10.0 Steam and Power Conversion System

This section describes the steam and power conversion system for the U.S. EPR.

Depending on site-specific data, equipment availability and utility requirements, alternative designs for the steam and power conversion system may be considered by the applicant for a combined license (COL). An optional design description for portions of the U.S. EPR steam and power conversion system is provided in alternative Sections 10.1A, 10.2A and 10.4.7A. These alternative sections outline the changes in the steam and power conversion system configuration to support the use of an optional turbine-generator design. Those areas of the U.S. EPR steam and power conversion system not affected by selection of the optional turbine-generator design are so identified within the alternative sections. Only one of the design descriptions are used by the applicant within the site-specific FSAR.

A COL applicant that references the U.S. EPR design certification will select Sections 10.1, 10.2 and 10.4.7 or 10.1A, 10.2A and 10.4.7A for inclusion in the COL FSAR as applicable to the chosen turbine-generator design option.

10.1 Summary Description

The steam and power conversion system removes energy from the reactor coolant in the steam generators and converts it into electric power in the turbine-generator. The steam and power conversion system comprises the following process systems:

- Turbine-generator (TG).
- Main steam supply system (MSSS).
- Main condensers.
- Main condenser evacuation system (MCES).
- Turbine gland sealing system (TGSS).
- Turbine bypass system (TBS).
- Circulating water system (CWS).
- Condensate cleanup system.
- Condensate and feedwater system.
- Steam generator blowdown system (SGBS).
- Emergency feedwater system (EFWS).

The following portions of the steam and power conversion system have safety-related functions:

- Main steam piping between each SG outlet nozzle and the fixed point restraint downstream of its respective main steam isolation valve (MSIV) (refer to Section 10.3).
- Main feedwater piping between each SG inlet nozzle and the fixed restraints upstream of its respective feedwater isolation valves (refer to Section 10.4.7).
- Containment isolation valves for condensate system cooling water supply and return to the first stage SG blowdown cooler inside containment (refer to Section 10.4.7).
- SG blowdown piping between each SG blowdown nozzle and its respective outermost CIV (refer to Section 10.4.8).
- EFWS (refer to Section 10.4.9).

Figure 10.1-1, Design Heat Balance for Steam and Power Conversion System Cycle, provides an overall system flow diagram of the power cycle and the design heat balance. Figure 10.1-2, Valves Wide Open Heat Balance for Steam and Power Conversion System Cycle, provides the valves wide open (VWO) heat balance for the steam and power conversion cycle. Table 10.1-1, Major Steam System Parameters and Turbine-Generator Design Data, provides the major steam system parameters at rated thermal power, along with TG design data.

10.1.1 General Description

Steam generated in the four SGs is supplied by the MSSS to the high pressure (HP) turbine through stop and control valves which regulate steam flow. After expanding across the HP turbine blading, exhaust steam is reheated in two moisture separator reheaters (MSR). The MSRs supply the intermediate pressure (IP) turbine through stop and intercept valves. After expanding across the IP turbine blading, exhaust steam flows to the three low pressure (LP) turbines.

The main condenser condenses the LP turbine exhaust and transfers the heat rejected in the cycle to the CWS. The CWS rejects heat to the normal heat sink. The main condenser operates at a vacuum maintained by the MCES.

Feedwater pumps return the condensate to the SGs through regenerative feedwater heaters that heat the condensate and the feedwater using extraction steam from the turbines. A feedwater storage tank is integrated into the cycle to deaerate and heat the condensate. This tank also provides a buffer volume to accommodate minor system transients.

Water quality in the steam-water cycle is maintained by the SGBS and the condensate cleanup (polishing) system. Makeup water for the cycle is conditioned in a demineralizing system, stored in the demineralized water storage tank and fed as required to the steam cycle.

