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UK ABWR Generic Design Assessment

Generic PCSR Sub-chapter 15.4 : Electrical Equipment

Hitachi-GE Nuclear Energy, Ltd.

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Table of Contents

15.4.1 Grid Connection

15.4.1.1 Introduction

The ABWR is connected to the external grid via a main connection and a standby connection. The main connection is the connection between the generator transformer (GT) and the external grid. The standby connection is the connection between the auxiliary standby transformer (AST) and the external grid.

During normal plant operation, on-site electrical power is supplied from the generator via the auxiliary normal transformer (ANT). At plant startup or shutdown, the main generator is disconnected by the generator load switch (GLS) and on-site electrical power is supplied from the main connection via the generator transformer and the auxiliary normal transformer. The standby connection backs up the main connection.

The generator disconnecting switch (GDS) is installed on the grid side of the GLS. The GDS is closed during normal plant operation, and opens for maintenance of the GLS or the generator to disconnect the circuit after GLS opens.

The role of the grid connection is to transmit the electrical power generated in the ABWR plant to the external grid and to supply reliable power to the unit auxiliaries including the engineered safety systems during both normal operation and design basis faults. Normally, this function is performed by the main connection. When the main connection is not available due to maintenance or fault condition, the standby connection backs the main connection and supplies power to the unit auxiliaries via the auxiliary standby transformer.
If both connections are unavailable simultaneously, the unit auxiliary loads connected to the safety Class 1 buses are supplied from E D/Gs.

15.4.1.2 Scope

This section provides a description of the design and architecture for the grid connection. The grid connection system consists of following:

(1) The external grid transmission network
(2) The plant switchyard
(3) The connection lines from the plant switchyard to the GT, and to the AST
(4) GT
(5) AST
(6) ANT
(7) The main generator
(8) The isolated phase buses from the main generator to GT, and to ANT
(9) GLS
(10) GDS
(11) The non-segregated phase buses from ANT to the input terminals of the safety Class 3 medium voltage buses
(12) The non-segregated phase buses from AST to the input terminals of the safety Class 3 medium voltage buses

15.4.2 Transformers

15.4.2.1 Introduction

Transformers used in this plant and the roles of these transformers are as follows;

Generator Transformer …	Raises the generator voltage to the external grid voltage during normal plant operation. Also, at plant startup or shutdown, the generator transformer steps down the external grid voltage to the generator voltage.
Auxiliary Normal Transformer…	Steps down the generator voltage to the medium-voltage bus voltage.
Auxiliary Standby Transformer…	Steps down the external grid voltage to the medium-voltage bus voltage.

The electrical power generated by the generator is transmitted to the external grid via the generator transformer. During normal plant operation, unit auxiliary power is supplied from the generator via the auxiliary normal transformer. At plant startup or shutdown, the main generator is disconnected by the GLS and on-site electrical power is supplied from the main connection via the generator transformer and auxiliary normal transformer. When the main connection is not available or when a fault occurs on the generator voltage system, the generator transformer or auxiliary normal transformer, unit auxiliary power is supplied by standby connection via the auxiliary standby transformer.

When a fault occurs on the GT or ANT, the main generator will be tripped. This will result in a reactor scram.

These transformers are classified into Class3. Also, the AST is used as external power receiving equipment when the GT or ANT is not available. Thus, the AST is also classified into Class 3.

If the GT, ANT, and AST are not available simultaneously, the power supplies to structures, system and components (SSCs) providing the Category A safety functions will be supplied from the E D/Gs.

15.4.2.2 Generator Transformer (GT)

The GT raises the main generator voltage to the external grid voltage during normal plant operation. At plant startup, shutdown or when the reactor and turbine are unavailable, the main generator is disconnected by the GLS and on-site electrical power is supplied from the main connection via the generator transformer and auxiliary normal transformer.

When the power is supplied from the external grid, the GT steps down the external grid voltage to the generator system voltage. In addition, the ANT steps down the generator system voltage to the voltage of the medium voltage buses.

15.4.2.3 Auxiliary Normal Transformer (ANT)

The ANT steps down the main generator voltage to the medium-voltage bus voltage. During plant normal operation, the ANT is supplied from the main generator. At plant startup, shutdown or when the reactor and turbine are unavailable, the ANT is supplied from the external grid via the GT.

