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UK HPR1000 GDA Project

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Preliminary Safety Report
Chapter 11
Steam and Power Conversion System

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11.1 List of Abbreviations and Acronyms

AAD	Startup and Shutdown Feedwater System [SSFS]
ABP	Low Pressure Feedwater Heater System [LPFHS]
ADG	Feedwater Tank and Gas Stripper System [FTGSS]
AHP	High Pressure Feedwater Heater System [HPFHS]
APA	Motor Driven Feedwater Pump System [MFPS]
APG	Steam Generator Blowdown System [SGBS]
ARE	Main Feedwater Flow Control System [MFFCS]
ASG	Emergency Feedwater System [EFWS]
ASP	Secondary Passive Heat Removal System [SPHRS]
ATE	Condensate Polishing System [CPS]
BFX	Fuel Building
BMX	Turbine Generator Building
BNX	Nuclear Auxiliary Building
BRX	Reactor Building
BSA	Safeguard Building A
CEX	Condensate Extraction System [CES]
CI	Conventional Island
CRF	Circulating Water System [CWS]
DBC	Design Basis Condition
DEC	Design Extension Condition
EDG	Emergency Diesel Generator
FLB	Feedwater Line Break
FLCV	Full Load Control Valve
FLIV	Full Load Line Isolation Valve
GCT	Turbine Bypass System [TBS]
GDA	Generic Design Assessment

HPR1000 (FCG3)	Hua-long Pressurized Reactor under Construction at Fangchenggang Nuclear Power Plant Unit 3
LLCV	Low Load Control Valve
LLIV	Low Load Isolation Valve
LOCA	Loss of Coolant Accident
MIV	Main Isolation Valve
MSIV	Main Steam Isolation Valve
MSL	Main Steam Line
MSSV	Main Steam Safety Valve
MSR	Moisture Separator Reheater
NSSS	Nuclear Steam Supply System
RCP	Reactor Coolant System [RCS]
REN	Nuclear Sampling System [NSS]
RHR	Residual Heat Removal
SBO	Station Black Out
SEL	Conventional Island Liquid Waste Discharge System [LWDS (CI)]
SEN	Auxiliary Cooling Water System [ACWS]
SG	Steam Generator
SGTR	Steam Generator Tube Rupture
SLB	Steam Line Break
SSPB	Secondary Side Pressure Boundary
TER	Nuclear Island Liquid Waste Discharge System [NLWDS]
UK HPR1000	The UK version of the Hua-long Pressurized Reactor
UPS	Uninterrupted Power Supply
VDA	Atmospheric Steam Dump System [ASDS]
VLLCV	Very Low Load Control Valve
VPU	Main Steam and Drainage System for CI [MSDS]

VVP Main Steam System [MSS]

System codes (XXX) and system abbreviations (YYY) are provided for completeness in the format (XXX [YYY]), e.g. Turbine Bypass System (GCT [TBS]).

11.2 Introduction

This chapter supports the following high level objective: the design and intended construction and operation of the UK version of the Hua-long Pressurized Reactor (UK HPR1000) will protect workers and the public by providing multiple levels of defence to fulfill the fundamental safety functions.

This chapter will demonstrate the following:

The Steam & Power Conversion System removes heat from the Reactor Coolant System.

The steam and power conversion system is designed to remove heat energy from the reactor coolant system via the Steam Generators (SGs) and to convert it to electrical power in the turbine-generator.

The steam and power conversion system is divided into sub-systems. The safety requirements and system description of each sub-system are provided in the following sub-chapters:

11.3 Main Steam System (VVP [MSS])

11.4 Steam Generator Blowdown System (APG [SGBS])

11.5 Main Feedwater Flow Control System (ARE [MFFCS])

11.6 Circulating Water System (CRF [CWS])

11.7 Turbine Bypass System (GCT [TBS])

11.8 Condensate Polishing System (ATE [CPS])

The sub-chapters are structured to first discuss the design requirements placed on the system, then describe the system as designed and finally discuss how the design requirements are met by the system provided at Hua-long Pressurized Reactor under Construction at Fangchenggang Nuclear Power Plant Unit 3 (HPR1000 (FCG3)). It will be demonstrated in future GDA submissions that the design of the steam and power conversion system in the UK HPR1000 is acceptable in accordance with the principles set out in chapter 4.

A high level description of the steam and power conversion system is provided below to show the complete system prior to the description of the individual systems in the appropriate sub-chapter. The turbine-generator set is not covered in detail at this stage and will be discussed once the supplier of the equipment is confirmed to demonstrate that it will meet the design requirements. In particular, the consequences of turbine disintegration will be assessed in detail in future stages of the GDA in the relevant hazards chapter.

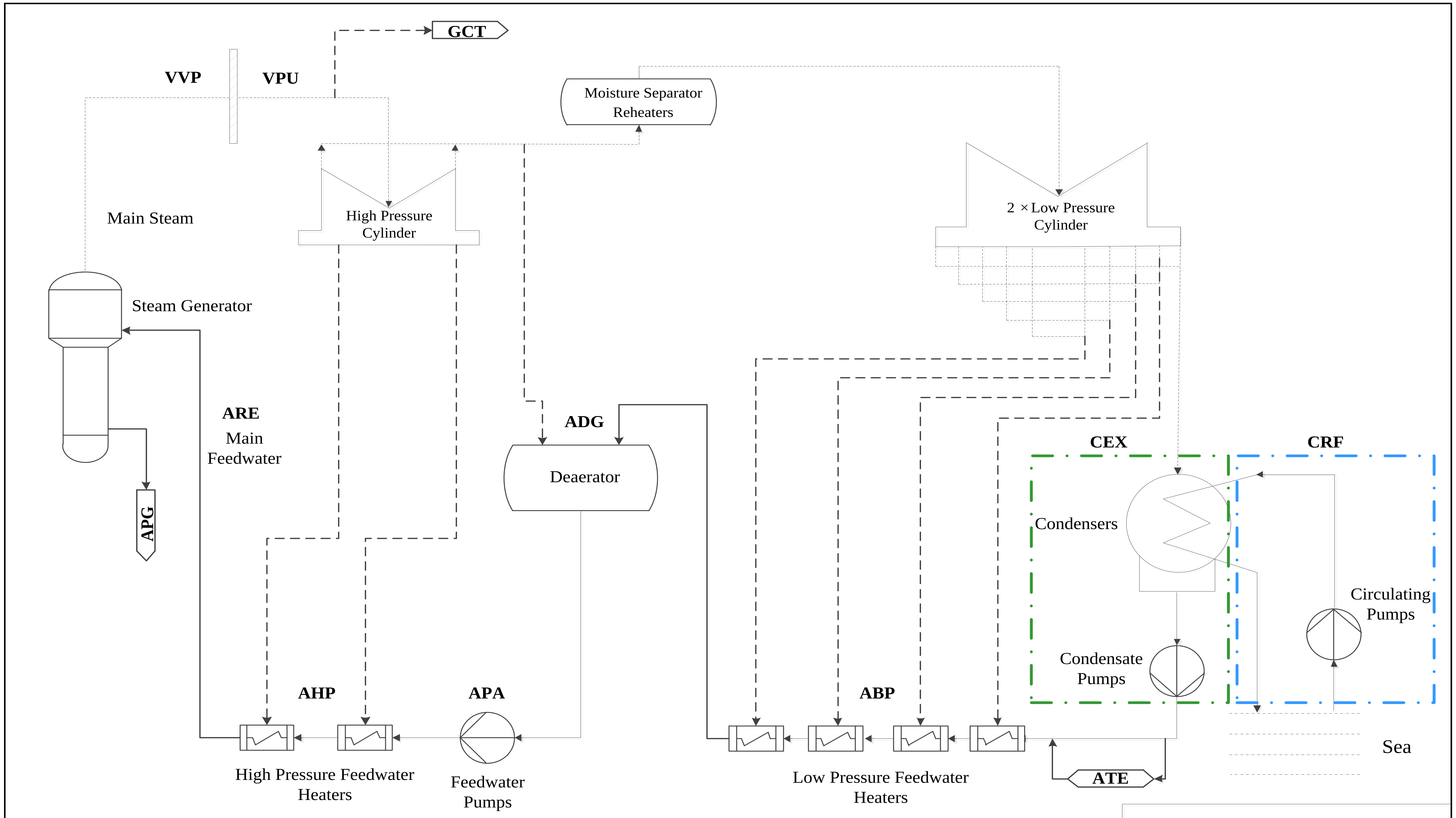
There are three SGs and each SG connects through a separate main steam line to a common main steam header in the Turbine Generator Building (BMX). There are four steam lines downstream of the main steam header delivering the steam to the turbine high pressure cylinder.

