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**UK ABWR**

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# UK ABWR Generic Design Assessment

## Generic PCSR Chapter 9 :
## General Description of the Unit (Facility)


**Hitachi-GE Nuclear Energy, Ltd.**

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# Table of Contents

# Executive Summary

This chapter provides a general description of the UK ABWR design that is assessed in this PCSR. In provides a high level overview of how the Structures, Systems and Components (SSCs), that are addressed in greater detail in subsequent PCSR systems chapters, are related to each other in respect of the safety functions they are claimed to deliver. Its purpose is to aid understanding of the safety roles of the facilities, structures and systems that are included in the UK ABWR design, as submitted to the Generic Design Assessment (GDA) process.

For readers unfamiliar with UK ABWR systems, Chapter 9 provides a useful starting point to understanding how the UK ABWR has been designed to be safe during normal operation and under fault conditions. Some of the main improvements made to the design of the ABWR from earlier BWR designs are briefly described.

The chapter describes the basic design characteristics of the UK ABWR reactor systems, Engineered Safety Features, steam and power conversion systems, Control and Instrumentation architecture, electrical power supplies, and Human-Machine Interfaces. The main auxiliary systems are described, including water systems, process auxiliary systems such as air, nitrogen and drainage systems, and heating ventilation and air conditioning (HVAC) systems. The chapter also provides a brief introduction to the fuel storage and handling facilities, radioactive waste management facilities, and severe accident management systems.

An overview of the generic plant layout for a single reactor unit is included, which identifies the main buildings, and briefly describes their contents. All of the UK ABWR design features listed above are described in greater detail elsewhere in the PCSR chapters, and links to the relevant chapters are given.

Given that the purpose of Chapter 9 is simply to provide a high level summary description of the plant, there are no requirements for any conclusions to this chapter.

# 9.1 Introduction

This chapter provides a general description of the UK ABWR design for which the safety case prepared for the Generic Design Assessment (GDA) process is presented in this PCSR. It provides a high level overview of how the Structures, Systems and Components (SSCs), which are addressed in greater detail in subsequent PCSR systems chapters, are related to each other in respect of the safety functions they are claimed to deliver. Its purpose is to aid understanding of the claimed safety roles of the facilities and SSCs that are included in the UK ABWR design, as submitted to the GDA process.

## 9.1.1 Background

For readers unfamiliar with the UK ABWR systems, this chapter provides a useful starting point to understanding how the UK ABWR has been designed to be safe during normal operation and under fault conditions. The chapter briefly describes the basic design characteristics and functions of the UK ABWR systems that are of significance to ensuring nuclear safety is maintained. The UK ABWR is based on an established Japanese design and takes account of operational experience. Some of the main improvements made to the design of the ABWR from earlier BWR designs are briefly described.

An overview of the generic plant layout for a single reactor unit is included, which identifies the main buildings, and briefly describes their contents.

All of the UK ABWR design features discussed briefly in this chapter are described in greater detail elsewhere in the other PCSR chapters, and links to the relevant chapters are identified.

## 9.1.2 Document Structure

The following sections are included in this chapter:

Section 9.2 Purpose and Scope: This section explains the objectives of the chapter, and specifies which of the main SSCs and buildings are within the scope of this chapter.

Section 9.3 Basic Technical Characteristics: The introduction to this section briefly outlines the evolution of the ABWR design in Japan from the first ABWRs (KK-6 and KK-7), leading to the Japanese reference design that has been used for the UK ABWR. The rest of this section is arranged in the following main sub-sections:

- Section 9.3.1 Basic Plant Design Characteristics: This sub-section briefly describes the main improvements that have been made in the evolution of the ABWR plant design since the initial introduction of BWR technology. It also presents some key technical specifications of the UK ABWR.
- Section 9.3.2 Basic Design Characteristics of Systems, Structures and Components: This sub-section provides a brief description of the main SSCs of the UK ABWR that are important to nuclear safety of the facility. These are presented as technical summaries of the contents of each of the systems chapters of the PCSR, with an emphasis on the functions of the SSCs.

Section 9.4 Facility Layout: This section presents the standard plant layout arrangement of the main buildings of the UK ABWR that has been assumed for GDA (based on one ABWR unit). It explains how a number of considerations have influenced this conceptual plant layout, and describes the main functions of each of the buildings within the scope of GDA.

Section 9.5 Conclusion: This section simply summarises the information provided in the chapter. There are no conclusions related to the achievement of nuclear safety, as those type of conclusions are presented in other PCSR chapters.

Section 9.6 References: This section lists all documents that are referenced within the chapter.

This main links of this chapter with other GDA PCSR chapters are as follows:

- The evolution from the initial BWRs to the Japanese reference design that is briefly summarised in sections 9.3 and 9.3.1 is discussed in greater detail in PCSR Chapter 28: ALARP Evaluation.
- The SSCs that are briefly summarised in sub-section 9.3.2 are described in more detail in the PCSR systems chapters (Chapters 11 to 19,21 and 23). See section 9.2.2 below for links between items in this chapter's scope and other specific PCSR chapters.
- The main UK ABWR buildings that are briefly summarised in sub-section 9.4 are described in more detail in PCSR Chapter 10: Civil Works and Structures.

Environmental and security aspects of the UK ABWR design. For links to GEP, and CSA documentation, please see Generic PCSR Chapter 1: Introduction. For GEP, where specific references is required, for example in Radioactive Waste Management,
Radiation Protection, Decommissioning, these are included in the specific sections within the Generic PCSR.

## 9.2 Purpose and Scope

### 9.2.1 Purpose

The overall purpose of this chapter is to provide a basic understanding of the functions of the main SSCs and buildings of the UK ABWR that contribute to nuclear safety.

Specific objectives of the chapter are to:

- describe the overall arrangement of the UK ABWR unit for GDA, including brief descriptions of the buildings and structures;
- provide a high level summary description of the functions of the key systems, structures and components of the UK ABWR and provide links to the corresponding chapters in the Generic PCSR where detailed information is provided;
- specify key technical aspects of the UK ABWR (e.g. Plant Output, Key SSCs and features); and
- define the buildings and structures included in the scope of GDA.

### 9.2.2 Scope

The scope of the chapter is as follows:

Functions of SSCs -

- Chapter 11: Reactor Core
- Chapter 12: Reactor Coolant Systems, Reactivity Control Systems and Associated Systems
- Chapter 13: Engineered Safety Features
- Chapter 14: Control and Instrumentation
- Chapter 15: Electrical Power Supplies
- Chapter 16: Auxiliary Systems (including Severe Accident Management systems)
- Chapter 17: Steam and Power Conversion Systems
- Chapter 18: Radioactive Waste Management
- Chapter 19: Fuel Storage and Handling
- Chapter 21: Human-Machine Interface
- Chapter 23: Reactor Chemistry

Facility layout -

- Reactor Building
- Control Building
- Heat Exchanger Building
- Turbine Building
- Radwaste Building
- Service Building
- Backup Building
- Emergency Diesel Generator Building

## 9.3 Basic Technical Characteristics

Hitachi-GE Nuclear Energy, Ltd. (Hitachi-GE) has developed the Advanced Boiling Water Reactor (ABWR) with the concepts of enhanced safety, higher operability, reduced dose equivalent, better performance and enhanced cost efficiency. The first ABWRs are the Unit 6 and Unit 7 of Kashiwazaki-Kariwa Nuclear Power Station (KK-6 and KK-7) of Tokyo Electric Power Company, Inc (TEPCO). KK-6 has been operating successfully since 1996 and KK-7 since 1997. Hitachi-GE has also been appointed by the Japanese electric power company as the main designer of the reactor technology for four ABWRs within Japan.

Although the standard Japanese ABWR design in Japan has been established since the completion of KK-6 and KK-7, the UK ABWR design has required some changes to deal specifically with UK requirements. However, KK-6 and KK-7 with further improvements and optimisation incorporated in Ohma-1, Shika-2 and Shimane-3 are used as the reference Japanese design for the UK ABWR. The reference design is confirmed at the Design Reference Point.

This section provides an overview of the system description including the basic technical characteristics of the UK ABWR, details of which are discussed in later chapters.

### 9.3.1 Basic Plant Design Characteristics

The UK ABWR is designed with the aim of simplifying the design and operation of the plant as well as enhancing the safety and reliability of structures, systems and components (SSCs). Simplification, safety and reliability enhancements have been, and continue to be, a continuous effort since the initial introduction of the BWR technology in the 1950s. Some of the major ABWR improvements and differences relative to previous BWRs, and include:

- improvements of safety and reliability,
- improvement of the capacity factor,
- reduction of radiation dose to which workers are exposed, and
- improvements in operability and maintainability.

Additionally, the UK ABWR is developed based on demonstrated technology from both domestic and overseas construction and operational experience. The main improvements in systems and equipment applied to the ABWR are as follows :

(1) Reactor Internal Pumps (RIP)
ABWR RIPs are directly attached to the bottom of the Reactor Pressure Vessel (RPV) to directly circulate the flow of water (coolant) inside the reactor. In the earlier BWR designs the recirculation loop is located outside of the RPV, and the recirculation pump, in combination with the jet pump inside the reactor, provides circulation flow of the coolant. The ABWR RIP design is improved in the following ways:
(a) There are no external pumps for recirculation; therefore, the installation position of the Primary Containment Vessel (PCV) is lower. Hence, the centre of gravity of the reactor is lowered improving resistance to earthquakes.
(b) The RIP uses a wet motor which is immersed in water in the casing and has no shaft seal. Therefore, reliability in leak tightness is improved.
(c) As the external pipes used in the conventional BWRs are eliminated, the amount of radiation exposure to workers during maintenance inspection work is reduced.
(d) The potential for large diameter pipe breaks on Cooling Water Recirculation Lines is eliminated by the adoption of the RIPs, which eliminates the necessity of supplying water to the reactor core.

(2) Fine Motion Control Rod Drive (FMCRD)
In the ABWR the Control Rod Drive (CRD) mechanism uses an electric motor during normal operations and the hydraulic drive during emergency Control Rod (CR) insertions instead of the Locking Piston Control Rod Drive (LPCRD) used in previous BWR designs.
The FMCRD is improved as follows:
(a) The FMCRD has 2 power sources, hydraulic drive and electric motor drive. Scram is achieved using the hydraulic power. Once fully inserted, a latch prevents the CR from moving out from the core. After scram, all electric motor drive mechanisms act as back up for CR insertion.
(b) The FMCRD is designed to let the water flow into the reactor, a system to discharge scram water is unnecessary. Therefore, exposure of workers to radiation is mitigated.
(c) Only 1 CR could be activated at maximum with the LPCRD, but the adoption of an electric motor drive enables the operation of 26 CRs at maximum (gang mode operation), reducing start-up time.

(3) Reinforced Concrete Containment Vessel (RCCV)
The ABWR uses a cylindrical RCCV which is integrated with the Reactor Building (R/B), instead of the conventional steel containment vessel. This containment vessel is composed of a

concrete part which is pressure-resistant and a steel liner (lining) which prevents leakage.
The RCCV is improved as follows.

(a) There is greater freedom in shape selection compared to steel containment vessels, due to the adoption of the reinforced concrete containment vessel, enabling equipment to be positioned in a rational manner inside the containment vessel.
(b) The strength of reinforced concrete allows for the direct support of equipment and pipes and the space inside the containment vessel can be used more effectively.
(c) The pedestal that supports the RPV can include the vent pipe in the horizontal vent configuration, so space efficiency of the containment vessel is increased and the number of vent pipes can be reduced compared to the conventional steel pipe vertical vent configuration.

(4) The Emergency Core Cooling System (ECCS)
The ECCS of the ABWR is provided with three independent divisions which are composed of the High Pressure Core Flooder System (HPCF), Reactor Core Isolation Cooling System (RCIC) and Low Pressure Core Flooder systems (LPFL). It is designed to secure submergence of the core during a Loss of Coolant Accident (LOCA).

The ECCS is improved as follows.

(a) There are no large diameter pipes connected below the Top of Active Fuel (TAF) due to the adoption of the RIPs. The Emergency Core Cooling System (ECCS) is designed with a focus on LOCAs from medium and small-diameter pipes. Each individual division of the ECCS is installed with its own HPCF or RCIC.
(b) Each of the LPFL installed in the 3 independent divisions of the ECCS has a heat exchanger, therefore offers sufficient core cooling functions for both the short to long term after a LOCA.