15.4.2.4 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 AST. The AST steps down the external grid voltage to the medium-voltage bus voltage.

15.4.3 Auxiliary Distribution buses

Auxiliary AC power distribution systems consist of three groups according to role carried out;

Safety Class 3 buses – supplied from ANT or AST

Safety Class 1 buses – supplied from safety Class 3 medium voltage buses or E D/Gs

B/B Class 2 buses – supplied from safety Class 3 medium voltage buses or A/Gs

15.4.3.1 Safety Class 3 AC Power Distribution System

15.4.3.1.1 Safety Class 3 Medium Voltage Distribution System

The safety Class 3 medium-voltage buses supply power to the loads necessary during normal operation. Since normal loads are under safety Class 3 equipment, the safety Class 3 medium-voltage buses are classified into class 3 (the detailed list of the loads which are connected to safety Class 3 buses is to be shown in supporting documents such as [Ref-1], [Ref-2], [Ref-3] in the following GDA steps). The normal loads are generally arranged into 2 redundant groups so the safety Class 3 medium-voltage buses are divided into two groups (A and B). Also, in consideration of the total capacity of the loads which are connected to safety Class 3 medium-voltage buses and the capacity of buses and circuit breakers applicable, safety Class 3 medium-voltage buses of standard ABWR plant consist of four (4) buses (A-1, A-2 and B-1, B-2).

During plant startup or shutdown, these buses receive power from the external grid via the GT and ANT. After the main generator is synchronized and connected to the external grid, these buses receive power from the main generator via the auxiliary normal transformer.

If an electrical fault occurs in the generator main circuit which includes the main generator, excitation system, GT and ANT, the electrical protection relays installed to protect the generator main circuit detect the fault and send a trip signal to the GT circuit breaker (CB), the incoming CBs of the safety Class 3 medium-voltage buses from ANT and the main generator field switch (FS) to isolate the affected zone.

After tripping the incoming CBs of safety Class 3 medium-voltage buses from ANT, the incoming CBs of the safety Class 3 medium-voltage buses from AST are closed automatically.

As described above, safety Class 3 buses have two possible sources of power (ANT side and AST side). During plant normal operation, only the ANT side incoming CB is closed.

The design includes the capability to manually switch the safety Class 3 buses to the AST side with power interruption or using check synchronizing.

15.4.3.1.2 Safety Class 3 Low Voltage Distribution System

15.4.3.1.2.1 Power Centers

Electrical power for the safety Class 3 low-voltage auxiliaries is supplied from power centers (P/Cs) which consist of medium-voltage/low-voltage transformers and associated switchgear.

The low-voltage power centers are sized to supply motor control centers (MCCs) and motor loads greater than 90kW, and not greater than 300kW in principle.

15.4.3.1.2.2 Motor Control Centers

The safety Class 3 low-voltage MCCs are sized to supply power to auxiliary loads of not greater than 90kW in principle.

15.4.3.1.3 Safety Class 1 AC Power Distribution System

15.4.3.1.3.1 The Safety Class 1 Medium Voltage Distribution System

The safety Class 1 medium-voltage buses supply power to the safety Class 1 SSCs supporting the delivery of Category A safety functions. Each of these buses is normally supplied from a specific safety Class 3 medium-voltage bus.

15.4.3.1.3.2 The Safety Class1 Low Voltage Distribution System

15.4.3.1.3.3 Power Centers

Electrical power for the Class 1 low-voltage auxiliaries is supplied from P/Cs which consist of medium-voltage/low-voltage transformers and associated switchgear.

The safety Class 1 low-voltage buses are fed by their own power transformer.

The low-voltage power centers are sized to supply MCCs and motor loads greater than 90kW, and not greater than 300kW in principle.

15.4.3.1.3.4 Motor Control Centers

The safety Class 1 low-voltage MCCs are sized to supply power to auxiliary loads of not greater than 90kW in principle.

15.4.3.1.4 B/B Class 2 AC Power Distribution System

15.4.3.1.4.1 The B/B Class 2 Medium Voltage Distribution System

The B/B Class2 medium-voltage 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. Since the Class 2 FLSS is a 2×100% system, the backup-building medium-voltage buses consist of two systems (M/C-B/B1 and M/C-B/B2). In normal operation the B/B needs power supply to maintain battery chargers, Heating Ventilating and Air Conditioning system (HVAC), Alternative AC generator (A/G) starting system, etc. Therefore the B/B Class2 medium-voltage buses are each normally connected to a specific safety Class 3 medium-voltage bus. A bus tie line is installed between each of the back-up buses in consideration of maintenance of safety Class 3 medium-voltage buses during reactor maintenance. The CBs of this tie line are interlocked and are open during plant normal operation.