The functional diagram of the steam and power conversion system for HPR1000 (FCG3) is illustrated in F-11.2-1. The steam from the SGs is passed through VVP [MSS] before entering the BMX into the high pressure cylinder. The exhaust steam from the high pressure cylinder is delivered to the Moisture Separator Reheaters (MSR), before the reheated steam is fed into the low pressure cylinders. The turbine exhaust steam at this stage is then condensed in the open circuit seawater-cooled condenser which is part of CRF [CWS] that provides the heat sink for the unusable thermal energy in the cycle.

The condensate is pumped up from the condenser hotwell by condensate pumps, after which the Condensate Polishing System (ATE [CPS]) cleans up the condensate to meet the secondary water chemistry specifications. The condensate then passes through the Low Pressure Feedwater Heater System (ABP [LPFHS]) and the Feedwater Tank and Gas Stripper System (ADG [FTGSS]). After its pressure is increased by the Motor Driven Feedwater Pump System (APA [MFPS]), the feedwater is further heated by High Pressure Feedwater Heater System (AHP [HPFHS]) before it is delivered to the inlet of the steam generator through ARE [MFFCS], completing the secondary steam-water closed circulation.

When the turbine is unavailable, the steam produced by the steam generators could be dumped through GCT [TBS] directly to the condenser. The GCT [TBS] is also used to dump steam to the condenser during a fast load rejection (e.g. house load operation).

The APG [SGBS] helps maintain high quality secondary water chemistry quality under all plant operating conditions by removing concentrated impurities in the steam generator.



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F-11.2-1 The Steam and Power Conversion System

11.3 Main Steam System (VVP [MSS])

11.3.1 Safety Requirements

11.3.1.1 Safety Functions

The requirements placed on the design of the VVP [MSS] for HPR1000 (FCG3) for the three essential safety functions are identified below.

a) Reactivity Control

During normal operation, the VVP [MSS] does not participate in reactivity control directly. However, under accident conditions, the VVP [MSS] should support the control of reactivity by isolating the Main Steam Line (MSL) to limit the over-cooling of the Reactor Coolant System (RCP [RCS]) primary side.

b) Residual Heat Removal

During normal operation, the VVP [MSS] should remove decay heat by transferring steam to the condenser. During events considered within Design Basic Conditions (DBC), the VVP [MSS] should remove decay heat by dumping steam to the condenser via the GCT [TBS] or to the atmosphere via the Atmospheric Steam Dump System (VDA [ASDS]) described in chapter 7.

c) Containment of Radioactive Substance

During events under DBC or Design Extension Condition (DEC), the VVP [MSS] should ensure containment isolation of the main steam line that penetrates containment to limit radioactive releases.

11.3.1.2 Safety Functional Requirements

The following safety functional requirements have been placed on the design of the VVP [MSS] system.

a) Codes and Standards Requirements

The VVP [MSS] should be designed in accordance with the requirements specified in sub-chapter 4.8.

b) Safety Related Requirements

1) Safety Classification

The VVP [MSS] should be designed in accordance with the safety classification principles presented in sub-chapter 4.7.

2) Single Failure Criterion

The VVP [MSS] is not itself a safeguard system, but the single failure criterion is applied to the sub-systems or components that provide safety Category 1 function (FC1) that are part of the VVP [MSS] system (see T-11.3-1).

3) Seismic Classification

The seismic classification principles presented in sub-chapter 4.7 are applied.

4) Emergency Power Supply

All of the electrical equipment which supports the delivery of the safety functions should be supplied by appropriately qualified emergency power supplies following the loss of the normal power supplies.

5) Hazard Protection

The VVP [MSS] should be protected against internal hazards and external hazards in accordance with the requirements of chapters 18 and 19.

6) Testing

The functions of the system should be demonstrated by appropriate commissioning tests. Safety related components are subject to periodic testing. The layout and design of the system should ensure easy access for in-service inspection and periodic testing of all class FC1 equipment which may not be used frequently.

11.3.2 Role of the System

11.3.2.1 Normal Conditions

In addition to the safety functions outlined in sub-chapter 11.3.1, the VVP [MSS] should fulfil the following functions in normal conditions:

a) Transfer steam from the SGs to the turbine and other systems that require steam.

b) Remove steam from the SGs to the condenser during startup and shutdown of the plant.

c) Protect the SGs from overpressure.

11.3.2.2 Fault Conditions

The VVP [MSS] provides overpressure protection of the steam generator secondary side.

In the event of a Main Steam Safety Valve (MSSV) or VDA [ASDS] relief train inadvertently opening or remaining stuck in the open position, the VVP [MSS] limits the uncontrolled discharge of more than one SG. This isolation function is provided to maintain reactor vessel integrity and limit fuel damage.

During DBC events, the VVP [MSS] provides decay heat removal by dumping steam to the condenser via the GCT [TBS] or to the atmosphere via the VDA [ASDS] to allow the safe state to be reached.

During DEC events, if the Emergency Feedwater System (ASG [EFWS]) is unavailable, the VVP [MSS] provides cooling of the primary circuit via the Secondary Passive Heat Removal System (ASP [SPHRS]) until the safe state is reached.

In the events of Steam Line Break (SLB) or Feedwater Line Break (FLB), the VVP [MSS] prevents a rapid reduction of steam pressure in more than one SG by isolating the main steam lines.

11.3.3 Design Basis

11.3.3.1 Safety Design Basis

The Main Steam Isolation Valves (MSIVs) are designed to close automatically after receiving a steam line isolation signal and to be able to isolate the MSL from two directions.

The MSSVs, together with the VDA [ASDS], are designed to have sufficient capacity to exhaust steam produced during DBC events to prevent the integrity of the SG or the main steam lines from being threatened.

11.3.3.2 Operation Design Basis

The VVP [MSS] is capable of the necessary functions for continuous normal operation of the plant.

a) Supply steam generated by the SGs to the turbine and other systems require steam.

b) Control the primary heating rate by dumping steam to the condenser or to the atmosphere during startup and shutdown.

11.3.4 System Description

11.3.4.1 General System Description

This system consists of the pipes and valves that take the steam from each SG to a common main steam header in the BMX. Each main steam line connects to a SG and passes through the containment boundary into a safeguard building before it reaches the BMX.

As shown in F-11.3-1, in each of the three steam lines, there are connections to the VDA [ASDS] and two MSSVs to discharge steam to atmosphere, followed by a connection to the ASP [SPHRS] which will be used under DEC conditions. The MSIV is the next component in the steam line. The steam then exits from the safeguard building and is transferred into the Main Steam and Drainage System for CI (VPU [MSDS]) system.

There is a small bypass line to bypass the MSIV in each individual main steam line. The drain line is connected to the bypass line in order to remove the condensate water during start-up and normal operation of the unit. The condensate water is collected by the VPU [MSDS] system.

11.3.4.2 Main Equipment

Main components are described as follows:

a) Main Steam Line

Three main steam lines transfer steam from the SG to the turbine. The design pressure and design temperature are identical to those of the secondary side of the SG.

b) Main Steam Isolation Valve

Each main steam line has a MSIV, which is outside of the containment in an isolated compartment together with the MSSV. The MSIV is a gate valve. It closes automatically to isolate the secondary side of the SGs after receiving a steam line isolation signal from the protection system.

c) Main Steam Safety Valve

On each main steam line, there are two spring-loaded safety valves located between the containment penetration and the MSIV. The MSSVs provide overpressure protection for the SG secondary side.

11.3.4.3 System Layout

The main components of the VVP [MSS] are arranged in the Reactor Building (BRX) and Safeguard Buildings to ensure that the three main steam lines are physically separated from each other.

11.3.5 Preliminary Design Substantiation

11.3.5.1 Compliance with Codes and Standards

The VVP [MSS] design is compliant with the requirements identified in sub-chapter 4.8.

11.3.5.2 Compliance with Safety Related Requirements

According to the principles described in sub-chapter 4.7, the main components of the VVP [MSS] are categorized as Category FC1.