(5) Human-machine Interface (HMI) System in the Main Control Room (MCR)
This type of HMI had been developed for ABWR, in order to improve operator performance based on experiences in BWR plants. It comprises the Main Control Console (MCC) and the Wide Display Panel (WDP).

The HMIs are improved as follows.

(a) The WDP encompasses information to be monitored during times of normal operation and fault condition. It also improves the ability of operators in the MCR to share information.
(b) Digital technology has been adopted in more C&I systems than in the BWR plants which leads to an expansion in the scope of automatic operation to reduce the operator burden. It also enables the application of large graphical display equipment to provide sufficient support for operators to understand plant status.

(6) Turbine Equipment
Turbine equipment has been designed to increase efficiency and to enhance plant performance.

Turbine Equipment is improved as follows.

(a) The Moisture Separator Re-heater (MSR) and heater drain pump-up systems are used to improve plant thermal efficiency.
(b) A forged mono block rotor is used in the steam turbine. The rotors transmit the power of the turbine and must withstand not only the torque during normal operation, but also the greater torque resulting from unusual events such as generator short circuits.

### 9.3.1.1 Key Specifications of UK ABWR

Table 9.3-1 shows typical key specifications of the UK ABWR.

**Table 9.3-1: Key Specifications of the UK ABWR**

| Item | Specification | |
|---|---|---|
| Output | Plant Gross Electrical Output | Approx. 1,350 MW |
| | Reactor Thermal Output | 3,926 MW |
| Reactor rated pressure | | Approx. 7.2 MPa (abs) |
| Reactor Core | Fuel Assemblies | 872 |
| | Control Rods | 205 |
| Reactor Equipment | Recirculation System | Internal pump method |
| | Control Rod Drive (CRD) | Hydraulic / electric motor drive method |
| Primary Containment Vessel (PCV) | | Reinforced Concrete Containment Vessel |
| ECCS | | 3 divisions |
| Residual Heat Removal System | | 3 divisions |

## 9.3.2 Basic Design Characteristics of Systems, Structures and Components (SSCs)

### 9.3.2.1 Reactor Core and Fuel

A detailed description of this system is provided in generic PCSR Chapter 11: Reactor Core.

#### 9.3.2.1.1 Fuel System

**(1) Fuel Assembly**

The GE14 fuel assembly consists of a fuel bundle (composed of fuel rods, water rods, spacers, and upper and lower tie plates), and a channel that surrounds the fuel bundle. This fuel type has 92 fuel rods (fourteen partial length rods) in a 10×10 rod array and two large central water rods. The fuel rods and water rods are spaced and supported by the upper and lower tie plates with intermediate spacing provided by eight spacers. The upper and lower tie plates are fixed by eight tie rods, which hold the fuel bundle together. The upper tie plate has a handle for transferring the fuel assembly. The fuel design is described in generic PCSR Chapter 11.

**(2) Fuel Channel**

The fuel channel encloses the fuel bundle and provides:

(a) a barrier between two parallel coolant flow paths, one for flow inside the fuel bundle and the other for flow in the bypass region between channels,
(b) a bearing surface for the control rod, and
(c) rigidity for the fuel bundle.

The channel fastener attaches the channel to the fuel bundle and, along with the channel spacer buttons, delivers fixed and resilient fuel/channel geometry.

### 9.3.2.2 Reactor Coolant Systems, Reactivity Control Systems and Associated Systems

A detailed description of this system is provided in generic PCSR Chapter 12: Reactor Coolant Systems, Reactivity Control Systems and Associated Systems.

#### 9.3.2.2.1 Reactor Coolant Systems and Associated Systems

The Reactor Coolant Systems (RCS) generates steam through the thermal nuclear fission process and directly transfers it to the turbine system. A Heat Balance (HB) showing the major parameters of the RCS for the rated power conditions is shown in Figure 9.3-1. The RCS comprises the following systems:

- Reactor Pressure Vessel housing the nuclear fuel and its internal components,
- Reactor Recirculation System (RRS),
- Nuclear Boiler System (NB),
- Reactor Water Clean-up System (CUW),
- Residual Heat Removal System (RHR),
- Leak Detection System (LDS), and
- Valve Gland Leakage Treatment System (VGL).

**(1) Reactor Pressure Vessel and Reactor Internals**

The Reactor Pressure Vessel (RPV) contains the reactor core (nuclear fuel) which is the heat source for steam generation. The vessel serves as one of the fission product barriers during normal operation.

The RPV is designed and fabricated in accordance with applicable codes for the design pressure of 8.62 MPa (gauge). The nominal operating pressure in the steam space above the separators is 7.17 MPa (abs). The RPV is fabricated of low alloy steel and is clad internally with stainless steel or high nickel alloy (except for the top head, RIP motor casing, nozzles other than the steam outlet nozzle, and unclad nozzle to shell weld zone).

The RPV contains the Reactor Internal Pumps (RIPs), core and core support structures, the steam separators and dryers, the spargers for the Feedwater and Core Flooder Systems, the Control Rod Drive (CRD) housings, and other components. The main connections to the vessel include steam lines, feedwater lines, RIPs, CRDs and nuclear instrument detectors.

The reactor core is cooled by demineralised water that enters the lower portion of the core and boils as it flows upward around the fuel rods. The steam leaving the core is dried by steam separators and dryers located in the upper portion of the reactor vessel. The steam is then directed to the turbine through the main steam lines. Each steam line is provided with two isolation valves in series, one on each side of the containment barrier.

A venturi-type flow restrictor is a part of the RPV nozzle configuration for each main steam line.
The restrictor limits the discharge flow of steam from a fractured pipe in case of main steam line break inside the containment. At this time, the restrictors of the unfractured steam line limit the flow of steam from the reactor vessel before the Main Steam line Isolation Valves (MSIVs) are closed. In addition, the restrictors limit the flow of steam from the reactor vessel before the MSIVs are closed in case of a main steam line break outside the containment.

**(2) Reactor Recirculation System (RRS)**

The RRS has two main functions. It provides forced circulation of reactor coolant for heat transfer from the fuel to the coolant. For this purpose, the RRS uses an arrangement of ten RIPs mounted at the bottom of the RPV to force reactor coolant flow through the lower plenum of the reactor and upward through openings in the fuel support castings, the fuel bundles, steam separators, and down to the annulus to be mixed with feedwater and recirculated again. The RRS can also be used to control reactor power by adjusting the RIPs speed to change the recirculation flow.

**(3) Nuclear Boiler System (NB)**

The NB is divided into two subsystems, as described below:

- The Main Steam System (MS) which consists of four steam lines to direct the steam flow from the RPV steam outlet nozzle to the main turbine; and
- The Feed Water System (FDW) which consists of two lines that transport feedwater from the feedwater pipes in the steam tunnel through the RCCV penetrations to the nozzles on the RPV.

The MS is provided with steam flow restrictors in each steam outlet nozzle to limit the flow rate in the event of a postulated main steam line break. The system also incorporates provisions for relief of over-pressure conditions in the RPV through the Safety Relief Valves (SRVs) and Main Steam Isolation Valves (MSIVs) on each line to isolate the primary containment when necessary.

**(4) Reactor Water Clean-up System (CUW)**

The CUW provides a continuous purifying treatment of reactor water by removing soluble and insoluble impurities to maintain water quality within acceptable limits during each of the plant operating modes. The CUW also provides a route to discharge the expansion in the volume of reactor water generated due to temperature increases into the Low Conductivity Waste (LCW) Collection Tank or the Suppression Pool (S/P) during reactor startup.

**(5) Residual Heat Removal System (RHR) -Reactor Shutdown Cooling Mode (SDC)**

The RHR provides reactor cold shutdown during reactor normal shutdown and in the event that the main condenser is not available. The RHR removes the reactor decay heat so that refuelling and maintenance can be undertaken after shutdown. Reactor water is directly drawn from the RPV through the reactor shutdown cooling suction nozzle, cooled by passing through the RHR Heat Exchanger and returned to the reactor.

**(6) Leak Detection System (LDS)**

The LDS detects and monitors leakage from the reactor coolant pressure boundary (RCPB) and initiates isolation of the leakage source if necessary. The system initiates isolation of the process lines that penetrate the containment by closing the appropriate isolation valves. The LDS monitors leakage inside and outside the drywell and annunciates excessive leakages in the MCR.

**(7) Valve Gland Leakage Treatment System (VGL)**

The purpose of the VGL is to prevent the discharge of radioactive fluids outside the system by transferring the designed fluid leakage from the valve gland to the drywell Low

Chemical Impurities Waste (LCW) Sump or the Suppression Pool (S/P) through the piping system. The VGL collects the fluid leakage from valves with gland seals (except for the valves which do not leak by design such as bellow seal valves, etc.) that form part of the RCPB.

#### 9.3.2.2.2 Reactivity Control Systems

**(1) Control Rod Drive System (CRD)**

The CRD controls changes in core reactivity during power operation by movement and positioning of the neutron absorbing control rods within the core in fine increments according to the control signals from the Rod Control and Information System. The drive mechanism for this mode of operation is the Fine Motion Control Rod Drive (FMCRD) which positions the control rod by electric motor for insertion and withdrawal during normal operation.

Additionally, the CRD provides rapid control rod insertion in response to the signals from the Reactor Protection System to rapidly shut down the reactor (scram). In this case the motive power for rapid rod insertion (as required in response to abnormal conditions) is provided by stored hydraulic power from compressed nitrogen gas.

**(2) Standby Liquid Control System (SLC)**

The SLC provides an alternate reactivity control method to bring the nuclear fission reaction to sub-criticality and to maintain sub-criticality. The system makes possible an orderly and safe shutdown in the event that not enough control rods can be inserted into the reactor core to accomplish shutdown in the normal manner. This is achieved by injecting a neutron absorbing solution into the reactor core. The system is sized to counteract the positive reactivity effect from rated power to the cold shutdown condition.

### 9.3.2.3 Engineered Safety Features

A detailed description of this system is provided in generic PCSR Chapter 13: Engineered Safety Features.

#### 9.3.2.3.1 Containment Systems

**(1) Primary Containment System**

The Primary Containment System has the function of providing a fission product barrier. The structure of the containment is capable of keeping leakage low even at the increased pressures that could follow design basis accidents such as a main steam line break or a fluid system line break.

(a) Primary Containment Vessel

The main features of the primary containment design include:

- The drywell, a cylindrical steel-lined reinforced concrete containment vessel (RCCV) surrounding the RPV,
- The S/P filled with water, which serves as a heat sink during normal operation and accident conditions, and
- The air space above the S/P.

In the event of a LOCA, the steam-water mixture released into the drywell is routed to the S/P water through the vent pipes. The steam is cooled and condensed by this pool water, thus suppressing the pressure rise in the drywell. Any radioactive substances are retained inside the containment vessel.

(b) Primary Containment Isolation System (PCIS)

The main role of the PCIS is to provide protection against the release of radioactive material from the Primary Containment Vessel (PCV) to the environment during fault conditions, by isolating the pipes of the systems penetrating the primary containment and thus forming a barrier to confine the radioactive material. This barrier is called the Primary Containment Vessel Boundary (PCVB).

(c) Primary Containment Vessel Gas Control System

(i) The purpose of the Flammability Control System (FCS), based on Passive Autocatalytic Recombiners (PARs), is to limit the concentration of hydrogen and oxygen below the lower flammability limits in the PCV following a LOCA.

(ii) The main function of the Atmospheric Control System (AC) is to inject nitrogen into the PCV to inert the atmosphere against hydrogen combustion. The AC inerts the PCV after refuelling outages, maintains a slightly positive pressure within the PCV and de-inerts the PCV for plant shutdown by replacing it with air.

(d) Containment Heat Removal Systems

(i) The primary system for Containment Heat Removal is the Residual Heat Removal System (RHR) through its several operation modes: Low Pressure Flooder (LPFL), Suppression Pool Cooling Mode (SPC) and PCV Spray cooling.

(ii) The alternative means for Containment Heat Removal is the Containment Venting System (CVS). The CVS consists of the Atmospheric Control System (AC) and the Filtered Containment Venting System (FCVS). The AC releases non-condensable gases and steam to the main stack through the hardened vent line bypassing the SGTS to prevent damage to the PCV due to overpressure. The FCVS releases non-condensable gases and steam to the main stack through the vent line of FCVS to prevent damage to the PCV due to overpressure.

(e) Drywell Cooling System (DWC)

The DWC maintains the required thermal environment and humidity so that the components in the drywell operate in a correct manner during normal plant operation and in the event of Loss of Off-site Power (LOOP). The DWC also cools the atmosphere in the drywell so that the working environment temperature during plant inspection and maintenance is acceptable for personnel access.

