digital (e.g., microprocessor, field programmable gate array)

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

transients with the potential to damage a turbine

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 above described features and those in the following sections are functional requirements to be used in selecting an appropriate turbine and TGCS.

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)).

as described in Subsection 10.2.2.3.2

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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, separation) (COL 10.2(2)).

A simplified, generic schematic is provided by Figure 10.2.2-2.

10.2.2.3.1.1 Speed Control

using technology different from those used for the electrical overspeed trip

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-~~ digital based controller is activated during a high load rejection. The valves are fully closed ~~below 105~~ at 103 percent.

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.

Automatic controls are provided to avoid unnecessary turbine trip and to permit subsequent operation at house load (i.e., load required to run station auxiliaries) in the event of a loss of load from 100 percent power. Also, automatic action is provided to balance the TG loads following a small, brief mismatch between generator load and generator power, without loss of synchronization during load mismatch transients, up to full power.

Control logic provides reasonable assurance that the necessary conditions have been satisfied prior to changes in mode of operation, to communicate status information between the load control unit and other elements of the TGCS, and to provide switching signals to devices in the TGCS.

10.2.2.3.1.3 Flow Control

When the output flow reference signal is at the limit value, the load set runback is initiated to drop the load setpoint. To prevent an excessive decrease of the main steam pressure, a main steam pressure limiter circuit is provided to close the controlling valve set when the main steam pressure falls below a preset level. The regulation of this circuit is fixed at 10 percent. When the main steam pressure falls below an adjustable setpoint, the flow reference signal to the controlling valve set is limited to the value permitted by the level of the main steam pressure. The pressure setpoint is adjustable from zero to rated pressure by using the keyboard or cursor-positioning device on the control console in the control room. Control room ~~meters indicate~~ displays show the pressure setpoint that has selected, as well as the actual main steam pressure. An acceleration limiter operates when the field breakers open and the turbine acceleration is too high.

First-stage feedback is incorporated into the control system to provide more linear turbine response to the desired load signal and to maintain near constant turbine output while testing control valves.

The turbine and its CVs are designed to pass the rated flow at the existing throttle pressure at the MSVs and CVs at the rated output of the nuclear steam supply system (NSSS). The load control function and maximum load limiter function are protected against overload. The feedback of live steam pressure is provided for a constant control gain.

All stop valves are hydraulically operated from the common hydraulic safety system equipped with limit switches for stroke testing. The closing time of all stop valves during testing is short and corresponds to the time at turbine trip.

10.2.2.3.1.4 Valve Control

The CVs position loop consists of electrical circuitry, an electro-hydraulic servo-valve, hydraulic actuator, and linear position transducer. By use of a valve position feedback control, the control valve flow control unit positions the CVs according to the flow demand signal from the load control unit or directly from the control panel. Valve position control is performed by using a feedback path that transmits the actual valve position back to a point where it is compared algebraically with the reference input. The error signal positions the hydraulic actuator using the servo-valve to make it zero value. CV testing is designed to allow regular testing of each valve with the effects to the online turbine operation minimized. This testing is performed by the position controller using the integrated servo-valve.

Three IVs are equipped with a position controller and a servo-valve.

Three control processors can control servo valves with up to three coils. These control processors are connected to each coil. In a failure of a controller, its output port or the physical connection to the output coil results in the other two servo drives compensating for the failed channel and keeping the valve properly positioned.

The flow of main steam entering the HP turbine is controlled by four MSVs and CVs. Each MSV is either fully open or fully closed by an electro-hydraulic actuator. The MSVs shut off the steam flow to the turbine when required, such as for actuation of the electrical overspeed trip. The CVs are positioned by electro-hydraulic servo actuators in response to signals from their individual flow control unit. The flow control unit positions the CVs for wide-range speed control through the normal turbine operating range and for load control after T/G synchronization.

The intermediate stop (ISVs) and intercept valves (IVs), located in the hot reheat lines at the inlet of the LP turbines, control steam flow to the LP turbines. During normal operation of the turbine, they are fully open. The IV flow control unit positions the valve during

startup and normal operation and closes the valve rapidly on loss of turbine load. The IVs and ISVs close completely on turbine overspeed and turbine trip.

Typical valve

~~Valve~~ characteristics and closure times are provided in Table 10.2.2-2.