As stated earlier the power system of backup-building supplies power to the Class 2 equipment such as the FLSS which is the second line means of providing the ECCS function. Therefore the power system of the B/B is designed to be diverse in relation to the safety Class 1 system in the reactor-building

If off-site power is lost, A/Gs are automatically started and supply power to the backup-building Class 2 buses.

The medium voltage A/G connected to back up building bus 1 is capable of supplying the Class 1 safety loads connected to any one of the safety Class 1 buses.

15.4.3.1.4.2 The B/B Class 2 Low Voltage Distribution System

15.4.3.1.4.3 Power Centers

Electrical power for the B/B Class 2 low-voltage auxiliaries is supplied from P/Cs which consist of medium-voltage/low-voltage transformers and associated switchgear.

The B/B Class 2 low-voltage buses are fed by their own power transformer.

The low-voltage power centers are sized to supply MCCs and motor loads greater than 90kW, and not greater than 300kW in principle.

15.4.3.1.4.4 Motor Control Centers

The B/B Class 2 low-voltage MCCs are sized to supply power to auxiliary loads of not greater than 90kW in principle.

15.4.4 Emergency Diesel Generators

15.4.4.1 Emergency Diesel Generators

The role of the emergency diesel generators (E D/Gs) is supply 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 occurs simultaneously.

Since the E D/Gs supply power to the safety Class 1 buses delivering supplies to Class 1 SSCs, they are classified as Class 1. Three E D/Gs are installed in consideration of the redundancy requirement, and each of the generators and associated control panels is installed in an independent room.
Each E D/G and its auxiliary systems are classified Seismic Category 1.
The E D/Gs start when a loss of voltage occurs on the safety Class 1 medium-voltage bus, or when a loss of coolant accident occurs. Low voltage detection relays detect the loss of voltage and simultaneously send commands to open the load circuit breakers and the incoming CB (from the normal bus) and send a starting signal to the E D/Gs. All the loads connected to the safety Class 1 buses are disconnected with the exception of the power transformers and the low-voltage motor control centers (MCCs) connected to the low-voltage bus.

When the frequency and voltage of the E D/G reaches the specified value, the E D/G is connected to the safety Class 1 bus automatically and the required loads are connected automatically and sequentially in accordance with a priority of safety importance.

The automatic switching is generated by a Class 1 safety timer and logic controller which starts when the safety bus voltage is recovered. This equipment will be described in a supporting document [Ref-5].

On the other hand, when the LOCA signal (reactor water level low signal or Drywell pressure high signal) is sent by the safety system logic and control (SSLC), E D/G starts up automatically regardless of the unit auxiliary power supply availability. On this occasion, if the power supply of safety Class 1 bus is not lost, the E D/Gs remain in no load operation and continue this way until they are shut down manually.

When a Loss of Coolant Accident and a loss of the safety Class 1 medium-voltage bus occur simultaneously, loads related to the SSCs supporting the delivery of Safety Functions will be connected automatically to the emergency diesel generators.

Fuel storage facilities enabling the emergency diesel generator to operate continuously for seven (7) days are provided inside the power station site.

The main loads connected to each of the emergency diesel generators are those belonging to the following systems;

○Emergency diesel generator (Division I)
Residual Heat Removal System
Reactor Auxiliary Cooling System
Ventilation and Air-conditioning Systems (such as Main Control Room, Emergency Diesel Generator Room)
Standby Liquid Control System
Emergency Gas Treatment System
Flammability Control System
Instrumentation and Controlling Equipment

○Emergency diesel generator (Division II)
High-Pressure Core Flooder System
Residual Heat Removal system
Reactor Auxiliary Cooling System
Ventilation and Air-conditioning Systems (such as Main Control Room, Emergency Diesel Generator Room)
Standby Liquid Control System
Emergency Gas Treatment System
Flammability Control System
Storage Battery Chargers
Reactor Containment Vessel Isolation Valve
Instrumentation and Controlling Equipment

○Emergency diesel generator (Division III)
High-Pressure Core Flooder System
Residual Heat Removal system
Reactor Auxiliary Cooling System
Ventilation and Air-conditioning Systems (such as Emergency Diesel Generator Room)
Storage Battery Chargers
Reactor Containment Vessel Isolation Valve
Instrumentation and Controlling Equipment

Table 15.4-1 shows the loads arrangement of each division.