The Single Failure Criteria is not applied to closure of the MSIV in case of Steam Generator Tube Rupture (SGTR). During other Design Basic Conditions (such as Steam Line Break), if one MSIV is fail to close, the unaffected MISVs shall isolate their SGs from break. And the main feedwater line of affected SG shall be isolated. The actuator of the MSIV is equipped redundant manifolds so as to prevent MSIV failure to close caused by malfunction of any manifold.

The two MSSVs are redundant for the SG overpressure protection.

The bypass line of MSIV is equipped with an isolation valve and a control valve. During accident condition the bypass line control valve can perform isolation function in company with bypass line isolation valve. The bypass line isolation valve and bypass line control are redundant for bypass line isolation.

The drain line of VVP [MSS] is fitted with two redundant isolation valves in order to prevent failure of drain line isolation.

The VVP [MSS] is protected against external hazards mainly by the civil structures (see chapter 18). This system is located in the Reactor Building and the Safeguard Buildings.

For internal hazards, as discussed in chapter 19, FC1 classified equipment of the VVP [MSS] is protected by physical separation.

All of the VVP [MSS] electrical equipment which supports the safety functions can be powered by appropriately qualified emergency power provisions. The MSIV is powered by Emergency Diesel Generators (EDG), Station Black Out (SBO) diesel generators and Uninterrupted Power Supply (UPS). The bypass line valves and drain line valves are powered by EDG.

The compliance with requirements related to safety classification is described in T-11.3-1.

11.3.5.3 Compliance with Testing Requirement

The VVP [MSS] will be subject to commissioning tests before being placed into operation, to verify that its component performance meets the design requirements and that the safety functions of the system are achieved.

The VVP [MSS] is designed to be capable of monitoring different components during normal operation, to ensure that all functions of the system can be correctly executed, and be able to perform periodic tests on components which contribute to safety functions, to verify the availability of the safety functions.

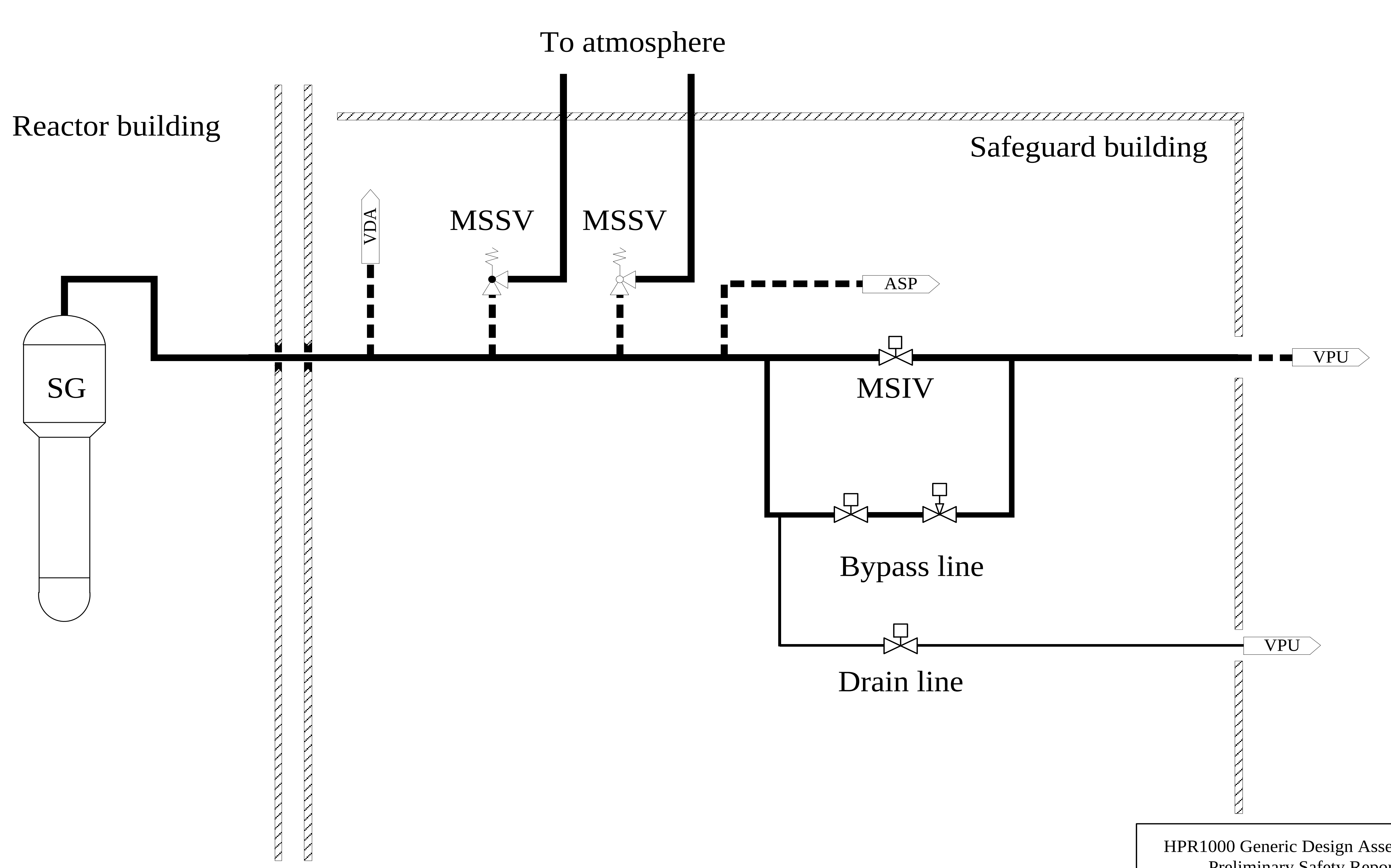
The maintenance of the VVP [MSS] is implemented during the shutdown of the plant.

11.3.6 Functional Diagram

The functional diagram of the VVP [MSS] is included as F-11.3-1.

T-11.3-1 Compliance with Requirements Related to Safety Related Requirements

Subsystem /Components	Functional Classification	Single Failure	Physical and Electrical Separation	Emergency Power Supply	Periodical Test	Seismic Classification
Main Steam Line upstream of MSIV	FC1	N/A	YES (Physical Separation)	N/A	YES	SSE1
Main Steam Isolation Valve	FC1	N/A	YES	YES EDG and UPS	YES	SSE1
Main Steam Safety Valve	FC1	YES	YES	N/A	YES	SSE1
Bypass Line Isolation Valve	FC1	YES	YES (Electrical Separation)	YES EDG	YES	SSE1



HPR1000 Generic Design Assessment
Preliminary Safety Report

F-11.3-1 Main Steam Supply System (VVP)

11.4 Steam Generator Blowdown System (APG [SGBS])

11.4.1 Safety Requirements

The requirements placed on the design of the Steam Generator Blowdown System APG [SGBS] for HPR1000 (FCG3) for the three essential safety functions are identified below.

11.4.1.1 Safety Functions

a) Reactivity Control

The APG [SGBS] does not contribute to reactivity control.

b) Residual Heat Removal

In the event of loss of main feedwater, APG [SGBS] isolation valves are closed to help maintain the water inventory of the SG secondary side.

c) Containment of Radioactive Substance

If a Steam Generator Tube Rupture (SGTR) occurs, the APG [SGBS] should isolate the affected SG to limit the amount of contaminated fluid released.

The APG [SGBS], as a system penetrating the containment, is able to ensure containment isolation during DBC 2-4 and DEC accidents.

Following an SGTR, the APG [SGBS] can be used to transfer the water in the affected SG to an unaffected SG to prevent the release of contaminated water into the environment due to overfilling in the affected SG.

11.4.1.2 Safety Functional Requirements

The following safety functional requirements have been placed on the design of the APG [SGBS] system.

a) Codes and Standards Requirement

The APG [SGBS] should be designed in accordance with the requirements specified in sub-chapter 4.8.

b) Safety Related Requirements

1) Safety Classification

The APG [SGBS] should be designed in accordance with the safety classification principles presented in sub-chapter 4.7.

2) Single Failure Criterion

The single failure criterion is applied to sub-systems or components that support the APG [SGBS] FC1 and FC2 (see T-11.4-1).

3) Seismic Classification

Seismic classification principles presented in sub-chapter 4.7 are applied.

4) Emergency Power Supply

All of the electrical equipment which supports the delivery of the safety functions should be supplied by appropriately qualified emergency power supplies following the loss of the normal power supplies.