**(2) Secondary Containment System**

(a) Secondary Containment

The Secondary Containment is a reinforced concrete building that forms an envelope surrounding the PCV above the basemat (with the exception of the barrier inside the main steam tunnel). As well as providing containment, it also protects the PCV from the impact of external loads.

(b) Standby Gas Treatment System (SGTS)

The SGTS controls the emission of fission products by maintaining a negative pressure in the secondary containment and by filtering gaseous effluents prior to discharge to the atmosphere following a postulated LOCA or a fuel handling accident. The SGTS also processes gaseous effluents from the PCV and the secondary containment to limit the discharge of radioactivity to the environment during normal and abnormal plant operation.

#### 9.3.2.3.2 Emergency Core Cooling Systems (ECCS)

The purpose of the Emergency Core Cooling Systems (ECCS) is to inject water into the RPV and depressurise it as necessary to ensure core cooling function. The ECCS configuration comprises 3 redundant divisions provided with high pressure and low pressure water injection systems, which are supplied AC power from the respective divisions of the redundant Emergency Diesel Generator Systems (EDGs) in the event of loss of off-site power. The ECCS injection network is comprised of one RCIC train and two HPCF trains for high pressure injection, and three LPFL trains for low pressure injection in conjunction with the Automatic Depressurisation System (ADS) which supports the injection network under certain conditions.

**(1) Reactor Core Isolation Cooling System (RCIC)**

The purpose of the RCIC is to supply makeup water into the RPV to ensure that sufficient reactor inventory is maintained in order to perform adequate core cooling and prevent reactor fuel overheating during LOCA.
The RCIC is automatically initiated either by a high pressure in the drywell signal or a low water level in the RPV signal and injects high pressure water into the RPV using a steam-driven pump, which makes it operable even on total loss of AC power, (also known as Station Black-Out (SBO)). The RCIC steam supply line branches from one of the main steam lines leaving the RPV and goes to the RCIC turbine.

**(2) High Pressure Core Flooder System (HPCF)**

The purpose of the HPCF is to maintain the reactor vessel water inventory during LOCA which does not depressurise the reactor vessel and thus limit the fuel cladding temperature. The system also operates as a backup to the RCIC in order to restore reactor water level conditions in case of transitional events and loss of feed-water accidents. The System consists of two independent and physically separated divisions automatically initiated either by a high pressure in the drywell signal or a low water level in the RPV signal.

**(3) Residual Heat Removal System (RHR) - Low Pressure Core Flooder System (LPFL)**

The purpose of the LPFL is to provide reactor vessel water inventory makeup and core cooling during LOCA and to provide containment cooling. Following ADS initiation, the LPFL also provides inventory makeup water following small and medium piping breaks. The LPFL consists of three independent and physically separated divisions automatically initiated either by a high pressure in the drywell signal or a low water level in the RPV signal.

**(4) Automatic Depressurisation System (ADS)**

The ADS utilises part of the Safety Relief Valves (SRVs) to reduce reactor pressure during small and medium piping breaks. This feature is very useful in the event of HPCF failure because by automatic or manual actuation of the SRVs the reactor pressure can be quickly reduced and thus water inventory can be supplied to the reactor pressure vessel using the LPFL.

In addition, the alternative systems described below are provided in to perform similar functions in the event the ECCS failed to perform its functions. The detailed design of these systems is presented in Generic PCSR Chapter 16: Auxiliary Systems section 16.7 about Severe Accidents Mechanical Systems.

**(5) Flooder System of Specific Safety Facility (FLSS)**

The FLSS provides core cooling water supply to the RPV when the reactor is in low pressure condition in the event of failure of the primary cooling means (RCIC, HPCF and LPFL).

**(6) Reactor Depressurization Control Facility (RDCF)**

The RDCF depressurises the RPV to allow initiation of the FLSS in the event of failure of the primary cooling means (ADS etc.).

### 9.3.2.4 Control and Instrumentation (C&I)

A detailed description of this system is provided in generic PCSR Chapter 14: Control and Instrumentation.

#### 9.3.2.4.1 C&I Architecture

The C&I architecture is structured with consideration of defence in depth, which are composed of:

- the SSLC which is divided into two parts, RPS/MSIV and ECCS/ESF, the Safety Auxiliary Control System (SACS), and the Hardwired Backup System (HWBS): these systems provide protection in fault conditions,
- the Plant Control System (PCntlS), the Reactor / Turbine Auxiliary Control Systems (ACS) and the Plant Computer System (PCS) for normal operation, and
- the Severe Accident C&I (SA C&I) for severe accident mitigation.

**(1) Safety System Logic and Control System (SSLC)**

This system delivers safety functions to protect the reactor in fault conditions, spurious operation of systems (including C&I) which might possibly impair the reactor safety, or in cases where the occurrence of such events is anticipated. The SSLC which initiates mitigation operation delivers following safety functions, example of SSCs is also shown:

- Control of reactivity (shutdown the reactor): Reactor Protection System (RPS)
- Fuel Cooling, Long-term heat removal: e.g. C&I for ECCS
- Confinement/ Containment radioactive materials: e.g. C&I for MSIV, PCIS

**(2) Hardwired Backup System (HWBS)**

This system provides the secondary safety measures for design basis faults, and if it is available, prevents a beyond design basis accident arising from infrequent faults which may develop into severe accidents.
It is separated or segregated from the SSLC. It is also diverse from the SSLC, which is achieved by using diverse technology i.e. hardwired logic. The HWBS supports the following safety functions, and examples are also shown:

- Control of reactivity (shutdown the reactor):
  Hardwired logic for SLC, ARI, ATWS-RPT, and feedwater stop (FWSTP)
- Fuel cooling
  Hardwired logic for Flooder System of Specific Safety Facility (FLSS), Reactor Depressurisation Control Facility (RDCF)
- Long-term heat removal
  Hardwired logic for Containment Venting including Filtered Containment Venting System (FCVS), Hardened vent line

**(3) Safety Auxiliary Control System (SACS)**

This system provides the safety functions to support the SSLC or to mitigate fault conditions after the SSLC delivers its safety functions:

- Standby Gas Treatment System (SGTS)
- High Pressure Nitrogen Gas Supply System (HPIN)
- Suppression Pool Clean-up System (SPCU)
- Off Gas system isolation
- Post Accident Monitoring System (PAM)

**(4) Plant Control System (PCntlS)**

This system provides the means to control key parameters of the reactor, such as water level, pressure and reactor power. The major plant control sub-systems are:

- Automatic Power Regulator System (APR)
- Rod Control and Information System (RCIS)
- Recirculation Flow Control System (RFC)
- Electro-Hydraulic Turbine Control System (EHC)
- Feedwater Control System (FDWC)

**(5) Severe Accident C&I System (SA C&I)**

This system provides controls and parameters to mitigate consequences of an accident and to understand plant status such as core and spent fuel pool cooling. It delivers following safety functions:

- Fuel cooling: C&I for FLSS, RDCF, Flooder System of Specific Safety Facility (FLSR)
- Long-term heat removal: C&I for Alternate Heat Exchange Facility (AHEF), Containment venting

**(6) Reactor/ Turbine Auxiliary Control Systems (ACS)**

This system provides the means to control the turbine, the generator and their major auxiliaries such as cooling water and is divided into two parts; Reactor Auxiliary Control System and Turbine Auxiliary Control System.

**(7) Plant Computer System (PCS)**

This system provides functions to monitor and record process parameters, to monitor and analyse core performance, and guidance for automatic operation, in order to achieve reliable and safe plant operation. It does not directly control plant operation. This system is comprised of distributed computer servers, user interfaces, and related devices.

### 9.3.2.5 Electrical Power Supplies

A detail description is provided in generic PCSR Chapter 15: Electrical Power Supplies.

#### 9.3.2.5.1 Electrical Equipment

**(1) Exciter**

The generator excitation power is supplied from the generator terminals through the excitation transformer, and the Alternating Current (AC) power is converted to Direct Current (DC) power supply by a thyristor type converter.

**(2) Electrical Power Distribution System**

The safety Class 1 AC power system supplies power to the safety Class 1 loads. The unit auxiliary electrical power supply system is normally provided from the off-site power supply system. The safety Class 1 system includes diesel generators that serve as standby power sources independent of any onsite or offsite source. Therefore, the system has multiple power sources. Safety Class 1 batteries are provided for the Safety System Logic and Control System (SSLC).

**(3) Generator Transformer (GT)**

Generator Transformer (GT) raises the generator voltage to the external grid voltage during normal plant operation. Also, at plant startup or shutdown, the GT steps down the external grid voltage to the generator voltage.

**(4) Auxiliary Normal Transformer (ANT)**

Two (2) Auxiliary Normal Transformers (ANTs) are installed and step down the main generator voltage to the Medium Voltage (MV) bus voltage. During plant normal operation, the ANTs are supplied from the main generator. At plant start-up, shutdown or accident plant operation caused by the reactor and turbine, the ANTs are supplied from the external grid via the GT.

**(5) Auxiliary Standby Transformer (AST)**

When the GT-ANT line is not available or when a fault occurs on the main generator voltage system, the GT, or ANT on-site power is supplied from the Auxiliary Standby Transformer (AST). The AST steps down the external grid voltage to the MV bus voltage.

**(6) Isolated Phase Bus (IPB)**

The Isolated Phase Bus (IPB) duct system provides electrical interconnection from the main generator output terminals to the generator load switch (GLS) and from the GLS to the low voltage terminals of GT and the high voltage terminal of ANT. When the main generator is off line, the GLS is open and the external grid is fed to ANT via GT.

**(7) Non-Segregated Phase Bus**

Non-Segregated phase bus is used where a branching circuit is required at MV bus and Power Centre (P/C) system.

**(8) Auxiliary Main Distribution Buses**

Auxiliary AC power distribution systems consist of four (4) groups depending on the role carried out:

- Safety Class 3 buses - supplied from ANT or AST
- Safety Class 1 buses - supplied from safety Class 3 MV buses, Emergency Diesel Generators (EDGs) or Diverse Additional Generator (DAG)
- B/B Class 2 buses - supplied from safety Class 3 MV buses or Backup Building Diesel Generators (BBGs) Systems
- Safety Class 3 DAG bus – supplied from safety Class 3 MV bus or DAG

**Safety Class 3 bus**

Safety Class 3 MV buses are supplied from the ANT or AST. The safety Class 3 MV buses also supply power to the loads necessary during normal operation.

**Safety Class 1 bus**

Safety Class 1 MV buses are supplied from the safety Class 3 MV buses, EDGs or DAG. Safety Class 1 MV buses also supply power to the safety Class 1 Systems, Structures and Components (SSCs). Each of these buses is normally supplied from a specific safety Class 3 MV bus.

**B/B Class 2 bus**

The Backup Building (B/B) Class 2 LV (690V) buses supply power to the second line provision of the Emergency Core Cooling System (ECCS) safety function and related equipment e.g. the Flooder System of Specific Safety Facility (FLSS) which is the alternative Class 2 low-pressure flooder system.

**Safety Class 3 DAG bus**

The safety Class 3 DAG bus supplies power to the safety Class 1 electrical power supply system in the case of the combination of Loss of Off-site Power (LOOP) and EDGs CCF (Common Cause Failure). The DAG can be manually initiated to supply power to one (1) division of the safety Class 1 AC power supply system in order to support the Residual Heat Removal (RHR) system and its associated systems by using the bus coupling line between the safety Class 1 MV bus and the DAG bus.

**(9) Low Voltage Distribution system**

**Power Centres (P/C)**

Electrical power for LV auxiliaries is supplied from P/Cs which consist of MV/LV transformers and associated switchgear.
The P/C supplies power to auxiliary loads of over 90kW and not greater than 300kW in principle.

**Motor Control Centres (MCC)**

The Motor Control Centre (MCC) receives electrical power from P/C and supply power to auxiliary loads of not greater than 90kW in principle.

**(10) Direct Current Power Supply**

There are four groups of DC power supply system as follows:

- Safety Class 1 115V DC power supply system
- Safety Class 2 115V DC power supply system
- Non Safety Class 230V DC power supply system
- B/B Class 2 115V DC power supply system

**Safety Class 1 115V DC Power Supply System**

The safety Class 1 DC power supply system supplies power to the plant SSCs required to perform safety functions in the event of Station Black Out (SBO). This includes electrical power to the safety Control and Instrumentation (C&I) equipment including the Class 1 ECCS.