Table 15.4-1: Loads Arrangement of Each Division

Division-I	Division-II	Division-III
RHR RCW RSW E D/G supporting system HECW SPCU HVAC (MCR, electrical equipment room, pump room, E D/G room) SLC CAMS FPC CUW SPCU HPIN SAM SGTS FCS Power supply to C&I (AC, DC, UPS)	RHR HPCF RCW RSW E D/G supporting system HECW HVAC (MCR, electrical equipment room, pump room, E D/G room SLC CAMS FPC CUW SPCU HPIN SAM SGTS FCS Power supply to C&I (AC, DC, UPS)	RHR HPCF RSW RCW E D/G supporting system HVAC(electrical equipment room, pump room, E D/G room) Power supply to C&I (AC, DC, UPS)

The detailed information about the load will be described in supporting documents ([Ref-6] and [Ref-7]) in the following GDA steps.

15.4.5 Alternative AC generators in Backup-building

15.4.5.1 Alternative AC Generators in Back-up Building (B/B Class 2 A/G)

Two (2) B/B Class 2 A/Gs, and associated equipment are installed in the backup-building (medium-voltage A/G in system 1 and low-voltage A/G in system 2). The A/Gs are rated to supply power to backup-building equipment when off-site power is lost. For example A/G supplies power to FLSS in Class 2 which consists of two (2×100%) systems.

If the power of the B/B Class 2 medium-voltage bus in system 1 is lost, circuits connected to the bus are interrupted except the power transformer and the motor control center connected to the B/B Class 2 low-voltage buses. After the voltage and frequency of the alternative AC generator in system 1 has reached its rated values, the alternative AC generator is automatically connected to the B/B Class 2 medium-voltage bus, and power supply to the backup-building equipment in system 1 becomes possible.
Similarly, if the power of the B/B Class 2 low-voltage bus (Power Center: P/C) in system 2 is lost, the receiving C/B of the P/C is opened. After the voltage and frequency of the A/G in system 2 has reached its rated value, the A/G is automatically connected to the B/B Class 2 P/C, and power supply to the backup-building equipment in system 2 becomes possible.

Fuel storage facilities enabling the alternative AC generators to operate continuously for about seven (7) days are provided.

As explained above, A/Gs are installed in the back-up building so as to supply power to FLSSs and associated supporting systems, but the A/G of back-up building system 1 can also serve as power supply to any one safety Class 1 medium-voltage bus to support the ECCS function by using the bus coupling line between back-up building and the safety Class 1 medium-voltage bus. The connections between the Class 1 medium-voltage bus and M/C-B/B1 are achieved by remote manual operation. Further explanation of the safety interlocking systems applied to this design will be provided in [Ref-5]. The cross connections of the medium-voltage bus and M/C-B/B1 are installed in consideration of the flexibility of electrical power supply, so there is no safety claims associated with these cross connections.

The power supply system of B/B is designed to be diverse from the safety Class 1 power supply system, and the way that diversity is achieved will be described in supporting document ([Ref-8]). A/G in system 1 has the enough capacity to support one division of ECCS and its own load on the B/B Class 2 bus.

The detail of the system design and capacity evaluation for the A/G system will be described in supporting document ([Ref-9])

15.4.6 DC Power Supply System

There are four groups of DC power supply system as below.

・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

Each battery is housed in a ventilated room apart from its charger and distribution panels. Each battery feeds a DC main distribution panel and sub-distribution panels and, where required, a DC motor control center.

All batteries are sized and a suitable design margin applied to ensure that designed loads will be satisfied throughout their design life assuming 100% of design demand

The detail of architecture and load list will be described in supporting documents ([Ref-10],[Ref-11]).

15.4.6.1 Safety Class 1 115V DC Power Supply System

The safety Class 1 DC power supply system supplies power to SSCs required to perform Category A safety functions in the event of station blackout. This includes electrical power to safety C&I equipment including the Class 1 ECCS system.