5) Hazard Protection

The APG [SGBS] should be protected against internal hazards and external hazards in accordance with the requirements of chapters 18 and 19.

c) Testing

The functions of the system should be demonstrated by appropriate commissioning tests. Safety related components are subject to periodic testing. The layout and design of the system should ensure easy access for in-service inspection and periodic testing of all class FC1 equipment which may not be used frequently.

11.4.2 Role of the System

11.4.2.1 Normal Conditions

The APG [SGBS] is designed for the following major functions:

a) Collecting and treating the SG blowdown water to maintain the characteristics of the secondary side water within predetermined limits.

b) Recycling of the blowdown water to the condenser.

c) Draining of steam generator secondary side for maintenance.

d) Bubbling the SG secondary side water during SG wet layup.

11.4.2.2 Fault Conditions

During DBC 2-4 and DEC accidents, the APG [SGBS] isolates the SG blowdown lines following a containment isolation signal.

Following an SGTR, the control valves in the transfer lines should be opened to prevent the contaminated water from being released to the environment from the affected SG.

11.4.3 Design Basis

11.4.3.1 Safety Design Basis

The APG [SGBS] is designed to perform safety functions as described in sub-chapter 11.4.1.

11.4.3.2 Operation Design Basis

The APG [SGBS] is designed to treat a continuous blowdown of SG water at a flowrate of 1% of nominal main steam flow.

The APG [SGBS] heat exchanger is designed to cool the blowdown water so that the fluid can be demineralised by the demineraliser.

11.4.4 System Description

11.4.4.1 General System Description

The APG [SGBS] consists of the blowdown water collection, cooling, depressurisation and flow rate controlling and demineralising units.

a) Blowdown collection

The blowdown lines are connected to SG nozzles which are located at the SG tube sheet.

A branch to the Nuclear Sampling System (REN [NSS]) is used to monitor the characteristics of the SG blowdown water.

Each blowdown line is equipped with two blowdown isolation valves. The three blowdown lines are then connected to a common blowdown line.

b) Blowdown cooling

The blowdown water is cooled by a regenerative heat exchanger with cooling water supplied by the Condensate Extraction System (CEX [CES]). The steam generator blowdown heat is therefore transferred to feedwater returning to the steam generator.

c) Blowdown water depressurisation and flow rate control

The cooled blowdown water passes through a pressure reducing and flowrate control station. This station is made up of two lines in parallel, each one equipped with a control valve.

d) Blowdown treatment

After being cooled and depressurised, the blowdown water is transferred to the demineralising units, in order to be purified before being transferred to the condenser.

The demineralising units consist of two lines in parallel, each of which has a cation bed demineralizer, an anion bed demineraliser and a resin trap filter.

The treated water shall be transferred to the condenser, and in special cases (for example, the condenser is unavailable), to the Conventional Island Liquid Waste Discharge System (SEL [LWDS (CI)]) or Nuclear Island Liquid Waste Discharge System (TER [NLWDS]) depending on the radioactive level.

11.4.4.2 Main Equipment

Main components are described as follows:

a) Regenerative heat exchanger

The APG [SGBS] regenerative heat exchanger is of a tube and a shell design. The tube is filled with blowdown water and the shell is filled with cooling water provided by the CEX [CES].

b) Demineraliser

The APG [SGBS] demineralising unit consists of a cation bed demineraliser, an anion bed demineraliser and a resin trap filter.

The cationic bed demineraliser is used to remove the cations from the blowdown water. The resin replaces the cations with H^+ ions.

The anion bed demineraliser is used to remove the anions of the blowdown water. The resin replaces the anions with OH^- ions.

11.4.4.3 System Layout

The blowdown collection lines and transfer lines are located in the reactor building. The blowdown isolation valves are located in Safeguard Building A (BSA). The regenerative heat exchanger and pressure reducing and flowrate control station are in the Fuel Building (BFX). The demineralising units are in the Nuclear Auxiliary Building (BNX).

11.4.5 Preliminary Design Substantiation

11.4.5.1 Compliance with Codes and Standards

The APG [SGBS] design is in compliance with codes and standards described in sub-chapter 4.8.

11.4.5.2 Compliance with Safety Related Requirements

According to the principle described in sub-chapter 4.7, the functional classifications of main APG [SGBS] features are:

a) Secondary Side Pressure Boundary (SSPB) isolation: FC1.

b) Transfer water during SGTR: FC2.

c) Other parts of APG [SGBS]: NC.

Each blowdown line is equipped with two redundant isolation valves in order to ensure the blowdown line isolation function.

All of the APG [SGBS] electrical equipment which supports the safety functions can be powered by appropriately qualified emergency power provisions. The blowdown isolation valves are powered by EDG and UPS. The transfer line valves are powered by EDG.

The compliance with requirements related to safety classification is described in Table T-11.4-1.

11.4.5.3 Compliance with Testing Requirement

The APG [SGBS] will be subject to commissioning tests before being put into operation to verify that its component performance meets the requirements and the safety functions requirements of the system.

During outages, the blowdown isolation valves will go through periodic tests to verify safety functions.

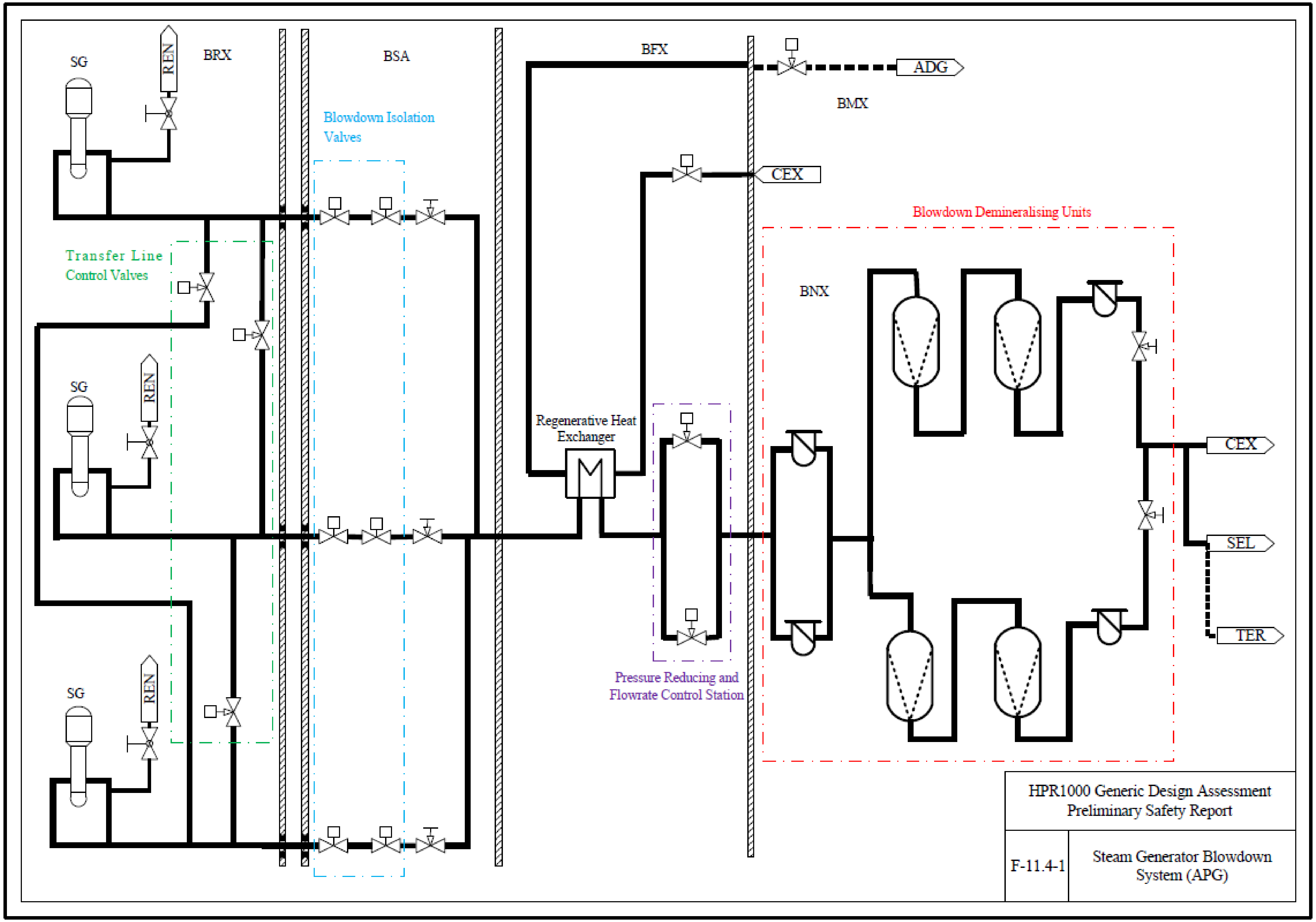
The maintenance of the APG [SGBS] is implemented during the shutdown of the plant.