**Safety Class 2 115V DC Power Supply System**

The safety Class 2 DC power supply system is provided as an uninterruptible standby power supply for loads to the Class 2 C&I equipment.

**Non safety Class 230V DC Power Supply System**

The non-safety Class 230V DC power supply system is provided to supply power to unclassified DC loads such as motors for plant investment protection (e.g. emergency oil pump).

**B/B Class 2 115V DC Power Supply System**

The B/B Class 2 115V DC power supply system supplies power to safety C&I equipment in the B/B which is needed to realise the function of Class 2 such as FLSS.

**(11) Emergency Diesel Generators (EDGs)**

Three (3) EDGs are provided. The role of the EDGs is to supply the power needed to shut down the reactor safely when off-site power is lost and to supply power to the electrical systems supporting the delivery of Safety Functions if a Loss of Coolant Accident (LOCA) occurs simultaneously.

**(12) AC Instrumentation Power Supply System**

The AC instrumentation power supply system consists of six (6) groups as follows:

- Safety Class 1 uninterruptible AC power supply system (Class 1 AC UPS)
- Safety Class 3 UPS (Class 3 AC UPS)
- Safety Class 1 AC instrumentation and control power supply system (Class 1 AC I&C PS)
- Safety Class 2 AC instrumentation and control power supply system (Class 2 AC I&C PS)
- Safety Class 3 AC instrumentation and control power supply system (Class 3 AC I&C PS)
- B/B Class 2 AC instrumentation and control power supply system (B/B Class 2 AC I&C PS)

**Safety Class 1 AC UPS**

The Class 1 AC UPS supplies power to Class 1 instrument and control systems which cannot tolerate momentary power failure, such as the Reactor Protection System (RPS) (four (4) divisions), radiation instrumentation and turbine control system.

**Safety Class 3 AC UPS**

The safety Class 3 AC UPS system supplies power to the Class 3 plant process computer system. It receives AC power from MCCs (which can be supplied from EDGs) located in the control room building or DC power supply from the plant process computer dedicated battery.

**Safety Class 1 AC I&C Power Supply**

The Class 1 AC I&C PS systems supply power to the Main Control Room (MCR) AC 115V power distribution panels. In the event of LOOP, this power supply is interrupted until the power supply from the EDGs is available.

**Safety Class 2 AC I&C Power Supply**

The safety Class 2 AC Instrumentation and Control (I&C) PS systems supply power to the Class 2 R/B, Turbine Building (T/B) I&C loads.

**Safety Class 3 AC I&C Power Supply**

The safety Class 3 AC I&C PS system supplies power to the Class 3 Radwaste Building (Rw/B) I&C loads.

**B/B Class 2 AC I&C Power Supply**

The B/B Class 2 AC I&C PS systems supply power to the Class 2 B/B I&C loads. Two (2) ×100 percent Class 2 systems are provided in B/B supplied from the B/B LV buses.

**(13) Backup Building Diesel Generators (B/B Class 2 BBGs)**

Two (2) B/B Class 2 BBGs and associated equipment are installed in the B/B (LV BBGs in system 1 and system 2). The BBGs are rated to supply power to B/B equipment when off-site power is lost.

**(14) Diverse Additional Generator (DAG)**

One (1) safety Class 3 DAG and associated equipment are installed to supply power to the one (1) division of the safety Class 1 electrical power supply system in the event of the simultaneous occurrence of LOOP and CCF of EDGs. The safety Class 3 DAG is manually configured to supply power to one (1) division of it by using the interconnection line between the safety Class 3 DAG bus and the safety Class 1 MV bus.

**(15) Communication System**

Communication systems are composed of a telephone system and a paging system. The telephone system is designed to communicate within the plant and with external

organisations. The paging system is designed to instruct and to alarm from the MCR to the plant areas.

**(16) Lighting and Servicing Power Supply**

Lighting Systems are composed of non-safety AC lighting, safety Class 3 AC lighting and emergency escape lighting. Non-safety AC lighting system is powered from safety Class 3 AC LV buses. Safety Class 3 AC lighting system is powered from safety Class 1 and 3 AC LV buses. Safety Class 3 AC lighting in the MCR is also provided and is powered by BBGs and DAG on loss of safety Class 3 AC power and safety Class 1 AC power. Emergency escape lighting is designed to allow escape.

**(17) Power Trucks**

The provision of mobile power trucks is designed as a countermeasure against Severe Accident (SA).

#### 9.3.2.5.2 Electrical Protection

Protection is applied to the generator main circuit, power distribution bus, EDGs etc. In addition, earthing, lightning and electrical penetration protections are installed in the electrical power supply system.

**(1) Earthing System**

The earthing system is designed to prevent physical injures and equipment damage and to minimise damage from earth fault currents. The system is designed to protect electrical signals from Electromagnetic Interference (EMI) and is designed to protect equipment from lightning.

**(2) Lightning Protection System**

The lightning protection system is installed to:
- Mitigate the effect of a lightning strike, and
- Mitigate the effect of a lightning induced surge.

**(3) Electrical Penetration**

Electrical penetration is installed in the Reinforced Concrete Containment Vessel (RCCV) and supplies power, control and signals to equipment in the RCCV.

#### 9.3.2.5.3 Panel and Raceway Layout

**(1) Raceway System**

Safety Class 1 electrical equipment and raceways are designed to be electrically and physically separated to maintain independence.

### 9.3.2.6 Auxiliary System

A detailed description is provided in generic PCSR Chapter 16: Auxiliary Systems.

#### 9.3.2.6.1 Water System

**(1) Ultimate Heat Sink (UHS)**

The UHS provides the source of cooling water for the RSW and is the final repository for the heat removed from the safety related equipment in the RCW.

**(2) Reactor Building Cooling Water System (RCW)**

The RCW provides cooling water to certain designated equipment located in the R/B, T/B, Control Building (C/B), and Rw/B. Heat is removed from the closed loop by the Reactor Service Water System. Capacity and redundancy is provided in heat exchangers and pumps to ensure adequate performance of the cooling system under all postulated conditions. During loss of offsite power, emergency power for the system is available from the onsite emergency diesel generators. The closed loop design provides a barrier between radioactive systems and the reactor service water discharged to the environment. Radiation monitors are provided to detect contaminated leakage into the closed systems.

**(3) Reactor Building Service Water System (RSW)**

The RSW supplies service water as cooling water to the RCW Heat Exchanger (RCW-HEX) and removes heat from the RCW to the UHS.

**(4) Turbine Building Cooling Water System (TCW)**

The TCW supplies cooling water to turbine auxiliary equipment such as oil coolers, motor coolers, shaft bearings, and the Heating Ventilating and Air Conditioning System (HVAC) Normal Cooling Water System (HNCW) chillers.

**(5) Turbine Building Service Water System (TSW)**

The TSW supplies service water as cooling water to the TCW Heat Exchanger (TCW-HEX) and removes heat from the TCW.

**(6) Make Up Water Condensate System (MUWC)**

The MUWC supplies required condensate at Start-up, System shutdown and Power operation to each component which may potentially have radioactive contamination.
The Condensate Storage Tank (CST) is used as a water source for the RCIC, HPCF, SPCU and CRD, and also receives water from the LCW.

**(7) HVAC Normal Cooling Water System (HNCW)**

The HNCW is designed to provide chilled water as a cooling medium to each cooling coil of the Drywell Cooling System (DWC) Dehumidifiers, the various Normal HVAC Supply Air Treatment Facilities and the Normal Local Cooling Units in each building.
The HNCW consists of following three sub-systems.

- HNCW
- Rw/B HNCW

- S/B HNCW

The HNCW supplies cooling water to the DWC, the Normal HVAC Supply Air Treatment Facilities and the Normal Local Cooling Units in the Reactor Building (R/B), Control Building (C/B), Turbine Building (T/B), Heat Exchanger Building (Hx/B), and Filter Vent Building (FV/B). The Radwaste Building (Rw/B) HNCW supplies cooling water to the Rw/B. The Service Building (S/B) HNCW supplies cooling water to the S/B. The HNCW, Rw/B HNCW and S/B HNCW are operated during normal operation, shutdown and refuelling outage.

**(8) HVAC Emergency Cooling Water System (HECW)**

The HECW provides chilled water as a cooling medium to the cooling coils of the Normal/Emergency Heating Ventilating Air Conditioning System (HVAC) Supply Air Treatment Facilities and Local Cooling Units during normal operation, shutdown, refuelling outage and fault conditions such as LOCA and LOOP shown in Table 9.3-2.

**Table 9.3-2: HVAC Sub-system associated with HECW**

| No. | Bldg. | HVAC Sub-system | Safety Division |
|---|---|---|---|
| 1 | R/B | Reactor Building Emergency Electrical Equipment Zone [RBEEE (A), (B) and (C)/Z] HVAC | Normal/Emergency |
| 2 | EDG/B | Emergency Diesel Generator Electrical Equipment Zone [DGEE (A), (B) and (C)/Z] HVAC | Normal/Emergency |
| | | Emergency Diesel Generator Room [EDG (A), (B) and (C)] Local Cooling Units | Emergency |
| 3 | C/B | Control Building Emergency Electrical Equipment Zone [CBEEE (A), (B) and (C)/Z] HVAC | Normal/Emergency |
| 4 | C/B | Main Control Room [MCR (A) and (B)] HVAC | Normal/Emergency |
| 5 | Hx/B | Heat Exchanger Building Emergency [Hx/B- Emergency (A), (B) and (C)] Local Cooling Units | Emergency |

**(9) HVAC Backup Building Cooling Water System (HBCW)**

The HBCW provides chilled water as a cooling medium to the following cooling coils of the Normal/Emergency Heating Ventilating Air Conditioning System (HVAC) Supply Air Treatment Facilities and Local Cooling Units during normal operation, shutdown, refuelling outage and fault conditions such as frequent design basis faults, beyond design basis faults and severe accidents shown in Table 9.3-3.

**Table 9.3-3: HVAC Sub-system associated with HBCW**

| No. | Bldg. | HVAC Sub-system | Safety Division |
|---|---|---|---|
| 1 | C/B | Control Building Class2 Electrical Equipment Zone [CBC2EE/Z] HVAC | Normal/Emergency |
| 2 | B/B | Backup Building Electrical Equipment Zone [BBEE (A) and (B)/Z] HVAC | Normal/Emergency |
| | | Backup Building Generator Room [BBG (A) and (B)] Local Cooling Units | Emergency |
| 3 | B/B | Backup Building Emergency Control Room [BBECR (A) and (B)] HVAC | Normal/Emergency |
| 4 | FV/B | Filter Vent Building [FV/B] HVAC | Normal/Emergency |

**(10) Emergency Equipment Cooling Water System (EECW)**

The main role of the EECW is to supply recirculation cooling water to the Backup Building Generators (BBG) in order to ensure power supply to the BBG loads in the event of frequent design basis faults with failure of the Class 1 core cooling systems and in the event of beyond design basis faults and severe accidents. The EECW recirculates cooling water through a closed loop to remove heat from the BBG auxiliaries and transfers it to the Air Fin Coolers (AFCs) which cool down the water by transferring heat to the ambient air.

**9.3.2.6.2 Process Auxiliary System**

**(1) Service Air System (SA)**

The SA provides a continuous supply of compressed air of suitable quality and pressure for general plant use. The SA compressor discharges compressed air into the SA air receivers which are then distributed throughout the plant.

**(2) Instrument Air System (IA)**

The IA provides a continuous supply of dry, filtered, compressed instrument air for control and use in all air operated instrumentation and equipment. The IA compressor discharges compressed air into the IA air receivers which are then distributed throughout the plant.

**(3) High Pressure Nitrogen Supply System (HPIN)**

Nitrogen gas is normally supplied by the Atmospheric Control System to meet the requirement of (1) the SRV automatic depressurisation and relief function accumulators, (2) the inboard MSIVs, and (3) instruments and pneumatic valves using nitrogen in the drywell. When this supply of pressurised nitrogen is not available, the HPIN automatically maintains nitrogen pressure to this equipment. The HPIN consists of high pressure nitrogen storage bottles with piping, valves, instruments, controls and control panel.

**(4) Plumbing and Drainage System (P&D)**

The system role of P&D is to collect and transfer the drain generated from each area in the building. The drain generated from each area in the building is classified and collected according to its property and divisional area and transferred to the drain sump of the Radioactive Drain Transfer System (RD), the Miscellaneous Non-Radioactive Drain Transfer System (MSC) or outside the system (intake seal pit and discharge seal pit).