Since the safety logic of the UK ABWR consists of four channels (2 out of 4 logic), there are four divisions of safety Class 1 DC power supply system.

Each division consists of one (1) charger that receives power from one of the safety Class 1 MCCs, a battery that is kept at float charging status by this charger, a main DC distribution panel and sub DC distribution panels for supplying 115V DC power to DC loads of that division.

Two (2) common standby chargers are installed, each common to two divisions for use as backup during maintenance power outage of the upstream 420V AC P/C / MCC. The standby chargers are not connected to the main chargers and batteries during plant normal operation. An interlock scheme is installed for each standby charger to ensure that it is only fed from 1 AC bus and does not simultaneously supply power to two divisions.

The capacity of each of the safety Class 1 battery chargers is based on the largest combined demands of the continuous steady-state loads, plus charging capacity to restore the battery from the design minimum charge state to the fully charged state within about 10 hours.

The capacity of standby chargers which are common to two divisions is same as the larger main charger in the two divisions.

The battery chargers are designed to prevent the AC power supply from becoming a load on the battery. They also have provisions to isolate transients from AC power supply system from affecting the DC system; and conversely, provisions to isolate transients from the DC power supply system from affecting the AC power supply system.

The batteries are designed to have enough capacity to drive all the loads required for the bounding design basis fault sequence for eight (8) hours. DC loads which are not important for the reactor safety are disconnected by manual operation. Also, as measures to beyond design basis faults, the battery of Division I can supply power to the equipment needed for depressurization, feeding water and monitoring of the reactor for 24 hours.

Batteries are sized for the DC load in accordance with IEEE-485.

The battery output breaker has an over-current trip and interrupts fault current flow from the battery to a bus fault. Distribution bus load breakers have over-current trips coordinated with the battery output breaker. Fault current necessary to trip the load breakers is supplied by the battery because the battery charger has load limiting.

The safety Class 1 115V DC power supply systems supply DC power to Division I, II, III and IV, respectively, and are designed as safety Class 1 equipment. They are designed so that no single failure in any 115V DC system will result in conditions that prevent safety shutdown of the plant with the remaining AC power supply. The plant design and circuit layout from these DC power supply systems provide physical separation of the equipment, cabling and instrumentation essential to plant safety. Each division of the system is located in an area separated physically from other divisions. All the components of the safety Class 1 115V DC power supply system are installed in Seismic Category 1 structures.

15.4.6.2 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 of the normal Class 2 C&I equipment. The normal Class 2 C&I equipment is based on two (2) ×100% systems, so the safety Class 2 115V DC power supply system is divided into two groups (A and B). This power supply has a charger and storage battery for each system.

Each system is composed of one charger that receives power from a MCC which can be supplied from an E D/G, a battery that is kept at float charging status by this charger, a main distribution panel and sub-distribution panels for supplying power to 115V DC instrument and control device loads of the normal system.

A tie line is installed so that the other charger can supply power during maintenance of one charger. A standby charger is not installed. This tie line is only used during maintenance and is not used during plant normal operation.

Batteries are sized for the DC load in accordance with IEEE-485 and same method as safety Class 1 115V DC batteries.

15.4.6.3 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). The non-safety Class 230V DC power supply system consists of one charger that can receive power from one of two MCCs which can be supplied from E D/Gs, a battery that is kept at float charging status by this charger and main distribution panel for supplying power to loads (e.g. 230V DC power to DC motors).

A standby charger is installed to prevent discharge of the battery in the event of maintenance or failure of the main charger.

An interlock scheme is installed to ensure that the main charger receives AC power from only one of the upstream MCCs which can be supplied from E D/Gs. AC power is manually switched over during maintenance of one of the upstream MCCs.

Batteries are sized for the DC load in accordance with IEEE-485 and same method as safety Class 1 115V DC batteries.

15.4.6.4 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 back-up building which is needed to realize the function of Class 2 FLSS. Since the FLSS consists of two (2) × 100% systems, this power supply system is divided into two groups (DC bus 1 and DC bus 2).

The B/B Class 2 115V DC power supply system is designed to be diverse from the safety Class 1 115V DC power supply system. The way that diversity is achieved will be described in supporting document ([Ref-8]).