10.2.2.3.1.5 Power Load Unbalance

If the T/G is running at load and the load on the generator is suddenly lost, the following events take place in rapid succession:

a. The acceleration limiter operates on high acceleration.

b. The CVs and IVs are closed at the maximum rate.

c. The entrained steam between the valves and the turbine, in the turbine casing, and in crossover and extraction lines expands.

d. The expected overspeed is less than 10 percent at full load.

e. The IVs reopen when the actual speed is below the set value.

If the above sequence is not successful, the TGCS overspeed protection device is activated to protect the T/G. The main steam is bypassed to the condenser to reduce steam flow to the turbine (see Subsection 10.4.4).

10.2.2.3.1.6 Automatic Turbine Startup and Shutdown

The automatic turbine startup (ATS) receives commands from the operator using the operator interface or from a plant computer through a data link, compares it to the limits, and issues commands to the primary controllers. ATS routines are executed during all modes of operation. ATS routine results are used directly or also displayed during all modes of operation.

The primary mode of communication between the ATS and the operator is through the operator interface displays.

The ATS has the following phases:

a. Pre-roll monitoring and operation

b. Acceleration to the rated speed

c. Loading and unloading

d. Post-trip securing

10.2.2.3.2 Overspeed Protection

(MOTS)

The normal speed control system serves as the first line of defense against turbine overspeed. This system includes CVs, IVs, and fast-acting valve-closing functions within the TGCS. The TGCS begins to close the control and intercept valves at about 101 percent of the rated speed and completely closes the valves at 103 percent. If this system fails to prevent the overspeed, the overspeed protection system is activated to prevent overspeed. The overspeed protection system consists of two major subsystems: (1) a mechanical overspeed trip system in the front standard and (2) an electrical overspeed trip system.

(EOTS), which each cause the turbine steam valves to shut through the action of the emergency trip system (ETS)

~~Redundancy is built into the overspeed protection system. The failure of a single valve will not disable the trip functions. The overspeed protection components are designed to fail in a safe position. Loss of the hydraulic pressure in the emergency overspeed protection systems causes a turbine trip. Therefore, damage to the overspeed protection components results in the closure of the valves and the interruption of steam flow to the turbine.~~

approximately MOTS weight

The ~~mechanical overspeed trip system is the emergency overspeed protection and~~, upon reaching a setpoint that is 110 percent of the rated speed, acts to bring the turbine to a safe shutdown condition. It consists of an unbalanced ~~ring~~ that is activated by a centrifugal force against a spring when the turbine overspeeds, thus causing an eccentric movement that ~~strikes the trip finger on~~ the emergency trip valve. ~~This action causes a depressurization of the emergency trip system (ETS) hydraulic fluid and, via an interface relay, the common hydraulic safety system, closing all stop and control valves.~~ If the

mechanically opens

passive magnetic speed sensors that are diverse and independent from the TGCS sensors and

~~mechanical overspeed trip system~~ MOTS fails, the ~~electrical overspeed trip system~~ EOTS will activate the ETS trip valves, causing all steam valves to trip closed upon reaching the setpoint.

The ~~electrical overspeed trip system~~ EOTS consists of two speed calculating modules: a primary and backup. Each module uses the three ~~binary~~ signals from passive magnetic speed sensors that are diverse and independent from the TGCS sensors and the speed conditioning units to the 2-out-of-3 tripping device. The primary module and secondary module calculate ~~calculates~~ the trip setpoint ~~from~~ in a diverse manner, with one using software logic, and the other using ~~backup module calculates the trip setpoint from its~~ module firmware, which is independent of the primary module. These modules trigger hydraulic solenoid valves, and all stop and control valves are then closed. Each setpoint is 111.5 percent of the rated speed. The turbine is not expected to exceed 115 percent of the rated speed.

Insert (C) of next page

~~Redundancy is also achieved in the electrical overspeed trip system by using three independent channels from the signal source to the output device. The speed sensors used by the electrical overspeed trip system are completely independent of the speed sensors used by normal speed control. Each circuit monitors a separate speed signal. The sensing device, line and output device are of a different nature for each individual channel to increase reliability and reduce potential for common cause failure.~~

~~Diversity and independence in turbine overspeed protection is achieved by having one mechanical overspeed protection system and one electrical overspeed protection system that do not have common components. Common cause failures of the overspeed trip protection systems are prevented through the use of redundant and diverse hardware and software.~~

~~The following component redundancies are employed to guard against turbine overspeed:~~