**(5) Miscellaneous Non-Radioactive Drain Transfer System (MSC)**

The objective of the MSC is to collect and transfer the non-radioactive liquid waste (Non-Radioactive Storm Drain (NSD) and Service Water Storm Drain (SWSD)) generated in the radiation non-controlled areas during reactor operation and plant shutdown.

**(6) Radioactive Drain Transfer System (RD)**

The radioactive drain transfer system (RD) transfers drains generated in controlled areas to collection tanks in individual subsystems installed in the Radwaste building. Laundry drains and radioactive shower drains are transferred to laundry drain collection tanks, which are installed in the Service building. The RD transfer system is comprised of sump tanks, sump pumps, piping, valves, and instrumentation devices.

**(7) Sampling Systems**

The Sampling System (SAM) handle water monitoring. All these systems are furnished to provide process information that is required to monitor plant and equipment performance and changes in operating parameters. Representative liquid and gas samples are taken automatically and/or manually during plant operation for laboratory or online analysis.

**(8) Heating Steam System**

The Heating Steam system supplies non-radioactive steam to the steam jet air ejectors for condenser deaeration, the Turbine Gland Seal System, which prevents radioactive steam leakage out of the turbine casings and atmospheric air leakage into the casing at specific operating conditions, the off-gas system to preheat gaseous waste, and the Liquid Radwaste System evaporator, etc. The auxiliary boiler supplies steam through a connection to the auxiliary steam header.

#### 9.3.2.6.3 Heating Ventilating and Air Conditioning System (HVAC)

The HVAC controls temperature, pressure, humidity, and airborne contamination to ensure the integrity of plant equipment, provide acceptable working conditions for plant personnel, and limit offsite releases of airborne contaminants.

The following sub-systems of HVAC are provided.

(1) The Reactor Area (R/A) HVAC is categorised for following two functions.

- Normal function
  This system provides ventilation and air conditioning function for the R/A by the once-through ventilation method and maintains a negative pressure within the R/A with respect to atmosphere during plant normal operations. In addition, exhaust air is treated with HEPA filters before discharging to the main exhaust stack. The Normal LCUs supplement the R/A HVAC to maintain a controlled temperature environment in certain high heat load areas. During the plant normal shutdown, the RHR is operated in order to remove residual heat from the reactor. The RHR Pump Room LCUs are automatically started upon the RHR pump initiation signals and provide cooling to remove heat load from the RHR pumps. In addition, the nitrogen gas is exchanged with air within the Primary Containment Vessel (PCV) to provide access for operators and workers. To do so, HVAC supply air for the R/A is partially directed to the Atmospheric Control system (AC) via the PCV Purge Supply Filter Unit. Consequently, air is returned to the R/A HVAC exhaust system by means of the PCV Purge Exhaust Fan. A local Safe Change HEPA filter unit will be provided for high potentially airborne contamination areas as necessary

- Emergency function
  The emergency LCUs of the R/A HVAC are designed to provide suitable indoor environmental conditions to ensure the continued operation of the emergency SSCs during fault conditions. Heat load from the emergency SSCs is removed by the RCW passing through the LCU. The RHR [Low Pressure Flooder System (LPFL)] is composed of three independent divisions designated A, B and C. Therefore, the LCU is provided with three units according to division of the RHR. The LCUs are automatically started upon RHR pump initiation signals. The RCIC consists of a single pump. Therefore, the LCU is provided with one unit according to the RCIC. The LCU is automatically started upon RCIC turbine stop valve open signal. The HPCF is composed of two independent divisions designated B and C. Therefore, the LCU is provided with two units according to division of the HPCF. The LCUs are automatically started upon HPCF pump initiation signals. The FPC is composed of two independent divisions designated A and B. Therefore, the LCU is provided with two units according to division of the FPC. The LCUs are automatically

started upon FPC pump initiation signals and R/A isolation damper closing signals. The SGTS is composed of two independent divisions designated A and B. Therefore, the LCU is provided with two units according to division of the SGTS. The LCUs are automatically started upon SGTS initiation signals. Upon receipt of any of emergency isolation signals ("high radioactivity of the HVAC exhaust gas in the R/A", "high radioactivity in fuel handling area", "drywell high pressure" or "reactor water low level"), the R/A HVAC is automatically shutdown and the R/A Isolation Dampers mounted on the supply/exhaust duct of the R/A HVAC are automatically closed to isolate R/A while preventing exfiltration of the radioactive gas to outside by switching in the SGTS

(2) The RBEEE/Z HVAC provides the ventilation and air conditioning function for the RBEEE/Z by the partial recirculation ventilation method during the plant normal operations and fault conditions. The RBEEE/Z HVAC composed of three divisions designated A, B and C systems. Each system serves one divisional RBEEE/Z. The divisional HECW provides chilled water for the RBEEE/Z HVAC. After a fire event, in case cold smoke is generated within fire area, the ventilation method is changed from partial recirculation to the once-through for smoke purging.

(3) The DGEE/Z HVAC provides ventilation and air conditioning for the DGEE/Z by the partial recirculation ventilation method during the plant normal operations and fault conditions. The DGEE/Z HVAC is composed of three divisions designated A, B and C systems. Each system serves one divisional DGEE/Z. The divisional HECW provides chilled water for the DGEE/Z HVAC. After a fire event, in case cold smoke is generated within fire area, the ventilation method is changed from partial recirculation to once-through for smoke purging.

The EDG Room LCU is designed to provide suitable indoor environmental conditions to ensure the continued operation of the EDG during fault conditions. The LCU is supplied with chilled water by the divisional HECW.

The EDG Room Emergency Supply Fan provides filtered outside air cooling. The role of the Emergency Supply Fan is to maintain suitable environmental conditions under the loss of cooling by the EDG Room LCU due to failure of the HECW Chiller.

The EDG is composed of three independent divisions designated A, B and C. Therefore, the LCU and Supply Fan are each provided with two units per division. The LCUs and Supply Fans are automatically started upon EDG initiation signals

(4) The T/B HVAC provides ventilation and air conditioning function for the controlled area within the T/B by the once-through ventilation method and maintains a negative pressure within the controlled areas with respect to atmosphere during the plant normal operation. In addition, exhaust air is treated with the HEPA filters before discharging to main exhaust stack.

The LCUs supplement the T/B HVAC to maintain a controlled temperature environment in certain high heat load areas. Local Safe Change HEPA filter unit will be provided for high potentially airborne contamination areas as necessary.

In the event of LOOP, the T/B HAVC is inoperable.

(5) The Heat Exchanger Building Normal (Hx/B-N) HVAC provides ventilation and air conditioning function for the Hx/B by the type-2 ventilation method during the plant normal operations. After a fire event, in case cold smoke is generated within fire area, the smoke purging function is carried out by the once-through ventilation method.

(6) The Hx/B-E LCU is designed to provide suitable indoor environmental conditions to ensure the continued operation of the RCW and RSW in the Hx/B during fault conditions. The LCU is supplied with chilled water by the divisional HECW.

The Hx/B-E Supply Fan provides filtered outside air cooling. The role of the Emergency Supply Fan is to maintain suitable environmental conditions during the loss of cooling by the Emergency LCU due to failure of the HECW Chiller.

The RCW and RSW are each composed of three independent divisions designated A, B and C. Therefore, the LCU and Emergency Supply Fan are each provided with one unit per division. The LCUs and Emergency Supply Fans are automatically started upon RCW pump initiation signals.

(7) The CBEEE/Z HVAC provides ventilation and air conditioning function for the CBEEE/Z by the partial recirculation ventilation method during the plant normal operations and fault

conditions. After a fire event, in case cold smoke is generated within fire area, the ventilation method is changed from partial recirculation to once-through ventilation for smoke purging.

The CBEEE/Z HVAC is composed of three divisions and redundant cooling is provided to each of the CBEEE/Z divisions I through IV. The objective of the selected configuration described as follows is to ensure HVAC function is provided with sufficient redundancy by incorporating various system combinations; the HVAC division A (Ventilation area: CBEEE/Z division I and division IV), the HVAC division B (CBEEE/Z division II and division IV), and the HVAC division C (CBEEE/Z division III and division IV). Thus, divisions I through IV for CBEEE/Z are provided with their own HVAC even in the event of loss of one HVAC division

The Normal LCUs supplement the CBEEE/Z HVAC to maintain a controlled temperature environment in certain high heat load areas. The exhaust air from battery room for each division is discharged to outside directly through exhaust duct and openings by the Exhaust Fans.

(8) During the plant normal operations and fault conditions, the MCR HVAC is designed to maintain a habitable environment and to ensure the operability of nuclear safety components within the MCR by the partial recirculation ventilation method. The MCR is composed of two divisions designated A and B systems. The redundant divisional system is on standby. After a fire event, in case cold smoke is generated within fire area it is discharged to outside by the smoke purge fan which is part of fire protection system.

Upon receipt of any of emergency isolation signals ("high radioactivity of the HVAC exhaust gas in the R/A" and "high radioactivity in fuel handling area"), the Normal Operation Mode Air Intake Dampers close, the Exhaust Air Isolation Dampers close, the Exhaust Fan stops, the Emergency Mode Air Intake Dampers open, the Emergency Filter Train Inlet Damper opens and Recirculation Supply Fan starts. This initiates emergency operation mode. In emergency mode, a positive pressure is maintained in the MCR with respect to the outside atmosphere. The Emergency Filter Train treats a mixture of the MCR recirculated air and outside air to maintain a positive pressure with appropriate air flow rates.

The Emergency Filter Train is capable of filtering and eliminating radiological contamination and hazardous substances within the MCR.

(9) The Control Building Class 2 Electrical Equipment Zone (CBC2EE/Z) HVAC provides ventilation and air conditioning function for the CBC2EE/Z by the partial recirculation ventilation method during the plant normal operations and fault conditions. After a fire event, in case cold smoke is generated within fire area, the ventilation method is changed from partial recirculation to once-through ventilation for smoke purging.

(10) The Rw/B HVAC provides ventilation and air conditioning function for the Rw/B by the once-through ventilation method and maintains a negative pressure within the controlled areas with respect to atmosphere during the plant normal operations. In addition, exhaust air is treated with the HEPA filters before discharging to the main exhaust stack.

Local Safe Change HEPA filter unit is provided for potentially high airborne contamination areas as necessary.

In the event of LOOP, the Rw/B HAVC is inoperable.

(11) The S/B Controlled Area HVAC provides ventilation and air conditioning function for the S/B by the once-through ventilation method and maintains a negative pressure within the controlled area with respect to atmosphere during the plant normal operations. In addition, exhaust air is treated with the HEPA filters before discharging to atmosphere.

The LCU supplement the S/B Controlled Area HVAC to maintain a controlled temperature environment in certain high heat load areas.

The S/B Non- Controlled Area HVAC provides ventilation and air conditioning function for the S/B by partial recirculation ventilation method during the plant normal operations.

The LCUs supplement the S/B Non-Controlled Area HVAC to maintain a controlled temperature environment in certain high heat load areas.

As for the general habitable area, the FCU or Multi-Split ACU is used individually for cooling and heating, to maintain the habitability of the occupants if necessary.

In the event of LOOP, the S/B HAVC is inoperable.

(12) The Backup Building Electrical Equipment Zone (BBEE/Z) HVAC provides ventilation and air conditioning function for the B/B by the partial recirculation ventilation method during the plant normal operations and fault conditions. The BBEE/Z HVAC is composed of two divisions designated A and B systems. Each system serves the divisional BBEE/Z. After a fire event, in case cold smoke is generated within fire area, the ventilation method is changed from partial recirculation ventilation to once-through for smoke purging.
The BBG Room LCU is designed to provide suitable indoor environmental conditions to ensure the continued operation of the BBG during fault conditions. The LCUs are supplied with chilled water by the divisional HBCW.
The BBG Room Emergency Supply Fan provides filtered outside air cooling. The role of the Emergency Supply Fan is to maintain suitable environmental conditions during the loss of cooling by the BBG Room LCU due to failure of the HBCW Chiller.
The BBG is designated A and B. Therefore, the LCU and Emergency Supply Fan are provided with two units per division. The LCUs and Emergency Supply Fans are automatically started upon BBG initiation signals.