Each system is composed of one charger that receives AC power from one of the B/B Class 2 MCCs (B/B MCC 1 / 2), a battery that is kept at float charging status by this charger, a main distribution panel and sub-distribution panels for supplying power to the B/B Class 2 loads.

One (1) common use standby charger is installed as backup for the two systems to be used during maintenance of the upstream AC P/C and MCC. This standby charger is not connected to the main charger and battery during plant normal operation. An interlock scheme is installed to ensure that the standby charger is only fed from 1 AC bus and does not simultaneously supply power to two divisions.

Batteries are sized for the DC load in accordance with IEEE-485 and same method as safety Class 1 115V DC batteries.

15.4.7 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)

The detail of architecture and load list will be described in supporting documents ([Ref-12] and [Ref-13]) in the following GDA steps

(1) Class 1 AC UPSs

The Class 1 AC UPSs supplies power to Class 1 instrument and control systems which cannot tolerate momentary power failure, such as the reactor protection system (4 divisions), radiation instrumentation and turbine control system.
These are normally supplied from safety Class 1 Motor Control Centers (MCC).

These are also supplied from the safety Class 1 115V DC power supply system so that it can supply power to essential loads in the event of and during loss of on-site AC power.

Since the safety logic of the UK ABWR consists of four channels, four divisions of safety class1 AC UPSs are provided. There are three divisions of safety Class 1 AC power supply systems (three (3) E D/Gs), so the Class 1 AC UPS DIV-I, DIV-II and DIV-III are supplied from the Class 1 AC power supply system of each division, and the Class 1 AC UPS in DIV-IV is supplied from a Class 1 MCC AC power supply system DIV-II.

(2) 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 E D/Gs) located in the control room building or DC power supply from the plant process computer dedicated battery.
Two (2) × 100% Class 3 AC UPS systems are installed (main and back-up) to enable continuous operation of the computer monitoring system during system failure or maintenance.

(3) Class 1 AC I&C Power Supply

The Class 1 AC I&C PS systems supply power to the main control room AC 120V power distribution panels. In the event of loss of off-site power, this power supply is interrupted until the power supply from the emergency diesel generator(s) is available.

There are three (3), safety Class 1 AC I&C PS systems corresponding to the number of safety Class 1 AC power supply systems. Each system receives power from a safety Class 1 MCC of each division, and supplies power at 120V AC single-phase to instrument and control devices of each division during normal plant operation, at startup and shutdown, during plant outage period, at plant accident.

These safety, Class 1 AC I&C PS systems supply AC power to Class 1equipment such as the Containment Atmospheric Monitoring System (CAMS).
Each system is structured to be able to receive power from a normal MCC in the case of maintenance outage of the Class 1 P/C or MCC.

(4) Class 2 AC I&C Power Supply

The safety Class 2 AC I&C PS systems supply power to the Class 2 R/B, T/B I&C loads.

Safety Class 2 AC instrumentation power supply systems are installed for the reactor building and turbine building. Each system receives 420V AC power from either of 2 MCCs in different divisions, which can be supplied from E D/G.

Power is transformed to 120V single-phase and supplied to instrument and control devices during normal plant operation, at startup and shutdown, and during plant outage period.
In the event of loss of off-site power, this power supply to the R/B and T/B is interrupted until the power supply from relevant E D/G starts.

(5) 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.

The system can receive 420V AC power from either, an MCC which can be supplied from E D/G or the Class 3 Rw/B MCC. Power is transformed to 120V single-phase and supplied to instrument and control devices during normal plant operation, at startup and shutdown, and during plant outage period.

(6) 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% Class 2 systems are provided in the backup-building supplied from the backup-building low-voltage buses.

The systems supply power to the equipment necessary to fulfill the functions of the backup-building such as the Class 2 FLSS groups.

In consideration of CCF, the safety Class 1 AC I&C PS and the B/B Class 2 AC I&C PS are designed to be diverse. The way that diversity is achieved will be described in supporting document ([Ref-8]).

The Class 2 B/B I&C loads in system 1 and system 2 normally receive power from B/B MCCs 1 and 2. These systems are able to receive power from the common Class 2 B/B MCC in case of maintenance of B/B Class 2 P/C or MCC.