11.4.6 Functional Diagram

The functional diagram of the APG [SGBS] is included as F-11.4-1.

T-11.4-1 Compliance with Requirements Related to Safety Classification

Subsystem /Components	**Functional Classification**	**Single Failure**	**Physical and Electrical Separation**	**Emergency Power Supply**	**Periodical Test**	**Seismic Classification**
SSPB isolation	FC1	YES two redundant isolation valves	YES	YES EDG and UPS	YES	SSE1
Transfer water during SGTR	FC2	YES two transfer lines for each SG	YES	YES EDG	YES	SSE1
Blowdown cooling	NC	NO	NO	N/A	NO	SSE2
Other parts of APG [SGBS]	NC	NO	NO	NO	NO	NO



SG
REN
BRX
BSA
BFX
ADG
BMX
Blowdown Isolation Valves
CEX
Blowdown Demineralising Units
Transfer Line Control Valves
BNX
SG
REN
Regenerative Heat Exchanger
CEX
SEL
TER
SG
REN
Pressure Reducing and Flowrate Control Station
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F-11.4-1
Steam Generator Blowdown System (APG)

11.5 Main Feedwater Flow Control System (ARE [MFFCS])

11.5.1 Safety Requirements

The requirements placed on the design of the ARE [MFFCS] for HPR1000 (FCG3) for the three essential safety functions ARE [MFFCS] are identified below.

11.5.1.1Safety Functions

a) Reactivity Control

In any DBC events, the ARE [MFFCS] should ensure control of reactivity by isolating the main feedwater line to limit the cooling of the primary system.

b) Residual Heat Removal

During normal operation, the ARE [MFFCS] should maintain the SG level to ensure removal of residual heat following reactor shutdown.

c) Containment of Radioactive Substance

In any DBC events, the ARE [MFFCS] should limit mass and energy release to the containment to prevent containment over-pressurisation.

The ARE [MFFCS] should ensure containment isolation of the main feedwater line that penetrates containment to limit offsite exposure.

11.5.1.2 Safety Functional Requirements

The following Safety functional requirements have been placed on the design of the ARE [MFFCS] system.

a) Codes and Standards Requirement

The ARE [MFFCS] should be designed in accordance with the requirements specified in sub-chapter 4.8.

b) Safety Related Requirements

1) Safety Classification

The ARE [MFFCS] should be designed in accordance with the safety classification principles presented in sub-chapter 4.7.

2) Single Failure Criterion

The ARE [MFFCS] is not a safeguard system, but the single failure criterion is applied to the sub-systems or components that support FC1 classified safety functions and are part of the ARE [MFFCS] system (see T-11.5-1).

3) Seismic Classification

The seismic classification principles presented in sub-chapter 4.7 are applied.

4) Emergency Power Supply

All of the electrical equipment which supports the delivery of the safety functions should be supplied by appropriately qualified emergency power supplies following the loss of the normal power supplies.

5) Hazard Protection

The ARE [MFFCS] should be protected against internal hazards and external hazards in accordance with the requirements of chapters 18 and 19.

c) Testing

The functions of the system should be demonstrated by commissioning test. Safety related components are subject to periodic testing. The layout and design of the system should ensure easy access for in-service inspection and periodic testing of all class FC1 equipment which is not frequently used.

11.5.2 Role of the System

11.5.2.1 Normal Conditions

In addition to the safety functions outlined in sub-chapter 11.5.1, the ARE [MFFCS] is designed to ensure, during operation at power, the level of water in the SG is at the required value and within limits.

Under normal conditions, the ARE [MFFCS] regulates the supply of feedwater by the CI feedwater pumps. The Motor Driven Feedwater Pump System (APA) [MFPS] is used during normal operation and the Startup and Shutdown Feedwater System (AAD) [SSFS] is used during the start-up and shutdown phases to supply feedwater to the SGs. The Feedwater flow rate is controlled by the ARE [MFFCS].

11.5.2.2 Fault Conditions

In the events of SLB, the ARE [MFFCS] limits the mass and energy release to the containment by isolating the main feedwater line, to prevent containment over-pressurisation.

In the event of FLB, the ARE [MFFCS] prevents rapid emptying of more than one SG by isolating the main feedwater line.

In the events of SGTR, the ARE [MFFCS] prevents steam generator overfilling and main steam line flooding by isolating the main feedwater line.

In the events of LOCA, the ARE [MFFCS] piping inside containment, in conjunction with the steam generator shell and tubes, isolates the secondary fluid from the containment atmosphere.

11.5.3 Design Basis

11.5.3.1 Safety Design Basis

The full load isolation valves and low load isolation valves are designed to close automatically after receiving a main feedwater line isolation signal and to be able to isolate flow in either direction in the system.

The main feedwater line inside the reactor building is designed to remain intact and to form part of the containment boundary in the event of a reactor coolant pipe break.

11.5.3.2 Operation Design Basis

During normal operation, the ARE [MFFCS] should maintain the level of water in the SG within the normal operating range.

11.5.4 System Description

11.5.4.1 General System Description

This system consists of the pipes and valves that supply feed water from a common feedwater header to the three SGs. It does this during normal operation to remove the heat produced by the reactor core; and also to remove residual heat in the initial phase of shutdown operation before the Residual Heat Removal (RHR) connection.

Each main feedwater line contains a Full Load Control Valve (FLCV), Low Load Control Valve (LLCV), Very Low Load Control Valve (VLLCV), Main Isolation Valve (MIV), Full Load Line Isolation Valves (FLIVs) and Low Load Isolation Valves (LLIVs), all located in the valve compartment in the safeguard building.

FLCV, LLCV and VLLCV are connected via parallel lines. The principal purpose of these control valves is to maintain the level of water in their associated SG at a designated level.

Two FLIVs are installed upstream and downstream of each FLCV, whose main purposes are to isolate the full load line to limit feed water leakage into the containment and to isolate the SGs. Similarly, two LLIVs are installed upstream and downstream of each LLCV, whose main purposes are to isolate the low load line to stop feed water leaking into the containment and to isolate the SGs.

Each main feed line has a check valve close to the connection to the SG inside the containment to prevent reverse flow and uncontrolled discharge from the SG in the event of FLB.

11.5.4.2 Main Equipment

Main components are described as follows:

a) Full Load Line Isolation Valve (FLIV)

Every main feedwater line has two FLIVs, which are welded in the full load line inside the valve compartment. The FLIV is a gate valve, which closes automatically to isolate the full load feedwater line after receiving a safety signal from the protection system.

b) Low Load Isolation Valve (LLIV)

Every main feedwater line has two LLIVs, which are welded in the low load line inside the valve compartment. The LLIV is a motor operated valve, which closes automatically to isolate the low load feedwater line after receiving a safety signal from the protection system.

c) Main Isolation Valve (MIV)

Every main feedwater line has a MIV, which is welded in the straight pipe near the containment penetration. The MIV is a motor operated gate valve, which closes automatically to isolate the main feedwater line after receiving a safety signal from the protection system. The MIV also provides the containment isolation function in severe accident conditions.

d) Control valve

The principal purpose of each FLCV, LLCV and VLLCV is to maintain the level of water in the associated SG at a designated level during normal operation.

e) Main feedwater check valve

The main feedwater check valve is installed near the steam generator to prevent reverse flow and uncontrolled discharge from the SG.

11.5.4.3 System Layout

The main components of the ARE [MFFCS] are located in the reactor building and safeguard buildings in such a way that the three main feedwater lines are physical separated from each other.

11.5.5 Preliminary Design Substantiation

11.5.5.1 Compliance with Codes and Standards

The ARE [MFFCS] design is in compliance with the codes and standards described in sub-chapter 4.8.