(13) During the plant normal operations and fault conditions, the Backup Building Emergency Control Room (BBECR) HVAC is designed to maintain a habitable environment and to ensure the operability of nuclear safety components within the BBECR by the partial recirculation ventilation method. The BBECR HVAC is composed of two divisions designated A and B systems. The redundant divisional system is on standby. After a fire event, in case cold smoke is generated within fire area it is discharged to outside by the smoke purge fan which is part of fire protection system.
Upon receipt of any of emergency isolation signals, the Normal Operation Mode Air Intake Dampers close, the Exhaust Air Isolation Dampers close, the Exhaust Fan stops, the Emergency Mode Air Intake Dampers open, the Emergency Filter Train Inlet Damper opens and Recirculation Supply Fan starts. This initiates emergency operation mode. In emergency mode, a positive pressure is maintained in the BBECR with respect to the outside atmosphere. The Emergency Filter Train treats a mixture of the BBECR recirculated air and outside air to maintain a positive pressure with appropriate air flow rates.
The Emergency Filter Train is capable to filtering and eliminating radiological contaminants and hazardous substances within the BBECR.

(14) The FV/B HVAC provides ventilation and air conditioning function for the FV/B by the partial recirculation ventilation method during the plant normal operations and fault conditions. After a fire event, in case cold smoke is generated within fire area, the ventilation method is changed from partial recirculation to once-through ventilation for smoke purging.

#### 9.3.2.6.4 Other Auxiliary Systems

**(1) Fire Protection System (FP)**

The FP is designed to provide an adequate supply of water or chemicals to points throughout the plant where fire protection is required. Diversified fire detection and fire suppression systems are selected to suit the particular areas or hazards being protected. Appropriate instrumentation and controls are provided for the proper operation of the fire detection, annunciation and fire fighting systems.

**(2) Emergency Power Supply System**

The role of the Emergency Diesel Generator (EDG) is to supply the power needed to shut down the reactor safely when the off-site power is lost and to supply power to the electrical systems supporting the delivery of safety functions if a Loss of Coolant Accident (LOCA) should occur simultaneously.

The role of the Backup Building Generator (BBG) is to supply power to diverse provisions which are necessary for reactor safety in the event of Loss of Off-site Power (LOOP) and LOCA associated with LOOP.
The BBG also has a role as the source of electricity in the event of a severe accident.

The role of the DAG is to supply power needed to shut down the reactor safely when the off-site power is lost and to supply power to the electrical systems supporting the delivery of safety functions in the event of the simultaneous occurrence of LOOP and Common Cause Failure (CCF) of EDGs.

The EDG consists of three independent divisions, A, B, and C. Each division consists of the following main components.
(a) Engine
(b) Generator
(c) DG Fuel Oil System
(d) DG Cooling Water System
(e) DG Lubricant Oil System
(f) DG Compressed Air System
(g) DG Air Intake and Exhaust Gas System

The BBG consists of two independent divisions, system 1 and system 2. Each division consists of the following main components.
(a) Engine
(b) Generator
(c) BBG Fuel Oil System
(d) BBG Cooling Water System
(e) BBG Lubricant Oil System
(f) BBG Compressed Air System
(g) BBG Air Intake and Exhaust Gas System

The DAG consists of the following main components.
(a) Prime Mover
(b) Generator
(c) DAG Fuel Oil System
(d) DAG Lubricant Oil System
(e) DAG Air Intake and Exhaust Gas System

**(3) Suppression Pool Clean-up System (SPCU)**

The SPCU provides an intermittent purification of the S/P water. The system removes impurities by filtration, adsorption, and ion exchange processes. The system consists of a recirculation loop with a pump and isolation valves. Suppression pool water is passed through the FPC filter/demineralisers for treatment. Treated water may be diverted to refill the reactor well and the upper pool during refuelling outage. The SPCU may also provide, if available, makeup water to the fuel pool.

### 9.3.2.6.5 Severe Accident Management System

**(1) Flooder System of Specific Safety Facility (FLSS)**

The FLSS provides cooling water to a variety of destinations in the R/B to maintain cooling of the reactor, prevent damage of the PCV and keep sufficient water in spent fuel storage pool in the event of a Severe Accident (SA). Major components and control panels

of the FLSS are located and operated at control panels in Backup Building (B/B).

**(2) Flooder System of Reactor Building (FLSR)**

In the event of a Severe Accident the FLSR provides cooling water to variety of destinations via mobile pumps located outside the R/B. The FLSR water injection lines in R/B are shared with FLSS. This configuration enables the FLSR to work as a diverse means of supplying water to the FLSS.

**(3) Filtered Containment Venting System (FCVS)**

The purpose of the FCVS is to prevent damage to the PCV due to overpressure and prevent the consequential release of large quantities of fission products in the event of a Severe Accident. The FCVS filters the radioactive iodine and long-half life fission products (Cs) generated during severe accident in the PCV through the Vent Filter device. The FCVS releases non-condensable gases and steam through the main stack to prevent damage to the PCV due to overpressure.

**(4) Lower Drywell Flooder System (LDF)**

The LDF provides water to the Lower drywell from the Suppression Pool (S/P) in the unlikely event of a Severe Accident where the core melts and causes a subsequent vessel failure to occur and deposition of debris on the lower drywell floor. LDF operates automatically in a passive manner due to the activation of thermally activated plugs called Fusible Plugs (FPLGs).

**(5) Alternate Heat Exchange Facility (AHEF)**

The purpose of the AHEF is to recover cooling capacity of any one division of RHR by connecting the mobile alternate cooling unit after moving it beside the R/B in the event that the functions of RCW or RSW are lost. The AHEF removes heat of a RHR Heat Exchanger by supplying cooling water via RCW from the Mobile AHEF Cooling Unit which has AHEF Cooling Water Pumps and AHEF Heat Exchangers. The AHEF Heat Exchangers are cooled with service water driven by the Mobile AHEF Service Water Pumps.

**(6) Reactor Depressurisation Control Facility (RDCF)**

The RDCF depressurises the RPV when the ADS function is unavailable to enable the provision of cooling water to the RPV through the FLSS and FLSR. The RDCF consists of dedicated solenoid valves for the SRV and nitrogen feeder both installed in the R/B and are operable from control panels in B/B.

**(7) Alternative Nitrogen Injection System (ANI)**

The role of the ANI is to keep the hydrogen concentration inside the PCV below the lower flammability limit by supplying nitrogen gas into the PCV and to prevent PCV breach due to negative pressure caused by restarting the PCV cooling by the RHR. The ANI supplies nitrogen gas to the both sides of the W/W and the D/W in order to inactivate PCV atmosphere in the terminating phase after severe accident where PCV venting is operated. Nitrogen injection is carried out by the mobile nitrogen gas supply facility.

### 9.3.2.7 Steam and Power Conversion System

A detailed description is provided in generic PCSR Chapter 17: Steam and Power Conversion Systems.

#### 9.3.2.7.1 Turbine Generator

The main role of the Turbine Generator is to covert the thermal energy of the steam to electrical energy.
The turbine is of a tandem-compound 6 flow exhaust condensing-type. It consists of a double-flow High Pressure Turbine and 3 double-flow Low Pressure Turbines. The steam from the reactor passes through 4 Main Steam Valves (MSVs) and is controlled by 4 Steam Control Valves (CVs). After leaving the CVs, the steam is taken by 4 steam leads to 2 inlets in the lower casing and 2 inlets in the upper casing into the double-flow High Pressure Turbine.
After the steam expands at the HP turbine, it passes through 4 cold reheat lines from the lower casing and is taken to 2 Moisture Separator Reheaters (MSRs). The steam is dried and reheated in the MSRs.
Reheated steam leaves the 2 MSR vessels through 6 hot reheat pipes flowing through the 6 Combined Intermediate Valves (CIVs) then to the 6 Low Pressure Turbine inlets. Then the steam passes out through the exhaust outlets and is condensed into the condenser.
The generator is a direct-driven, three-phase, 50Hz, 1,500min$^{-1}$, four-pole synchronous generator with water-cooled stator and hydrogen cooled rotor. It converts the mechanical energy into electrical energy.
The generator is provided with gas control system, shaft sealing oil system and stator cooling water system in order to support the generator operation.

#### 9.3.2.7.2 Turbine Main Steam System

The Turbine Main Steam supplies steam generated from the reactor to drive the steam turbine and also to supply steam to the Turbine Auxiliary Steam (AS) and the Turbine Bypass System (TBP).

The AS supplies driving steam to the Reactor Feedwater Pump Turbine (RFP-T) and the Steam Jet Air Ejector (SJAE), and supplies heating steam to the Moisture Separator Reheater (MSR) and the Gland Steam Evaporator (GSE).

The TBP releases steam from the reactor to the condenser for reactor internal pressure control during the Startup and System Shutdown or when the reactor steam production exceeds turbine steam demand.

#### 9.3.2.7.3 Extraction Steam System

The Extraction Steam System (ES) supplies High Pressure Turbine (HP-T) exhaust steam to the Low Pressure Turbine (LP-T) through Moisture Separator Reheaters (MSRs). The ES supplies required heating steam to the Feedwater Heaters (FWHs) and MSR 1st Stage Reheater (MSR-1RH) from the HP-T and LP-Ts and processes condensate separated in the turbine stage to increase the plant thermal efficiency. The ES supplies steam required to drive Reactor Feedwater Pump Turbine (RFP-T) from the cross-around pipe at the MSR outlet. The ES supplies GSE heating steam at plant high load.

#### 9.3.2.7.4 Turbine Gland Steam System

The Turbine Gland Steam System (TGS) supplies sealing steam to the turbine shaft seal parts and the major valve gland parts to prevent leaking air into the condenser.

#### 9.3.2.7.5 Feedwater Heater Drain & Vent System

The Feedwater Heater Drain System (HD), the Feedwater Heater (FWH) and Moisture Separator Reheater (MSR) drain to heat feedwater to improve plant thermal efficiency. The High Pressure (HP) FWH drain is directly recovered on the Reactor Feedwater Pump (RFP) suction side, and the Low Pressure (LP) FWH drain is directly recovered on the High Pressure Condensate Pump (HPCP) suction side to further improve plant thermal efficiency and reduce the capacity of the Condensate and Feedwater System (CFDW) facility.
The Feedwater Heater Vent System (HV) discharges non-condensable gases from the FWHs to prevent a reduction in their heat transfer performance. Non-condensable gases from the MSR 1st and 2nd Stage Reheaters (MSR-1/2RHs) are discharged through their outlet header with steam to prevent overcooling of the heat transfer tubes. The HV is also equipped with FWH shell relief valves to protect the FWHs against damage due to excessive pressure in case of a tube leak.

#### 9.3.2.7.6 Condenser

The condenser cools steam to reuse as feedwater to the reactor. The condenser is also used to deaerate condensate and recover drain/steam from the respective systems.

#### 9.3.2.7.7 Circulating Water System

The Circulating Water System (CW) supplies cooling water to the condenser and cool the turbine exhaust and drain.

#### 9.3.2.7.8 Condensate and Feedwater System

The CFDW supplies feedwater from the condenser to the reactor, at the required flow rate, pressure and temperature.

#### 9.3.2.7.9 Condensate Purification System

The Condensate Purification System (CPS) consists of the Condensation Filter System (CF) and the Condensation Demineraliser System (CD) in series to remove soluble and insoluble impurities in the condensate and satisfy the water quality requirements.

### 9.3.2.8 Radioactive Waste Management

A detailed description is provided in Chapter 18: Radioactive Waste Management of the generic PCSR.

#### 9.3.2.8.1 Liquid Radioactive Waste Management System

The liquid waste generated in the controlled areas is segregated based upon the chemical impurity and radioactivity and is processed by the LWMS.

Wet solid waste that is generated within the LWMS (e.g. filter sludge and used demineraliser resin) is collected in tanks prior to transfer to the Solid Waste Management System (SWMS) where it is processed by the Wet-solid ILW or Wet-solid LLW Processing System, as appropriate.

The LWMS is housed in the Rw/B and S/B, and consists of the following subsystems:

- Low Chemical Impurities Waste (LCW) subsystem
- High Chemical Impurities Waste (HCW) subsystem
- Laundry Drains (LD) subsystem
- Controlled Area Drains (CAD) subsystem
- Spent Resin and Sludge (SS) system
- Concentrated Waste System

The LCW system is housed in the Rw/B and is one of two subsystems (the other being the HCW subsystem) which are used to treat radioactively or potentially radioactively contaminated waste water. The LCW system is designed to allow the efficient treatment of relatively large volumes of waste water containing low levels of both insoluble and soluble impurities. The LCW system treats the waste waters which are then returned to the Condensate Storage Tank for reuse.