15.4.8 Reactor Internal Pump Power Supply System

The power supply system to the Reactor Internal Pumps (RIPs) consists of following equipment.

a. Motor-generator (M-G) set
b. ASD (Adjustable Speed Drive)

(1) M-G set

The primary function of the motor-generator (M-G) set equipment is to provide additional energy storage capacity for extending the coastdown time of the connected RIPs during a complete loss of AC power bus incident. In normal operation, the M-G set converts the incoming electrical power to mechanical energy, then back to electrical power before using it to source the connected loads. By properly sizing the amount of inertia in the M-G set for kinetic energy storage, the generator's output can be made less sensitive to large fluctuations in the input power bus voltage. The design bases of the equipment are the following performance criteria:

(i) Following a complete loss of AC power bus input, the operating speed of the connected RIPs shall be maintained, up to the rated speed, for at least one second.

(ii) The subsequent speed reduction in the connected RIPs shall not be greater than −10% per second for a minimum period of two seconds. In addition to meeting the above equipment performance criteria, the M-G set is designed to tolerate certain ranges of normal voltage and/or frequency variations in input power source with negligible effect on generator output. These ranges include the normal, continuous variations in bus voltage up to ±10% of rated and in frequency of up to ±5% of rated. Also, fluctuations in bus voltage as caused by the starting or tripping of other large AC machines connecting to the same bus shall be tolerated.

Two M-G sets are provided; each is connected to the safety Class 3 medium voltage bus. Each M-G set is designed to provide constant voltage and constant frequency power to three ASDs. These ASDs are the static converter devices which generate the appropriate variable voltage, variable frequency power to the connected RIPs.
Each M-G set consists of the following components:

(i) An induction motor.

(ii) A generator and excitation system. The exciter design is of brushless type.

(iii) A flywheel of appropriate moment of inertia to satisfy the pump speed coastdown requirements

(iv) Control and protective circuits. The control circuit is designed to maintain generator output at a fixed voltage-to-frequency (V/f) ratio for optimum RIP speed modulation.
Protective logic and circuits, monitoring instrument, annunciators, indicators, etc. are provided to protect the M-G set components from being damaged by consequences of abnormal equipment operation.

The M-G set does not interface directly with the ASD/RIP loads; it interfaces with the loads through three isolation transformers. These isolation transformers provide two functions in the RIP power supply systems. They step down the M-G set voltage output to the level compatible with the rectifier circuit in the ASD. Also, by phase-shifting the output of the three transformers a the harmonic currents produced by ASD converter is canceled, thus preventing most of the negative-phase-sequence current from flowing back into the generator.

(2)ASD

ASDs supply power whose frequency is controlled in accordance with the command from the recirculation flow control system to RIPs. ASD consists of an input transformer rectifier, smoothing circuit, inverter and control panel. Input transformers step down the input voltage to the rectifier voltage. The rectifier converts the input AC to DC, and the smoothing circuit consists of DC filter and removes suppresses the DC ripples. The inverter converts DC to AC whose voltage and frequency are controlled in accordance with the requirement of the recirculation flow control system.