11.5.5.2 Compliance with Safety Related Requirements

According to the principle described in sub-chapter 4.7 and the ARE [MFFCS] functions, the safety classifications of main ARE [MFFCS] features are:

- Main feedwater isolation parts: FC1

- Containment isolation parts: FC1

- Steam generator level control parts: FC3

The ARE [MFFCS] is equipped with two redundant FLIVs in order to ensure the full load line isolation function. And the two LLIVs are redundant for the low load line isolation function.

All of ARE [MFFCS] electrical equipment which supports the safety functions can be powered by appropriately qualified emergency power provisions. The FLIVs are powered by EDG and UPS. The LLIVs are powered by EDG. The MIVs are powered by EDG and UPS.

The compliance with requirements related to safety classification is described in Table T-11.5-1.

The ARE [MFFCS] is protected against external hazards primarily by the civil works. The system is located in Reactor Building and Safeguard Buildings.

For internal hazards, the ARE [MFFCS] FC1 classified equipment is protected by physical separation.

11.5.5.3 Compliance with Testing Requirement

The ARE [MFFCS] will be subject to commissioning test before being put into operation to verify that its component performance meets the requirements and the safety functions requirements of the system.

The ARE [MFFCS] is designed to be capable of monitoring different components during normal operation, so as to ensure that all functions of the system can be correctly executed, and be able to perform periodic tests on components for safety functions, so as to verify the availability of the safety functions.

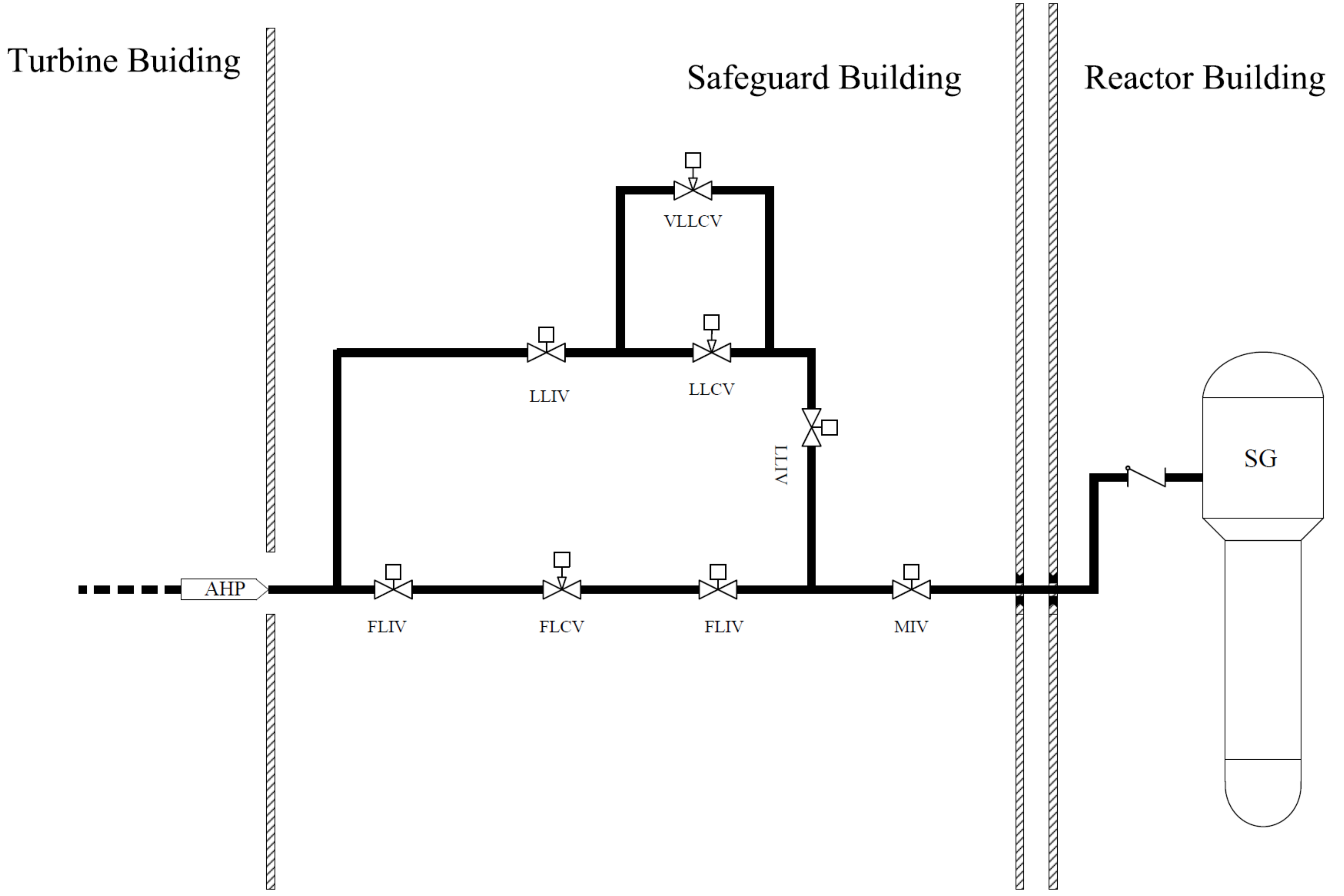
The maintenance of the ARE [MFFCS] is implemented during the shutdown of the plant.

11.5.6 Functional Diagram

The functional diagram of the ARE [MFFCS] is included as F-11.5-1.

T-11.5-1 Compliance with Requirements Related to Safety Related Requirements

Subsystem /Components	**Functional Classification**	**Single Failure**	**Physical and Electrical Separation**	**Emergency Power Supply**	**Periodical Test**	**Seismic Classification**
Main feedwater isolation parts	FC1	YES	YES	YES EDG and UPS	YES	SSE1
Containment isolation parts	FC1	YES	YES	YES EDG and UPS	YES	SSE1
Steam generator level control parts	FC3	NO	NO	NO	NO	SSE2



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F-11.5-1 Main Feedwater Flow Control System (ARE)

11.6 Circulating Water System (CRF [CWS])

11.6.1 Role of the System

The CRF [CWS] is designed for the following major functions:

a) Supply cooling water to the condenser and cool the turbine exhaust steam.

b) Supply the necessary flow of cooling water to the Auxiliary Cooling Water System (SEN [ACWS]).

c) Return the main and auxiliary cooling water to the outlet culverts.

11.6.2 Design Basis

a) The CRF [CWS] is designed to supply cooling water to the condensers of the turbine unit and SEN [ACWS] under various conditions encountered during power operation.

b) The CRF [CWS] is designed to optimise the cooling water flow rate to the condenser, taking into account site conditions.

11.6.3 System Description

11.6.3.1 General System Description

The CRF [CWS] continuously supplies cooling water to cool the turbine exhaust steam that flows into the condenser.

The cooling water passes through the drum screens, the circulating water pumps, the debris filters and the condenser waterboxes, and finally enters the outlet culverts.

The overall arrangement of the circulating water system allows the condensers to be divided into halves. Such division can be achieved by the shutdown of the associated circulating water pumps and the opening of the siphon breaking valves.

11.6.3.2 Main Equipment

The main components are described as follows:

a) Circulating pump

The circulating pump is located in the pumping station. It is designed to the flow rate requirement for the condenser cooling water supply.

b) Condenser waterbox

Both inlet and outlet waterboxes are provided to distribute the cooling water evenly to the condenser tubes.

The waterboxes are equipped with siphon breaking valves to avoid water hammer during pump shutdown and startup.