The HCW system is housed in the Rw/B and is one of two subsystems (the other being the LCW subsystem) which are used to treat radioactively or potentially radioactively contaminated waste water. The HCW Treatment System is designed to allow the efficient treatment of waste water containing high levels of soluble impurities. Treated water is either transferred to the Condensate Storage Tank for reuse or, in limited circumstances where there is not the capacity in the reactor system for re-use, disposed of to the environment following monitoring.

The CAD system collects water from the local air-conditioning system drains in the R/B and T/B, and also from the potentially contaminated drains of various equipment systems in the controlled areas of the R/B and the T/B. Liquid waste in the CAD System is not expected to be radioactive but has the potential to be contaminated.

The LD system processes waste water originating from the laundry and the S/B showers and hand washing facilities. These waste water streams contain detergent, suspended solids and organic material, as well as potentially low levels of radioactive crud, and are therefore unsuitable for re-use in a reactor system.

The SS system collects and stores the following secondary wastes in tanks before being transferred for solidification:

- Spent bead (ion exchange) resins from the CD, LCW and HCW demineralisers.
- Powder resin from the Reactor Water Clean-Up System (CUW) and Fuel Pool Cooling and

Clean-up System (FPC).
- Filter crud from Condensate Filter (CF) and LCW filter.

The purpose of the concentrated waste system (CONW) is to receive and store concentrated waste from the bottoms circuit of the HCW evaporator and then send it to the Wet-solid LLW solidification system. The concentrated waste from the HCW evaporator is collected and stored in a concentrated waste tank.

#### 9.3.2.8.2 Off-Gas Radioactive Waste Management System

The Off-Gas System (OG) is a key system of the UK ABWR design, which has the primary functions of maintaining the main Condenser vacuum by extracting non-condensable gas, providing abatement of radioactive species prior to atmospheric discharge, and recombining radiolytic hydrogen and oxygen generated in the reactor. Through performing these functions, the OG reduces the radiological release from the UK ABWR during normal conditions.

The OG is designed to perform the following functions:

- The OG extracts air and non-condensable gases ($H_2$ and $O_2$) from the main Condenser to achieve and maintain the main Condenser vacuum.
- The OG recombines hydrogen and oxygen to reduce the possibility of hydrogen combustion.
- The OG sufficiently reduces the radiological release to the environment during start-up, power and shutdown operation.
- The OG minimises the public and worker dose from the OG system faults.
- The OG reduces hydrogen combustion risk in the OG system faults.

#### 9.3.2.8.3 Solid Radioactive Waste Management System

The Solid Waste Management System (SWMS) has been designed to concept level to receive, sort and process/condition Very Low Level Waste (VLLW), Low Level Waste (LLW), Intermediate Level Waste (ILW) and High Level Waste (HLW) waste streams resulting from UK ABWR operation. Following processing and conditioning, VLLW/LLW is dispatched off-site for disposal either by incineration, recycling (in the case of recyclable metals) or direct disposal ILW is transferred for interim storage (pending availability of the Geological Disposal Facility (GDF)) in an on-site ILW store and HLW is dry stored on-site prior to disposal at GDF.

The SWMS concept design currently comprises the following facilities/systems:

- Wet-solid ILW Processing System (part of the Rw/B)
- Wet-solid LLW Processing System (part of the Rw/B)
- HLW decay storage facility
- ILW Store
- Solid Waste Processing including the LLW Monitoring and Marshalling Area (MMA), LCW Filter Packaging Room and Solid Waste Facility (SWF)
- Transportation of wastes on and off-site

### 9.3.2.9 Fuel Storage and Handling

A detailed description is provided in generic PCSR Chapter 19: Fuel Storage and Handling.

#### 9.3.2.9.1 New Fuel Storage & Spent Fuel Storage

**(1) Fuel Storage Facility**

New and spent fuel storage racks are designed to prevent inadvertent criticality. Sufficient cooling and shielding are provided in the spent fuel storage pool to prevent excessive pool heat up and personnel exposure. The design of the spent fuel storage pool provides for corrosion resistance and maintains subcritical conditions.

#### 9.3.2.9.2 Fuel Cooling and Clean-up System (FPC)

The Fuel Pool Cooling and Clean-up System (FPC) continuously maintains the fuel pool water level, and water temperature, and keeps water quality of the Spent Fuel Storage Pool (SFP) within the specified limits during all modes of plant operation. The FPC includes pumps and heat exchangers, each capable of removing the decay heat generated from a normal discharge of spent fuel, and filter/demineralisers, each unit having the capacity to process the system design flow to maintain the desired purity level.

#### 9.3.2.9.3 Reactor Building

**(1) Refuelling Equipment**

The fuel servicing equipment includes Reactor Building Overhead Crane (RBC), Fuel Handling Machine (FHM), and other related tools for reactor servicing.

The RBC handles the spent fuel cask from the cask pit to the truck bay. The FHM transfers the fuel assemblies between the storage area and the reactor core. New fuel bundles are handled by the RBC.

The handling of RPV head and PCV head during refuelling is carried out using the RBC.

**Refuelling Interlocks**

A system of interlocks that restricts movement of FHM and control rods when the reactor is in the refuelling and start up modes is provided to prevent an inadvertent criticality during refuelling operation. The interlocks affect movement of the FHM, hoists, Grapple, and control rods.

**(2) Miscellaneous Servicing Equipment**

The miscellaneous servicing equipment includes general handling fuel pool tools such as actuating poles with various end configurations. General area underwater lights and support brackets are provided to allow the lights to be positioned over the area being serviced independent of the platform. A general-purpose, plastic viewing aid is provided to float on the water surface to provide better visibility. A portable underwater closed circuit television camera may be lowered into the reactor vessel pool and/or the fuel storage pool to assist in the inspection and/or maintenance of these areas.

**(3) Reactor Pressure Vessel Servicing Equipment**

Equipment associated with servicing the reactor pressure vessel is used when the reactor is shutdown and the Reactor Pressure Vessel Head is being removed or installed. Tools used consist of strongbacks, nut racks, stud tensioners, protectors, wrenches. etc.

**(4) RPV Internal Servicing Equipment**

The majority of internal servicing equipment is designed to be attached to the FHM RIP Inspection Hoist and used when the reactor is open. A variety of equipment (e.g., grapples, guides, plugs, holders, caps, strongbacks and sampling stations) is used for internal servicing. The RIP handling devices are also included.

**(5) Under-vessel Servicing Equipment**

This equipment is used for the installation and removal work associated with the fine motion control rod drive (FMCRD), RIP and In-Core Monitor (ICM). A handling platform provides a working surface for equipment and personnel performing work in the under-vessel area. The polar platform is capable of rotating 180 degrees in either direction and has an FMCRD handling trolley with full traverse capability across the vessel diameter. All equipment is designed to minimise radiation exposure, contamination of surrounding equipment and reduce the number of workers required.

**(6) CRD Maintenance Facility**

The CRD maintenance facility is located close to the primary containment and is designed and equipped for maintenance of the FMCRD, provide for decontamination of the FMCRD components, perform the acceptance tests and provide storage.

**(7) Reactor Internal Pump Maintenance Facility**

The RIP maintenance facility is located in the Reactor Building and is designed for performing maintenance work on the motor assembly and related parts. The facility is designed to handle one motor assembly including decontamination in its assembled and disassembled states. The facility is equipped with all tools needed for inspection of motor parts and heat exchanger tube bundles. RIP handling tools associated with handling the impeller and diffuser are stored on the refuelling floor where they are used.

## 9.3.2.10 Human Machine Interface

A detailed description is provided in generic PCSR Chapter 21: Human-Machine Interface.

### 9.3.2.10.1 HMIs in the Main Control Room (MCR)

The HMIs in the MCR consists of Main Control Console (MCC), the Wide Display Panel (WDP), Hardwired Backup Panel (HWBP) and the Safety Auxiliary Panels (SAuxPs). In addition, desks for Main Control Room Supervisor (MCRS) and Control Room Operators (CROs) are installed to achieve safety functions during normal operation and fault condition, including severe accident if possible.
In summary:
(1) The MCC is equipped with Flat Displays (FDs) which are used for control and monitoring and Plant-level Flat Displays (PFDs) which show plant-level information and physical switches. The MCC is also equipped with the dedicated HMIs for the SSLC.
(2) The WDP provides plant-level information such as alarms or key plant parameters and plant status to be shared and understood among personnel within the MCR.
(3) The SAuxP is designed to consider Common Cause Failure (CCF) of HMI or the SSLC, which applies hardwired logic for Class 1 SSCs such as HPCF, RHR.
(4) HWBPs which are used for Class 2 to deliver Category A safety function are designed to deliver safety functions in case Class 1 SSCs fails to deliver their safety functions.

### 9.3.2.10.2 HMIs in the Remote Shutdown System (RSS) Control Panel Rooms

The controls and information and HMIs are provided outside the MCR, in order to bring the reactor from hot shutdown to cold shutdown in the event that an anticipated internal fire in the MCR leads to the evacuation of operators. HMIs including indicators, controls and switches which transfer controls with priority of controls from the HMIs in the MCR to the HMIs in the RSS control panel room are installed on the Remote Shutdown Panels (RSPs) located in the RSS control panel rooms. The RSS control panel rooms are situated in a separate location with enough distance from the MCR so that they are not both simultaneously affected by the same hazard.

### 9.3.2.10.3 HMIs in the Backup Building Control Panel Room

HMIs in the B/B control panel room are provided to control and monitor SSCs controlled by SA C&I, such as the FLSS and the RDCF.

### 9.3.2.10.4 HMIs in the Radwaste Building Main Control Room (Rw/B MCR)

Liquid radioactive Waste Management System (LWMS) is controlled and monitored from HMIs in the Rw/B MCR. The SSCs of Solid Radioactive Waste Management System (SWMS) are controlled and monitored from separate control rooms within each facility including Rw/B MCR.

### 9.3.2.11 Reactor Chemistry

A detailed description is provided in generic PCSR Chapter 23: Reactor Chemistry.

#### 9.3.2.11.1 Chemical Injection System (CIS)

For the contribution to maintain the structural integrity, Hydrogen ($H_2$) is injected from the CFDW in order to mitigate the corrosion environment in the reactor by the recombination reaction between Oxygen ($O_2$) and $H_2$. In order to treat excess $H_2$ by $H_2$ injection, $O_2$ is injected from the inlet of OG recombiner.

For the contribution to maintain the structural integrity, Pt is injected from the FDW in order to enhance the recombination reaction on the surface of SSCs by $H_2$ injection.

For the reduction of radiation exposure for the workers, Zn is injected from FDW in order to prevent the incorporation of Co-60 and Co-58 into the surface layer of SSCs.

#### 9.3.2.11.2 Oxygen Injection System (OI)

$O_2$ is injected in order to improve the anti-corrosion effect on pipelines, into the main condensate pipeline to form stable protective iron oxide films on the inner wall surfaces of equipment and pipes that constitute the CFDW.