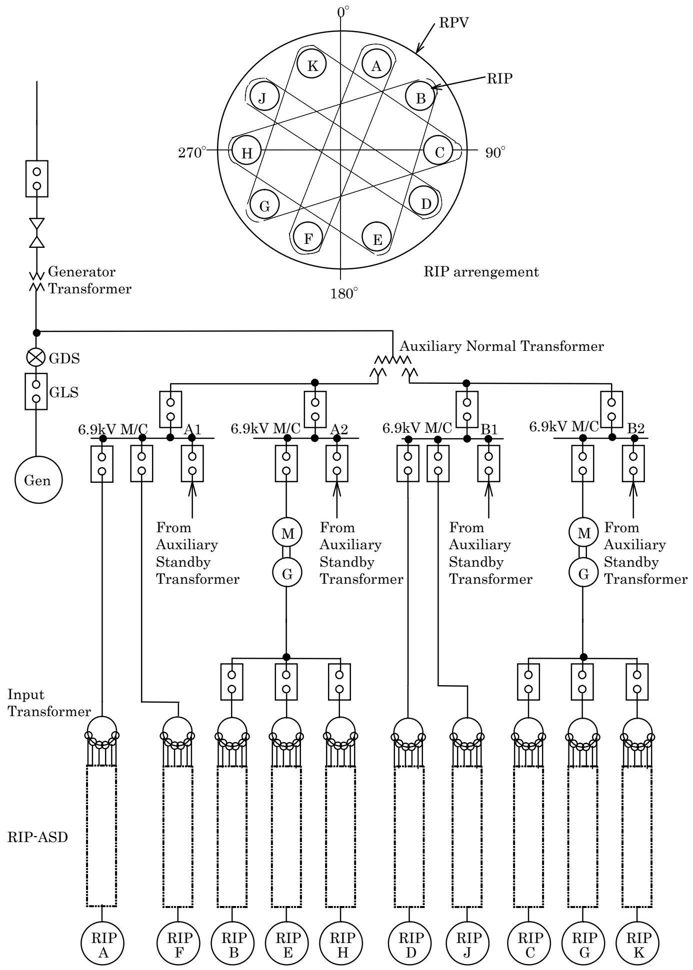

Figure.15.4-1: Reactor Internal Pumps

15.4.9 Communication System

Communication systems are composed of a paging system and a telephone system.

The paging system is designed to instruct and to alarm from the main control room to each place in the plant during normal operations and emergency conditions.

The telephone system is designed to communicate within the plant and external organizations.

The paging system is used during plant normal operation and emergency condition, so it is classified into none class and Class 3.

The telephone system is also used during emergency conditions within the plant and to external organizations, so it is classified into Class 3 and Class 2.

The paging system and the telephone system are powered from emergency AC low-voltage buses. The detailed functions of the paging system and telephone system are described in the supporting document ([Ref-14]).

15.4.10 Lighting System

Normal AC lighting system is powered from the safety Class 3 AC low-voltage buses. Emergency AC (Class 3) lighting system in the main control room and evacuation passages is powered from AC low-voltage buses which can be supplied from E D/G. Emergency (Class 2) DC lighting is also provided and is powered by storage batteries in case of loss of on-site AC power.

Lighting in rooms used under plant normal operation is classified into non class and is considered as part of the normal AC lighting system. Furthermore, lighting in main rooms of C/B, R/B, T/B used during LOOP is classified into Class 3 and includes normal AC lighting system and emergency AC lighting system. Lighting in rooms such as the main control room, diesel rooms and emergency electrical panel rooms is classified into Class 2 and includes normal AC lighting system, emergency AC lighting system and emergency DC lighting system.

Detail functions of normal lighting system and emergency lighting system are described in the supporting document ([Ref-15]).

15.4.11 References

[Ref-1] “Auxiliary Normal Transformer Design Specification (calculation report)” (GA33-3807-0004-00001, Rev.0)
[Ref-2] “Auxiliary Standby Transformer Design Specification (calculation report)” (GA33-3807-0002-00001, Rev.0)
[Ref-3] “Single Line Diagram (High Voltage)” (GA33-2201-0001-00001, Rev.0)
[Ref-4] “Electrical Power Distribution System System Design Description” (GR10-1001-0001-00001, Rev.0)
[Ref-5] “Station Electrical System Interlock Block Diagram” (GR10-2205-0001-00001, Rev.0)
[Ref-6] “Emergency Diesel Generator System System Design Description” (GR43-1001-0002-00001, Rev.0)
[Ref-7] “Emergency Diesel Generator System Capacity Calculation Report” (GR43-3807-0001-00001, Rev.0)
[Ref-8] “Diversity Strategy Report” (GA33-9920-0001-00001, Rev.0)
[Ref-9] “Alternative Generator System System Design Description” (GR44-1001-0002-00001, Rev.0)
[Ref-10] “DC Power Supply System System Design Description” (GR42-1001-0001-00001, Rev.0)
[Ref-11] “Battery and Charger Capacity Calculation Report” (GA33-3807-0001-00001, Rev.0)
[Ref-12] “Uninterruptible AC Power Supply System System Design Description” (GR46-1001-0001-00001, Rev.0)
[Ref-13] “Instrument and Control Power Supply System System Design Description" (GR47-1001-0001-00001, Rev.0)

[Ref-14] "Communication System Specification"
(GA33-3001-0001-00001, Rev.0)
[Ref-15] "Lighting and Service Power System Specification"
(GA33-1001-0006-00001, Rev.0)
[Ref-16] "Unit Transformer Design Specification (calculation report)"
(GA33-3807-0003-00001, Rev.0)