~~a. Main stop valves/Control valves~~

~~b. Intermediate stop valves/Intercept valves~~

~~c. Normal speed control/Mechanical overspeed trip system/Electrical overspeed trip system~~

~~d. Fast-acting solenoid valves/Emergency trip fluid system~~

Insert (C)

Following is a detailed functional performance description of the TGCS, MOTS, and EOTS.

a. Redundant, in-series turbine steam valves are used on each line admitting steam to the high and low pressure turbines. These are the MSVs and CVs for the high pressure turbine, and the ISV and IVs for the low pressure turbines. Each of these valves fail closed (held open by hydraulic control oil pressure maintained by a closed dump valve).

b. Closure of the turbine steam valves is accomplished by draining hydraulic control oil holding the dump valves closed, allowing the springs to shut each steam valve.

c. Draining hydraulic control oil from the MSVs and ISVs is accomplished by activating any of the three overspeed trips. Specifically:

1) Normal control system - receipt of a valid trip energizes the solenoid operated fast-acting valves, which drain off hydraulic control oil from each dump valve.

2) MOTS - movement of mechanical linkages repositions the mechanical trip valve, draining hydraulic control oil. A trip can occur for any of the following reasons:

a) Mechanical (i.e., rotating inertia increasing due to rising rotational speed) turbine trip that moves the trip linkages

b) Emergency manual trip activation at the turbine front standard by de-energizing a solenoid that moves the trip linkages

c) Emergency manual trip activation from the control room by de-energizing a solenoid that moves the trip linkages

3) EOTS - trip signals are processed by both a primary and backup unit to determine trip validity based on 2-out-of-3 voting, either of which then opens contacts to de-energize both solenoids of the master trip valve. This allows the master trip valve to reposition due to spring force, draining hydraulic control oil.

d. Draining hydraulic control oil from the CVs and IVs is accomplished when draining of hydraulic control oil pressure described in c. above also allows a spring to reposition a valve, which drains hydraulic control oil from the separate CV/IV header.

e. An extraction relay dump valve under normal operating conditions aligns the incoming instrument air supply to the operators of air-assisted, spring-closed, non-return valves in the higher-pressure extraction lines to hold them open. The non-return check valves close rapidly on turbine trip when the extraction relay dump valve vents air. Typical characteristics and closure times are provided in Table 10.2.2-2, but the number of valves, their closing times, and detailed design will be in accordance with the turbine manufacturer's requirements and the requirements of ANSI/ASME TDP-1-1998. Although held open by air, the valve closes as a non-actuated swing check valve. The design allows periodic trip confirmation.

f. The balance of the hydraulic control oil system must fulfill the following requirements:

1) Drains - Control oil from the valve actuators is collected in two stainless steel drain headers. There is one header for the MSVs (ISVs for low pressure turbines) and one for the CVs (IVs). These two headers drain to the hydraulic power unit reservoir through a common drain line. The drain headers are sized to handle the maximum hydraulic control oil flow requirements, maintaining the required valve stroke times, and are sloped to drain to the reservoir.

2) Failure of the hydraulic piping between the trip block and the valve actuator, or between the hydraulic fluid tank and the valve actuator will cause a loss of fluid pressure, which closes the turbine steam valves.

3) The hydraulic fluid in the trip and overspeed protection control headers is independent of the bearing lubrication system to minimize the potential for contamination of the fluid.

c. Primary speed calculating module/Backup speed calculating module

The turbine overspeed trips close all stop and control valves within a certain period after a trip signal that precludes an unsafe turbine overspeed condition, as described in Table 10.2.2-3.

To further decrease the possibility of an overspeed condition, two redundant reverse-power relays prevent overspeed after a turbine trip and prevent overheating of the last stages of LP turbine blades. Additionally, a T/G protection device interfaces with the main steam bypass system, which bypasses main steam to the condenser to reduce steam flow to the turbine (see Subsection 10.4.4).

The turbine overspeed protection devices are listed in Table 10.2.2-3. Each device has an on-load test provision.

The three lines of defense against overspeed during all modes of operation are as follows:

a. Speed control and overspeed protection in the TGCS

b. One mechanical overspeed trip at 110 percent of the rated speed

c. Electrical overspeed protection in 2-out-of-3 logic scheme at 111.5 percent of the rated speed

In case of malfunction of the normal speed control system coincident with a loss of generator load, the turbine accelerates and the mechanical and electrical overspeed trip systems activate at 110 percent and 111.5 percent of the rated speed, respectively, and trip the MSVs, ISVs, and non-return valves as the second and third lines of defense, respectively. The main CV and IV actuators also close. Subsequently, the turbine coasts down.