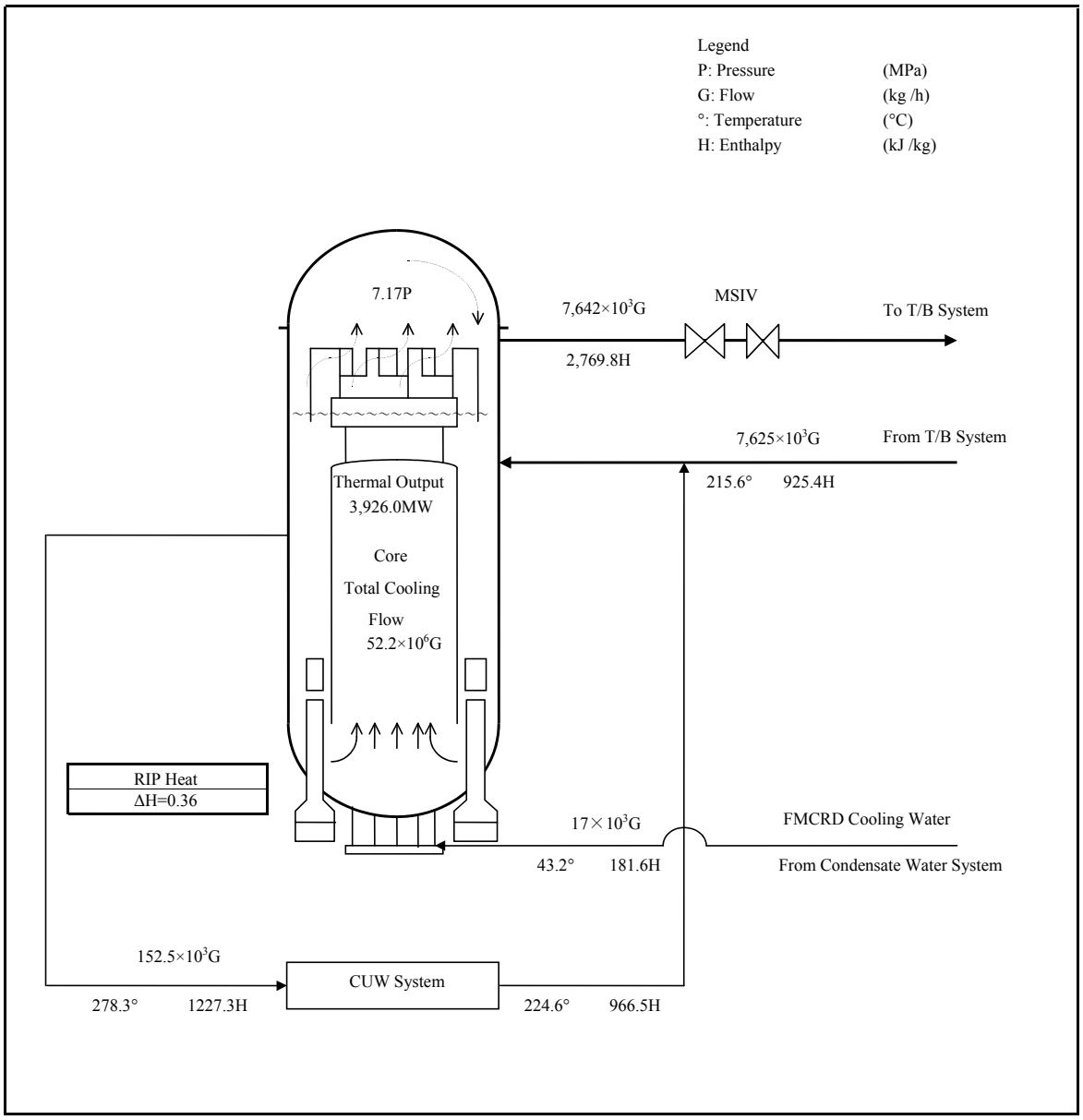



**Figure 9.3-1：Nuclear boiler system Heat Balance outline (HB design conditions)**

## 9.4 Facility Layout

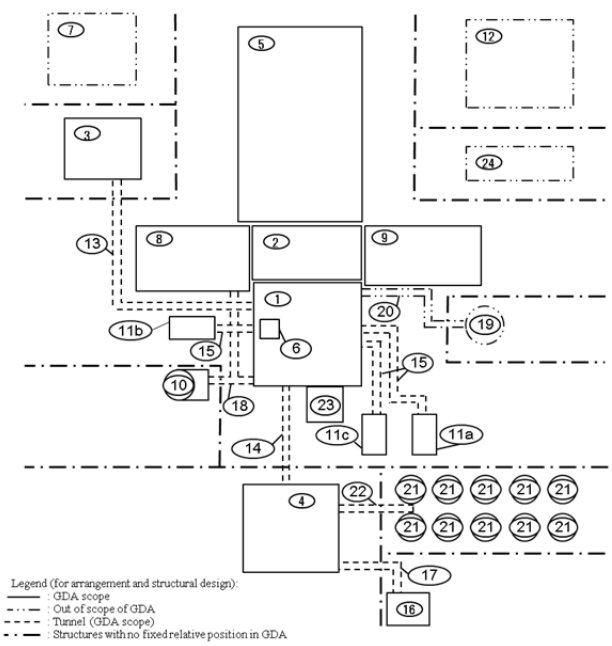
### 9.4.1 Plant Arrangement

The standard UK ABWR plant arrangement consists of the following main buildings:

- Reactor Building (R/B)
- Control Building (C/B)
- Heat Exchanger Building (Hx/B)
- Turbine Building (T/B)
- Radwaste Building (Rw/B)
- Service Building (S/B)
- Backup Building (B/B)
- Emergency Diesel Generator Building (EDG/B)

The standard plant is located on a site adjacent or close to a body of water with sufficient capacity for all cooling requirements.

The C/B houses the main control room and is located centrally as the hub of the plant operators' activities. The T/B is oriented to minimise the probability of a turbine missile strike, such that any plane perpendicular to the turbine generator axis does not intersect with the R/B and C/B. The standard UK ABWR plant arrangement is shown in Figure 9.4-1. Chapter 10: Civil Works and Structures of this generic PCSR describes safety requirements and design principles of UK ABWR civil structures within the GDA scope.




| No. | FACILITY |
|---|---|
| 1 | REACTOR BUILDING (R/B) |
| 2 | CONTROL BUILDING (C/B) |
| 3 | HEAT EXCHANGER BUILDING (Hx/B) |
| 4 | BACKUP BUILDING (B/B) |
| 5 | TURBINE BUILDING (T/B) |
| 6 | MAIN STACK |
| 7# | CIRCULATING WATER STRUCTURE (CW/S) |
| 8 | RADWASTE BUILDING (Rw/B) |
| 9 | SERVICE BUILDING (S/B) |
| 10 | CONDENSATE STORAGE TANK (CST) STRUCTURE |
| 11 | EMERGENCY DIESEL GENERATOR BUILDING (EDG/B) |
| 12# | SPENT FUEL STORAGE FACILITY |
| 13 | RCW TUNNEL, 3 connected cells |
| 14 | R/B-B/B CONNECTING SERVICE TUNNEL, 2 connected cells |
| 15 | R/B-EDG/B CONNECTING SERVICE TUNNEL, 1 cell * 3 division |
| 16 | LIGHT OIL STORAGE TANK (LOT) FOUNDATION |
| 17 | B/B-LOT CONNECTING SERVICE TUNNEL, 1 cell |
| 18 | R/B-CST-Rw/B CONNECTING SERVICE TUNNEL, 1 cell |
| 19# | SUPPRESSION POOL TANK (SPT) STRUCTURE |
| 20# | R/B-SPT CONNECTING SERVICE TUNNEL |
| 21 | FLSS WATER STORAGE TANK (FLSS WST) FOUNDATION |
| 22 | B/B-FLSS WST CONNECTING SERVICE TUNNEL, 2 connected cells |
| 23 | FILTER VENT BUILDING (Fv/B) |
| 24# | DIVERSE ADDITIONAL GENERATOR (DAG) AREA |

Note:
1. This drawing is only indicative. Final position of structures will be based on site location. Refer to each structural design report for the assumed size in GDA.
2. The civil engineering, i.e. general arrangement and structural design, of No.7, 12, 19, 20, 24 (shown with "#" in the table above) are NOT included in the GDA.

**Figure 9.4-1 : Generic Site Plan**

### 9.4.2 Plant Arrangement Considerations

The UK ABWR plant arrangement is designed with the following plant arrangement considerations.

**(1) Protection against Internal and External Hazards**

Divisional separation between the safety trains is arranged to ensure independency of a safety train during an internal hazard. The separations are achieved by reinforced concrete walls and slabs to prevent damage from hazards such as internal fire, flooding, missiles and explosion propagating from other safety divisions. Massive exterior walls, slabs and roofs are provided to protect SSCs inside the building from external hazards. Chapter 6: External Hazards and Chapter 7: Internal Hazards of this generic PCSR describe the internal and external hazards assessment. Chapter 10: Civil Works and Structures of this generic PCSR provides more information about safety requirements and design principles of UK ABWR civil structures within the GDA scope.

**(2) Minimising Dose**

The UK ABWR civil structures separate clean and radiation controlled areas within the buildings to minimise personnel exposure during operation and maintenance. Access routes from change rooms to contaminated areas are as direct as possible and are clearly separated from clean access ways. The SSCs that include higher dose are isolated from lower dose rate areas by concrete shielding walls and slabs. Access pathways are designed to maintain lower dose rates by appropriate shielding. Chapter 20: Radiation Protection of the GDA PCSR describes shielding design and ALARP strategies for effective radiation protection.

**(3) Plant Access and Maintenance**

Access pathways are provided for all surveillance, maintenance and replacement activities. At each floor, 360° access corridor is provided, if practicable. This concept enables direct access to each equipment room without interactions with other rooms. The 360° access corridor also provides more than one path to any point within a building to enhance redundancy of access to control functions that may require local manual intervention and evacuation from a hazardous situation.

Access to equipment above floor level is via platform stair access wherever practicable. Adequate headroom and maximum escape travel distances are incorporated in accordance with British Standards where appropriate; however where nuclear safety requirements govern, additional justification is given.

Laydown space and local service areas are provided for maintenance and replacement of equipment. Adequate hallways and equipment removal paths, including vertical access hatches are provided for moving equipment from its installed position to its service area or out of the building for repair or decommissioning. Decommissioning is discussed in more details in Chapter 31: Decommissioning of the PCSR.

Lifting devices including cranes, chain blocks and monorail are provided to facilitate equipment handling and minimise the need for re-rigging individual equipment movements.

The UK ABWR concept for access and maintenance provisions described above ensures that:

- the access for operating staff is appropriate and safe and complies with UK regulations and practice,

- the necessary maintenance for 60 years safe operation of the plant can be carried out, and
- the access for decommissioning activities is provided in line with the UK ABWR decommissioning strategy.

### 9.4.3 Characteristics of the Main Buildings

**(1) Reactor Building**

The Reactor Building (R/B) houses the reactor pressure vessel, the containment, major portions of the reactor steam supply system, steam tunnel, refueling area, emergency core cooling systems, heating ventilation and cooling (HVAC) systems and additional supporting systems.

The primary containment structure is the reinforced concrete containment vessel (RCCV). The secondary containment is the R/B reinforced concrete building structure that forms the external weather envelope. The secondary containment boundary encloses the RCCV primary containment above the basemat.

The R/B is segregated into three plant divisions; these are separated by internal walls constructed of substantial reinforced concrete in order to provide the robust barriers required.

**(2) Control Building**

The Control Building (C/B) includes the main control room (MCR), the computer facility, the cable tunnels, some of the plant essential switchgear, some of the essential power and the essential HVAC system. The main steam tunnel from the R/B to the T/B passes through the C/B at ground floor level.

**(3) Heat Exchanger Building**

The Heat Exchanger Building (Hx/B) is a structure which houses portions of the Reactor Building Cooling Water (RCW) System and Turbine Building Cooling Water (TCW) System. The Hx/B is located adjacent to the intake point of the plant cooling water system.

**(4) Backup Building**

The Backup Building (B/B) provides an alternative safety management capacity for accident management and diverse provision of Category A safety functions for frequent faults. The building houses an alternative alternating current (AC) power source as well as Instrumentation & Control (I&C) facilities. An alternative water source is also available via a water tank adjacent to the building. The building also includes transportable RCW replacement, water injection pumps and nitrogen supply facilities.

**(5) Turbine Building**

The Turbine Building (T/B) houses all equipment associated with the main turbine generator. Other auxiliary equipment is also located in this building.

**(6) Radwaste Building**

The Radioactive Waste Building (Rw/B) houses all equipment associated with the collection and processing of the solid and liquid radioactive waste generated by the plant.

**(7) Service Building**

The Service Building (S/B) is the entrance building to the plant main island, including clean area, radiation controlled area and main control room. The building houses change rooms, lockers, entry and exit hall, offices for normal operations and outage, hot laundry and separate HVAC plant for the clean and radiation controlled area.

**(8) Emergency Diesel Generator Building**

The UK ABWR provides three Emergency Diesel Generator Buildings (EDG/B) to allow each safety division its own dedicated EDG/B. Each EDG/B is a structure which houses

the engine, generator, fuel oil system, air intake and exhaust system and other related facilities for the Emergency Diesel Generator System. Each building also includes a light oil storage tank for 7 days operation of the emergency diesel without supply from the outside.

Chapter 10: Civil Works and Structures of this generic PCSR discusses safety requirements and design principles of the buildings stated in this chapter.

## 9.5 Conclusion

This chapter (Chapter 9: General Description of the Unit (Facility)) describes as follows:

- Describe the overall arrangement of the unit itself, including brief descriptions of the buildings and structures,
- Provide a high level summary description of the functions of the key systems, structures and components of the UK ABWR and provide links to the corresponding chapters in the Generic PCSR where detailed information in provided,
- Provides key specification of the UK ABWR ex. Plant Output, Key SSCs and features,
- Description of the layout of the key structures of the UK ABWR plant – on a generic site, and
- It defines the buildings and structures included in the scope of GDA.

## 9.6 References

This chapter is supported by other PCSR chapters as shown in section 9.1.2.