11.6.3.3 System Layout

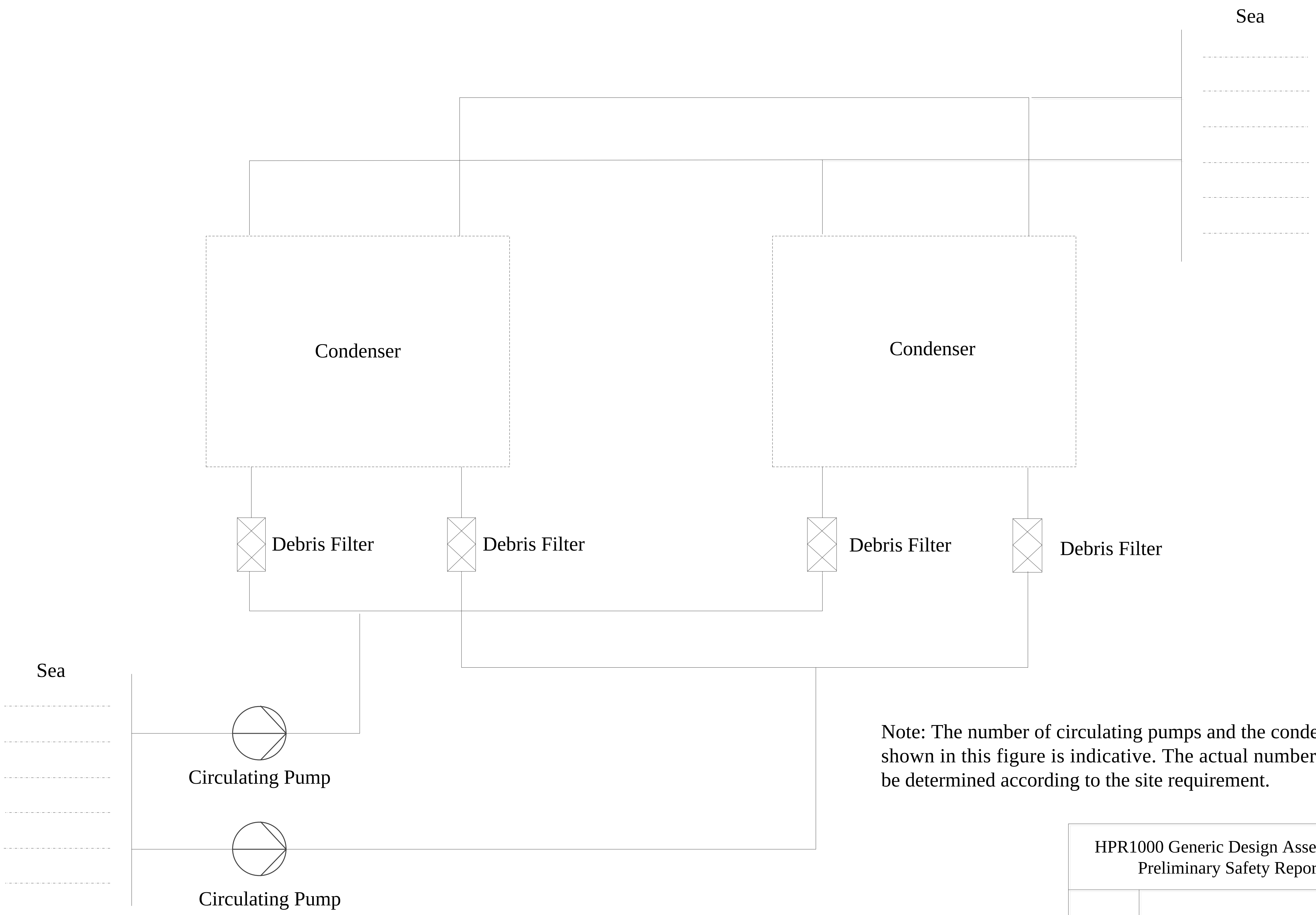
The circulating pumps are located in the pumping station. A circulating water pit is constructed in the BMX with inlet and outlet culverts arranged in the horizontal direction. One debris filter is fitted in each circulating water inlet pipe upstream of the condenser waterbox.

11.6.4 Preliminary Design Substantiation

Preoperational testing of the circulating water system is performed to ensure the function of components meets the requirement. The performance, structural and leak-tight integrity of the circulating water system components are continuous inspected during plant power operation.

11.6.5 Functional Diagram

The functional diagram of CRF [CWS] system is included as F-11.6-1.



Note: The number of circulating pumps and the condensers shown in this figure is indicative. The actual number shall be determined according to the site requirement.

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F-11.6-1	Circulating Water System (CRF)

11.7 Turbine Bypass System (GCT [TBS])

11.7.1 Role of the System

The GCT [TBS] is designed for the following major functions:

a) To discharge steam from the main steam header to the condenser when the turbine is unavailable.

b) To release steam to the condenser for reactor pressure control during the unit start-up and shutdown.

c) To compensate for the power imbalance between the turbine and the reactor during rapid transient conditions or power variations at low load.

11.7.2 Design Basis

The turbine bypass system directly discharges steam from the main steam header to the condenser in a controlled manner under transient conditions and when the turbine is unavailable.

a) Following reactor trip, it prevents primary circuit heat-up and a demand on the Atmospheric Steam Dump System (VDA [ASDS]).

b) It controls the temperature rise and cooling down of the reactor coolant system for the switch to residual heat removal mode during unit start-up and shutdown.

c) It controls the secondary pressure during turbine start-up and at synchronization.

11.7.3 System Description

11.7.3.1 General System Description

The system consists of two discharge manifolds connected to the main steam lines upstream of the turbine stop valves with lines of regulating valves (turbine bypass isolation and control valves) connecting the discharge manifolds to the condenser shell. The GCT [TBS] together with the Nuclear Steam Supply System (NSSS) control systems provide the capability to compensate for the power imbalance between the turbine and the reactor.

The GCT [TBS] is in its standby state while the turbine generator units are in steady-state load operation. The excessive steam is removed by the operation of the bypass system under conditions such as load rejection, turbine generator unit trip, operation of turbine generator units with plant power, and startup and shutdown of the reactor.

11.7.3.2 Main Equipment

The main equipment in the turbine bypass system is the turbine bypass valves. The turbine bypass valves are actuated in groups. When the condenser and quenching water are available, the control valves will have a sequential action or they VIA be opened due to trip by responding to the signals from the reactor control system. Upstream of each control valve is a manual normally-open isolation valve.

The turbine bypass valves are normally closed in the absence of a control signal.

11.7.3.3 System Layout

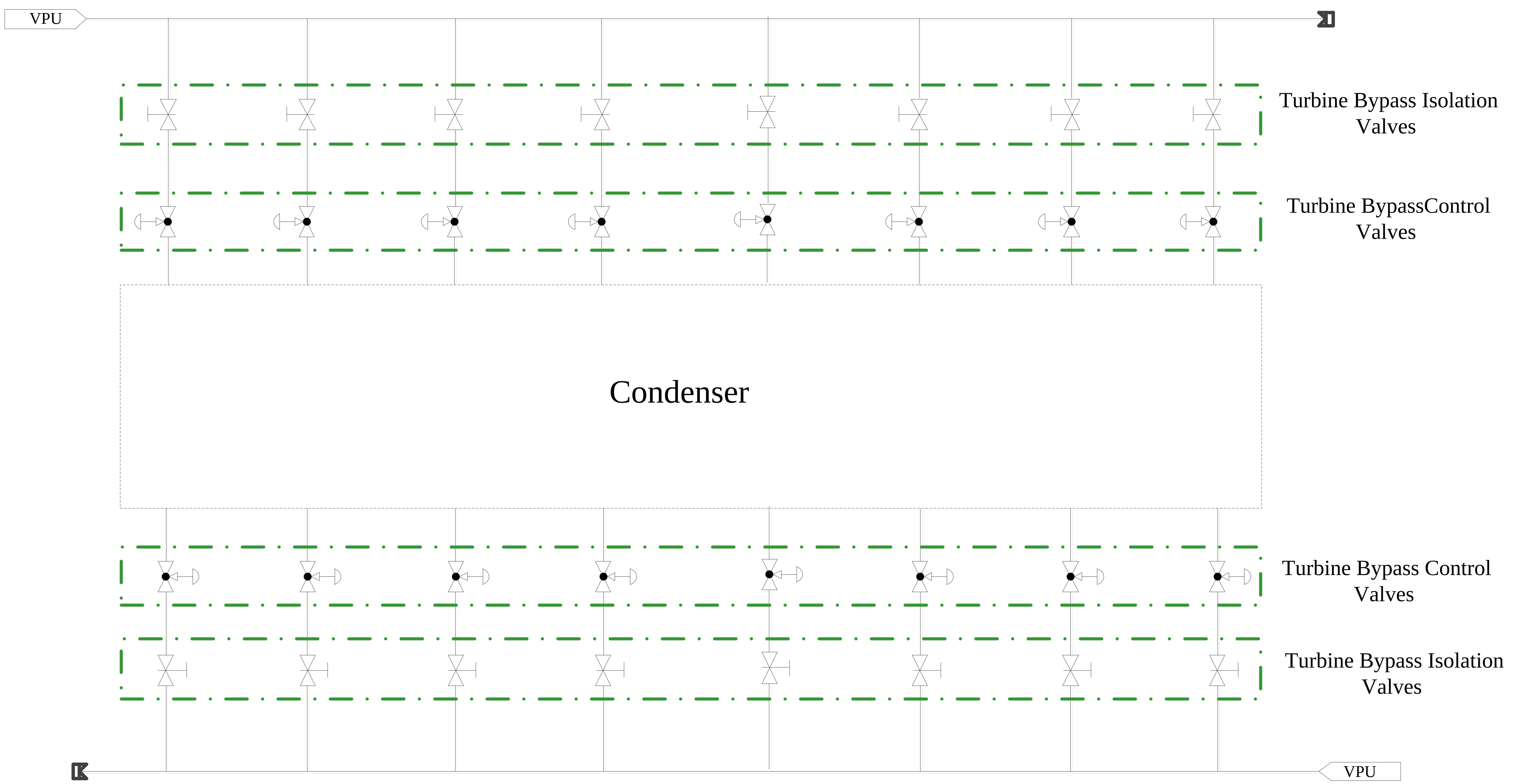
The high-energy lines of the turbine bypass system are located in the BMX.