10.2.2.3.3 Turbine Protection

The main function of the ETS is to check the validity of the trip demand signals and to provide reasonable high assurance that trip action results in immediate response to a valid trip

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:

a. Emergency Manual 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).

Insert (D) and (E) of next page

10.2.2.3.~~4~~ 3 <u>Inspection and Testing</u>

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

Insert (D)

The fundamental design principles are met as follows:

Diversity

a. A purely mechanical overspeed trip is available in conjunction with the normal control and electrical overspeed trips. The mechanical trip valve does not depend on availability of electric power (power is required to keep the mechanical trip solenoid valve energized to prevent the manual trip valve from draining hydraulic control oil).

b. The TGCS and EOTS use diverse speed inputs, determine trip validity using different technology, have different set points, and actuate to drain hydraulic control oil, to eliminate common cause failures from rendering the trip functions inoperable. The MOTS senses speed via physical repositioning of an eccentric weight, rather than counting rotations per unit time.

Separation

a. The ETS valves are located in the turbine front standard out of the way of turbine missiles and high pressure steam lines, whereas the TGCS solenoid-operated fast-acting valves are part of the main steam valve actuators.

b. The TGCS overspeed trip controllers and the EOTS primary and backup processors are located in different instrument cabinets.

c. Hydraulic control oil drain headers for MSVs and CVs and for ISVs and IVs are separate and separated on opposite sides of the turbines.

Redundancy

a. Each turbine steam inlet line has two valves (e.g., MSV and CV for high pressure turbine), closure of any one in each pair isolates that line.

b. Failure of any one component in overspeed protection systems will not prevent a turbine trip.

Independence

a. The normal control overspeed system, EOTS, and MOTS each determine turbine speed using independent means: diverse TGCS speed sensors, passive magnetic speed sensors, and rotational acceleration (“centrifugal force”).

b. A failure of one of the overspeed protection systems will not propagate to the others because they are electrically isolated and physically separated.

c. Closure or lack of closure of one of the series turbine steam valves (e.g., MSV and CV) will not prevent the other valve from closing within its timing requirements to prevent overspeed.

Single failure criterion

Single failures are addressed through redundancy and independence, but additionally: No single failure will cause a turbine to overspeed. This feature is desirable since the best way to protect for an overspeed is to designate TGCS features that assure no single failure can initiate the transient.

Insert (E)

Fail safe

a. Upon loss of power, valves transition to positions where hydraulic control oil is drained, tripping shut all turbine steam valves.

b. If a speed sensor fails, it is removed from the voting logic, leaving two out of two trip logic. If two speed sensors fail, a turbine trip is initiated.

c. Relays that provide the interface between the TGCS and the EOTS controllers and the valves of the hydraulic control and protection systems fail in a fail safe position on a loss of power.

Testability

a. Test valves and relays are provided to allow any turbine steam valve to be tested during operation.

b. Overspeed sensors, controllers, and trips are fully testable during normal operation.

c. To avoid the possibility that a test alignment error could block a trip and due its simplicity, the mechanical overspeed protection trip is not provided a means to test during operation. Instead, the turbine manual switches and associated linkages are tested during refueling outages prior to turbine start-ups or if maintenance work could have affected functionality.

The normal overspeed and EOTS controllers and relays are installed in separate cabinets; electric power for each is supplied by two AC sources for redundancy with a 120V AC single-phase station source and a vital control bus from a UPS or other reliable source.

subsequent startup if no maintenance is performed that affects the overspeed trip circuits and devices.

Inservice testing and functional checks are performed periodically as required by the vendor and by the turbine missile probability analysis. MSVs, CVs, ISVs, and IVs are exercised ~~at least once within quarterly intervals~~ by closing each valve and observing the remote valve position indicator for fully closed position status. This test also verifies operation of the fast close function of each MSV and CV during the last few percent of valve stem travel. Fast closure of the ISV and IV is tested in a same way. Non-return check valves are tested in accordance with vendor recommendations. Inspection and test requirements for the overspeed trip device are as required by the turbine missile probability analysis.