The turbines are connected in tandem and operate at 1800 rpm. A three phase synchronous electric generator is coupled directly to the turbine shaft. The generator has a hydrogen-cooled rotor and a water-cooled stator. It is equipped with a collector for the static excitation system directly coupled to the generator shaft.

10.1.2 Protective Features

10.1.2.1 Loss of External Electrical Load and/or Turbine Trip

In the event of a loss of load and/or turbine trip, steam is automatically dumped to the main condenser through the turbine bypass valves, and if necessary, to the atmosphere via the main steam relief trains (MSRT). Load rejection capabilities of the steam and power conversion system are further described in Section 10.3.

10.1.2.2 Overpressure Protection

Each main steam line has two ASME Boiler and Pressure Vessel (BPV) Code Section III (Reference 1) safety valves, located upstream of the main steam isolation valve (MSIV). The main steam safety valves (MSSV), along with the MSRTs, provide overpressure protection of the main steam piping and SGs. Refer to Section 10.3. Overpressure protection of the SG blowdown flash tank and SG blowdown first stage cooler is provided in accordance with Reference 1.

The following components are provided with overpressure protection in accordance with the ASME BPV Code, Section VIII (Reference 2).

- MSRs.
- LP feedwater heaters.
- HP feedwater heaters.
- Deaerator/feedwater storage tank.
- MSR drain tanks.
- Main feedwater pump suction strainers and associated piping in accordance with ASME Power Piping Code B31.1 (Reference 3).

10.1.2.3 Loss of Main Feedwater Flow

The loss of main feedwater flow results in the automatic actuation of the EFWS when the water level in any SG reaches its applicable setpoint level. This event is further addressed in Section 10.4.7.

10.1.2.4 Turbine Overspeed Protection

A protective trip system quickly closes the main stop, control, reheat stop and intercept valves to provide overspeed protection. Two independent overspeed trip devices are included. The overspeed trip device fully closes the valves at about 110 percent of rated speed. The actuation of the turbine protection system does not rely on components in the electro-hydraulic control system. Turbine overspeed protection is further addressed in Section 10.2.

10.1.2.5 Turbine Missile Protection

The probability of generating turbine missiles is minimized by maintaining the turbine rotor integrity. This is provided by the integrated combination of material selection, rotor design, fracture toughness requirements, inspections and tests. Turbine missile protection is further addressed in Section 3.5.1 and turbine rotor integrity is addressed in Section 10.2.3.

10.1.2.6 Radioactivity Protection

There are no detectable radioactive contaminants present in the steam and power conversion system during normal plant operation. However, the system is monitored for increases in radioactivity by the main steam line monitors (for N-16 and noble gases), monitors in the SGBS and the activity monitoring system for the MCES (for non-condensing gases extracted from the condenser). Section 11.5 describes these process and effluent radiological monitoring and sampling systems.

10.1.2.7 Flow-Accelerated Corrosion Protection

Piping in the steam and power conversion system is protected from erosion-corrosion. Refer to Section 10.3.6.3.

10.1.3 References

1. ASME Boiler and Pressure Vessel Code, Section III: “Rules for Construction of Nuclear Power Plant Components”, American Society of Mechanical Engineers, September 2004.

2. ASME Boiler and Pressure Vessel Code, Section VIII, Division 1: “Rules for Construction of Pressure Vessels”, American Society of Mechanical Engineers, September 2004.

3. ANSI/ASME B31.1-2004, “Power Piping”, American Society of Mechanical Engineers, September 2004.

Table 10.1-1—Major Steam System Parameters and Turbine-Generator Design Data

Major Steam System Parameters	Value
Steam pressure	1110.9 psia
Steam flow	20,684,700 lb/hr
Steam enthalpy	1186.6 btu/lb_m
Feedwater temperature	446°F
Turbine-Generator Design Data	**Value**
Operating speed	1800 rpm
Frequency	60 hz
Generator output	1710 MW
Power factor	0.90 lagging
Voltage	26 kV nominal