11.7.4 Preliminary Design Substantiation

Before being put into operation, the turbine bypass valves will be tested to verify that the valves function correctly. The system piping and valves are designed with consideration of accessibility for inspection. The logic blocks of the turbine bypass valves are inspected for availability. GCT [TBS] is designed to be capable of continuously monitoring during normal operation to ensure that all functions of the system can be correctly executed.

11.7.5 Functional Diagram

The functional diagram of GCT [TBS] system is included in F-11.7-1.



Note: The number of turbine bypass valves shown in this figure is indicative. The actual number of valves shall be determined according to the site requirement.

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F-11.7-1 Turbine Bypass System (GCT)

11.8 Condensate Polishing System (ATE [CPS])

11.8.1 Role of the System

The ATE [CPS] system is used to remove trace of silicon, copper, iron and dissolved salts from the condensate. Should seawater enter via condenser leakage, it will ensure feedwater and steam quality and protect the secondary system, especially the SGs, from the contamination by the impurities seeping or leaking into the condensate.

11.8.2 Design Basis

a) The condensate polishing system is designed to remove corrosion products, dissolved solids and other impurities from the condensate system and maintain a noncorrosive environment within the condensate, feedwater and SGs. CPS could improve the water chemistry condition of the secondary circuit.

b) The condensate polishing system is of a full flow bypass design.

11.8.3 System Description

11.8.3.1 General System Description

The system comprises:

a) Condensate polishing devices, including cation beds, mixed beds, resin trappers, condensate booster pumps and recirculating pumps.

b) Resin regeneration device.

c) Waste water neutralisation and discharge device.

d) Chemicals storage device.

The condensate polishing system is used during the operating modes of startup, hot standby, normal operation, safe shutdown, and cold shutdown. Utilisation of the condensate polishing system during startup assists in minimising the startup duration of the plant.

11.8.3.2 Main Equipment

Main components are described as follows:

a) Condensate polishing device

The condensate polishing device successively comprises the cation bed units, the mixed bed units, resin trappers, the booster pumps and recirculating pumps.

The system has two operation modes:

1) Simultaneous operation of cation beds and mixed beds.

2) Operation of mixed beds only.

The cation beds are provided with bypass valves to connect the water supply headers of the cation bed units to the inlet headers of the mixed bed units.

b) Resin regeneration device

The Resin regeneration device includes the cation bed resin regeneration device and the mixed bed resin regeneration device.

The cation bed resin regeneration device comprises the cation resin regeneration tower, cation resin storage tank, cation resin regeneration acid measuring system, etc.

The mixed bed resin regeneration device comprises the mixed bed resin separation tower, cation resin regeneration and storage tower, cation resin regeneration tower, mixed bed resin acid-base measuring system, etc.

c) Waste water neutralization and discharge device

All resin transport water and recycled water from the regeneration systems are discharged to the neutralisation pond. Waste water shall be neutralized before it is discharged.

11.8.3.3 System Layout

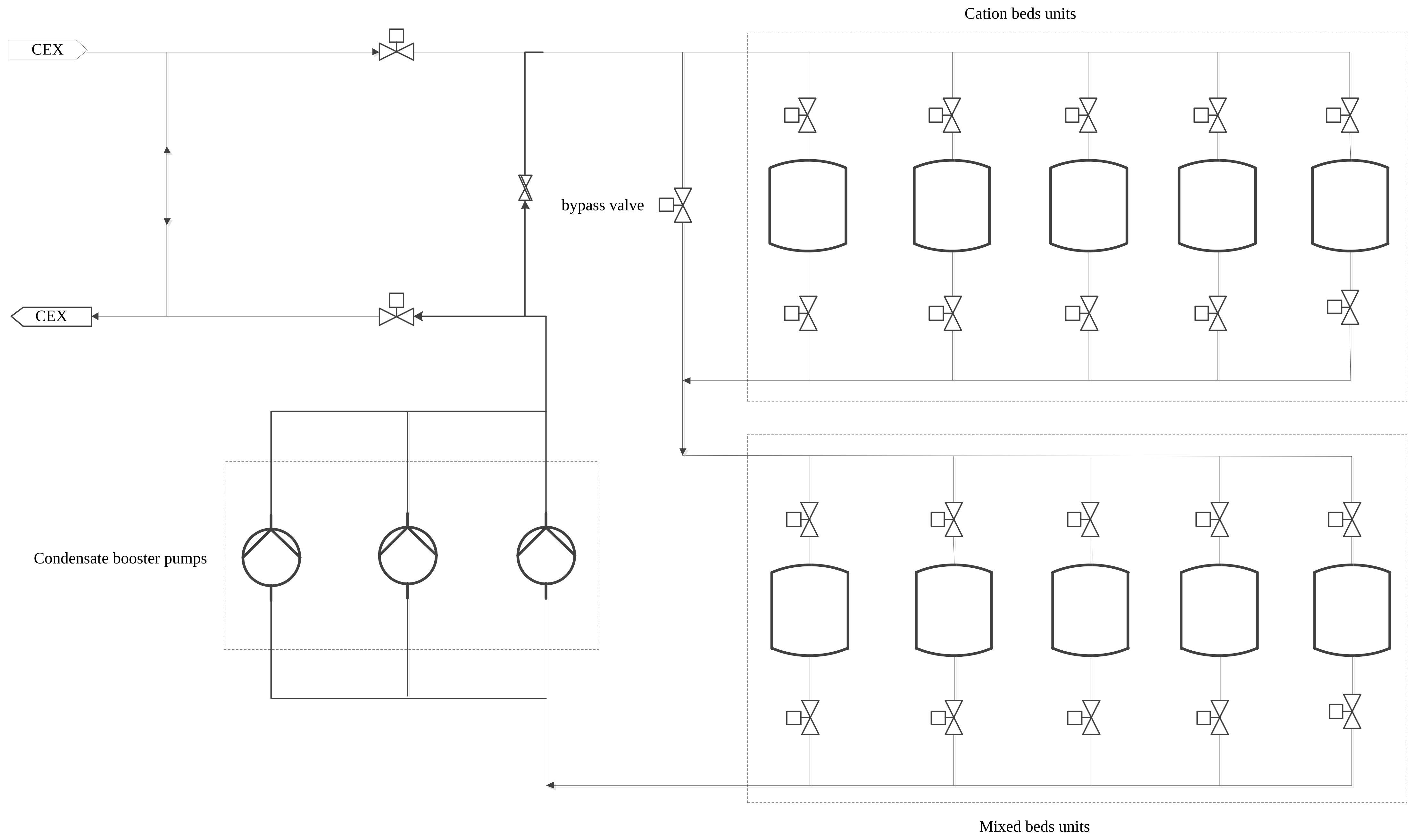
The condensate polishing system is arranged downstream of the condensate pumps and discharges to the low-pressure heaters.

11.8.4 Preliminary Design Substantiation

Performance, hydrostatic and leakage tests associated with pre-installation and preoperational testing are performed on the condensate polishing system. The system is designed to be capable of continuously monitoring during normal operation to ensure that all functions of the system can be correctly executed.

11.8.5 Functional Diagram

The functional diagram of ATE [CPS] system is included as F-11.8-1.



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F-11.8-1 Condensate Polishing System (ATE)

11.9 References

[1] NNSA, Safety regulations for Design of Nuclear Power Plants, HAF 102, 2004.