The checks include testing of components such as:

a. MSVs, CVs, ISVs, and IVs

b. Turbine trips and pressure switches for lube oil supervision

c. Electrical overspeed trips

d. Vacuum trips

e. Extraction power-assisted check valves

f. The control fluid pressure switch

g. All control devices and positioning of control valves

h. The mechanical overspeed trip device

i. Each lube oil pump

The inspection includes a complete inspection of all normally inaccessible parts, such as couplings, coupling bolts, LP turbine rotors, LP turbine buckets, and HP turbine rotor. The inspection consists of visual, surface, and volumetric examinations.

The inservice inspection of MSVs, CVs, ISVs, and IVs includes the following description. At ~~3-year~~ intervals in accordance with vendor recommendations and as supported by the turbine missile probability analysis, during refueling or maintenance shutdowns coinciding with the inservice inspection schedule required by ASME Section XI for reactor components, at least one MSV, one CV, one ISV, and one IV ~~are~~ is dismantled, and visual and surface examinations are conducted of valve seats, disks, and stems. If unacceptable flaws or excessive corrosion are found in a valve, all other valves of that type are dismantled and inspected. Valve bushings are inspected and cleaned, and bore diameters are checked for proper clearance. Non-return check valves are inspected by an inspection program in accordance with vendor recommendations.

10.2.3.6 Turbine Missile Probability Analysis

An analysis containing an evaluation of the probability of turbine missile generation is prepared by the COL applicant. The report provides a calculation of the probability of turbine missile generation using established methods and industry guidance applicable to the fabrication technology employed. The analysis is a comprehensive report containing a description of turbine fabrication methods, material quality and properties, and required maintenance and inspections that addresses:

a. The calculated probability of turbine missile generation from material and overspeed related failures based on as-built rotor and blade designs and as-built material properties (as determined in certified testing and nondestructive examination [NDE])

b. Maximum anticipated speed resulting from a loss of load, assuming normal control system function without trip

c. Overspeed basis and overspeed protection trip setpoints

d. Discussion of the design and structural integrity of turbine rotors

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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

as described in Subsection 10.2.2.3.2

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 (B) of next 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.

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Insert (B)

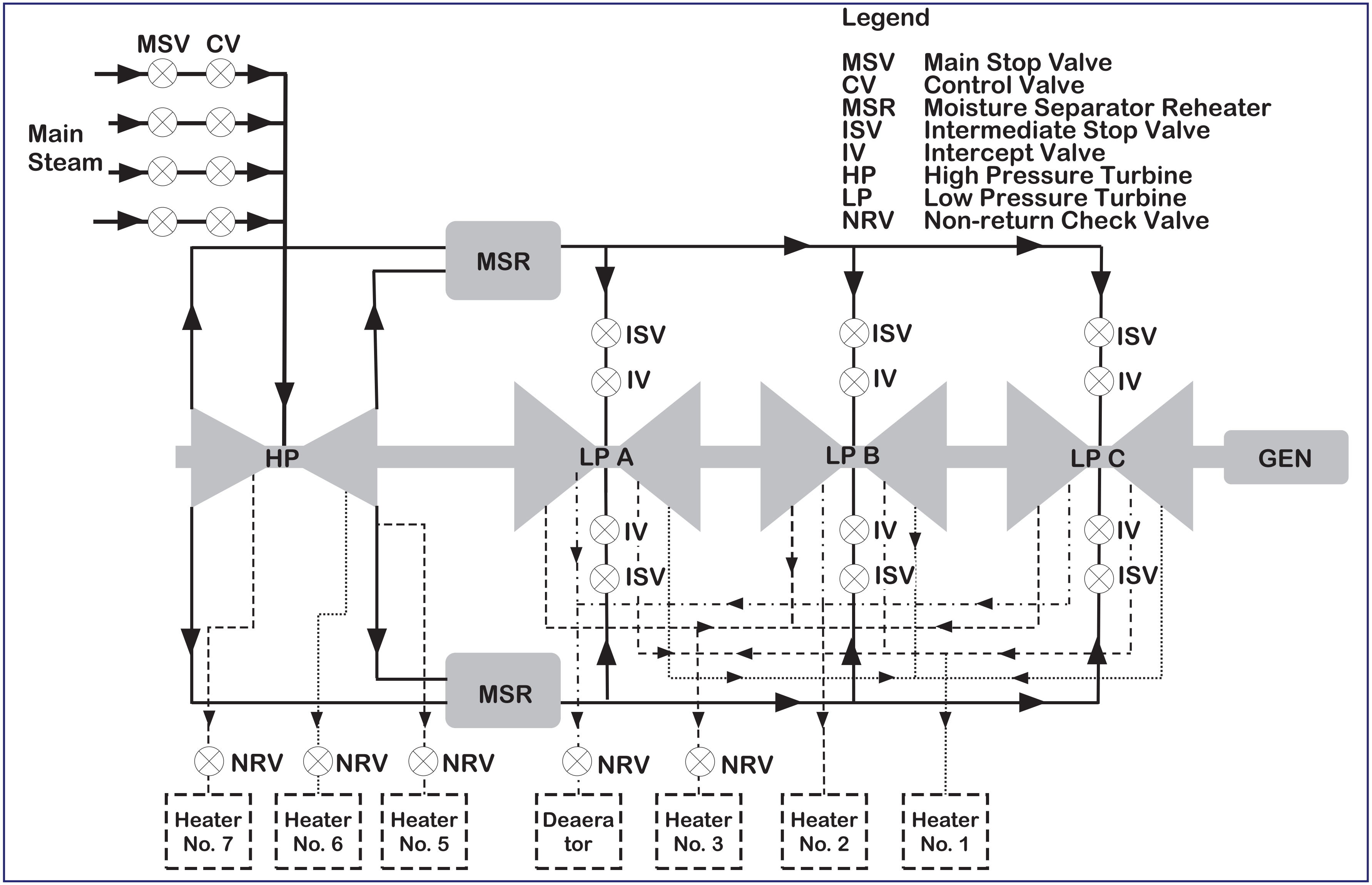
schematic(s) of the TGCS and overspeed protection systems that show the entire system end-to-end and all discrete components and interfaces (e.g., sensors, power supplies, control devices, manual emergency trips, the device that eventually drains the hydraulic/air fluid from turbine control valves). 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, separation)

Typical

Table 10.2.2-2

Turbine Valve Closure Times

Valve	Characteristic	Closure Time (seconds)
Main stop valves	The primary function is to quickly shut off steam flow to the turbine under emergency conditions. Hydraulic-actuated power actuator consists of a spring housing assembly and control package.	0.3
Control valves	The primary speed control acts as a first line against overspeed by closing on a proportional basis in response to a load rejection. Normal speed control should prevent the turbine from reaching the primary overspeed trip setpoint. The valves are opened by individual hydraulic cylinders.	0.3
Intermediate stop valves	The arrangement is welded directly to the cross–around pipe to locate the combined valve as close as possible to the turbine, thereby limiting the amount of uncontrolled cross-around steam that is available for overspeeding the turbine under emergency conditions. The valves are operated by individual hydraulic cylinders.	0.3
Intercept valves	The purpose of the intercept valve is to shut off steam flow from the cross around, which, because of its large storage capacity, could potentially drive the unit to a dangerous overspeed upon loss of generator load. The valves are operated by individual hydraulic cylinders.	0.3
Non-return check valves	The valves are employed to minimize potential to contribute to the turbine overspeed in the event of T/G trip. The valves are operated by air that is connected through air relay dump valve.	below 1.0



(Actual as-built arrangement will depend on turbine selected by COL applicant.)

Figure 10.2.2-1 Typical Arrangement of T/G System

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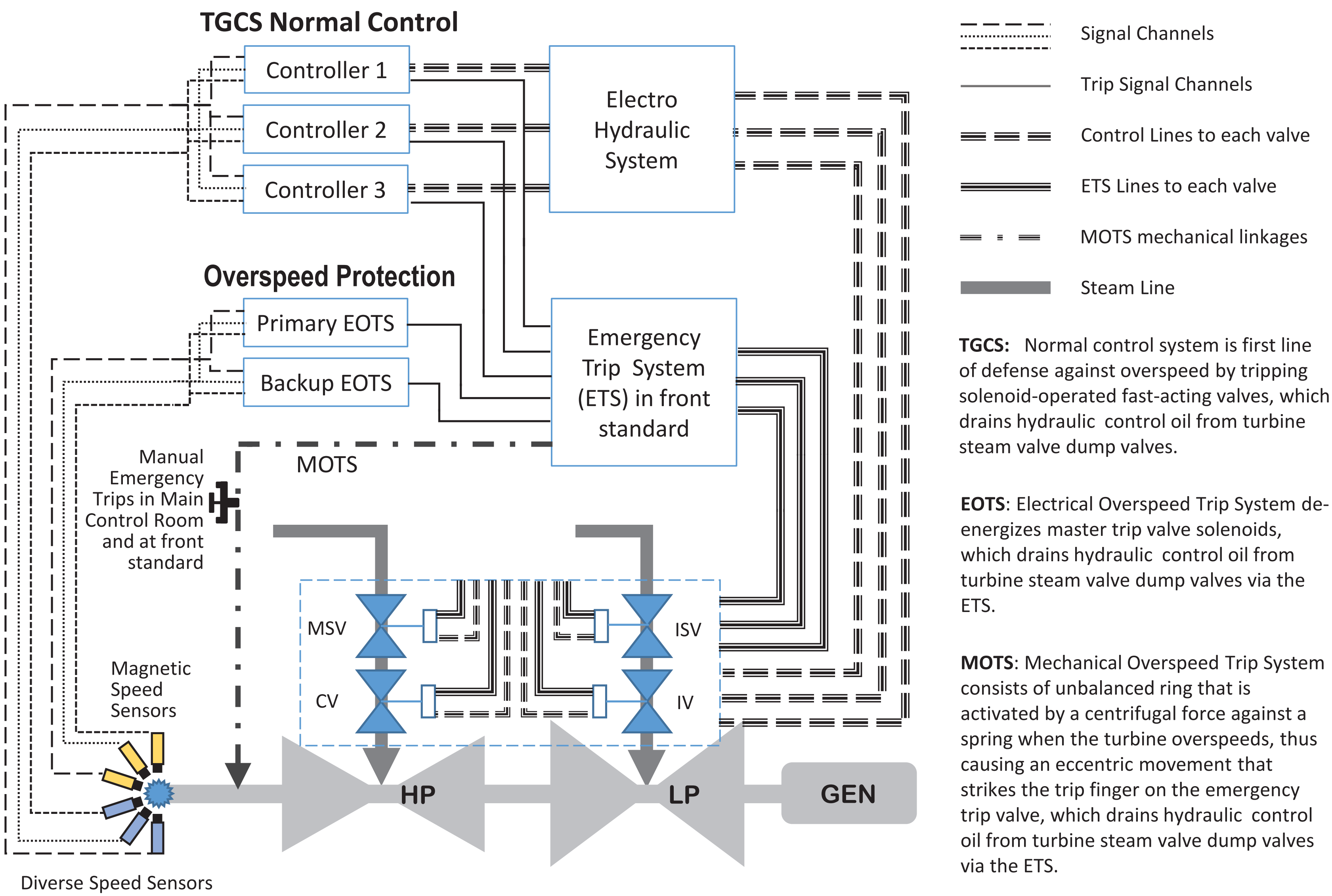

TGCS: Normal control system is first line of defense against overspeed by tripping solenoid-operated fast-acting valves, which drains hydraulic control oil from turbine steam valve dump valves.

EOTS: Electrical Overspeed Trip System de-energizes master trip valve solenoids, which drains hydraulic control oil from turbine steam valve dump valves via the ETS.

MOTS: Mechanical Overspeed Trip System consists of unbalanced ring that is activated by a centrifugal force against a spring when the turbine overspeeds, thus causing an eccentric movement that strikes the trip finger on the emergency trip valve, which drains hydraulic control oil from turbine steam valve dump valves via the ETS.

Figure 10.2.2-2 - High Level Overspeed Protection Architecture

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 [as described in Subsection 10.2.2.3.2] for the overspeed protection system are met and provide ~~a schematic of the TGCS and protection systems from sensors through valve actuators~~ [Insert (B) 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.

REVISED 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 Issue:	**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 – (Rev.1)

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)."

For further understanding, see the response to RAI Question 10.02-2.

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:

a. ~~Emergency~~ Manual 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

REVISED 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 Issue:	**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 – (Rev. 1)

See the response to RAI Question 10.02-2

Impact on DCD

DCD Subsection 10.2.2, Subsection 10.2.5 Combined License Information item (2), Figure 10.2.2-2 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.

REVISED 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 Issue:	**07/27/2015**

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 – (Rev.1)

See the response to RAI Question 10.02-2

Impact on DCD

DCD Subsection 10.2.2, Subsection 10.2.5 Combined License Information item (2), Figure 10.2.2-2 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.