UK EPR	
	Title: PCSR – Sub-chapter 8.1 – External Power Supply
	UKEPR-0002-081 Issue 04

Total number of pages: 11	Page No.: I / III
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REVISION HISTORY

Issue	Description	Date
00	First issue for INSA information	11/12/07
01	Integration of technical and co-applicant review comments	26/04/08
02	PCSR June 2009 update: – Integration of references	27/06/09
03	Consolidated Step 4 PCSR update: - Update of references - Clarifications to text (sections 2, 3.5, 4.6, 5.1).	29/03/11
04	Consolidated PCSR update: - References listed under each numbered section or sub-section heading numbered [Ref-1], [Ref-2], [Ref-3], etc - Minor editorial changes - Clarification of text (§2, §4.5, §5.1, §5.2) - New material added (sections 1, 2, 5.1) and other minor text changes for consistency with report 17074-709-000-RPT-0002, Issue 03 (CAE Document)	21/08/12

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SUB-CHAPTER 8.1 – EXTERNAL POWER SUPPLY

1. ROLE OF EXTERNAL SUPPLY

The unit is connected to the grid via a main connection and an auxiliary connection. These two external connections must be as independent as possible.

The main connection is designed to transmit the energy produced by the turbine generator to the grid and to feed all the unit's auxiliaries in all normal operating and accident situations.

The auxiliary connection is designed to use the grid to supply the unit auxiliaries needed to shut the unit down in both normal operating and accident situations. This connection acts as a back-up to the main connection when the latter fails. In this case, supply change-over occurs through a switchover device to ensure a continuous supply of power to the unit's internal network [Ref-1] to [Ref-4].

The two external supply connections are described in chapter C 1410 of the AFCEN RCC-E code [Ref-5], whereby the main external source supplies the unit auxiliaries via Step-down Transformers 1 and 2 (TS1 and TS2) and the auxiliary external source connects to the auxiliary feed network via the Auxiliary step-down Transformer (TA).

2. GENERAL DESCRIPTION

The following description does not describe specific technology, but specifies the functional requirements necessary for the External Power Supply.

The fundamental elements of the external connections are:

1. A main connection from the alternator to the grid through a main power transformer (TP), which consists of 3 separate poles.

2. A connection to the main connection, downstream of the main power transformer which enables electricity to be drawn either from the alternator if the unit is coupled or from the grid if the unit is decoupled. This is used to supply all of the unit's auxiliaries through step-down transformers.

3. Two unit step-down transformers (TS), connected to the main connection, both having two secondary windings.

4. An electricity distribution system for the nuclear island which is based on four trains (one train for each of the two windings of each of the two step-down transformers).

5. An auxiliary connection connected to the grid which enables certain auxiliaries (see section 5.2) to be supplied during shutdown in normal or accident conditions.

6. An auxiliary step-down transformer (TA), connected to the auxiliary connection. This has two secondary windings. Each winding is connected to two trains, thereby allowing the four trains to be connected to the TA.

7. The three transformers (TP - TS and TA) are located at the edge of the conventional island's non-classified electrical building and the turbine hall.

Loss of the main grid is defined as loss of the main grid connection with the auxiliary connection still available.

Loss of off-site power is the total loss of external electrical supplies to the 10kV busbars. This can be due to the failure of the main and auxiliary grid connections.

The relationship between the external power supplies, the transformers and the electricity distribution system for the Nuclear Island (NI), is shown on single line diagram Sub-chapter 8.3 - Figure 1.

3. MAIN CONNECTION

3.1. OPERATING ROLE

The main connection is used in preference to the other connections and is therefore used in all unit conditions, namely:

- Unit at power, when it enables the transmission of the energy produced by the alternator to the grid, and the supply of all of the unit's auxiliaries by using a fraction of the energy produced by the alternator.
- Unit in the start-up or normal shutdown phases, when it ensures the supply of all of the unit's auxiliaries from the grid.
- Unit in the shutdown phase in accident conditions and subsequent holding at a final steady state, when it ensures the supply of all of the unit's auxiliaries from the grid.

The main connection has other purposes in relation to:

- the transition between the unit at power and during the start-up/shutdown phases, and the phases of coupling/decoupling of the unit to the grid.
- maintaining unit operation under house load conditions when there are grid disturbances.

3.2. DESIGN BASIS

Electrical design studies of the nuclear island [Ref-1] [Ref-2] show that the following factors need to be taken into account in the general design of the main connections:

- the use of 4 trains corresponding to the nuclear island's four electrical divisions.
- preference for supplying the unit's auxiliaries through the main connection to the grid.
- the use of two unit step-down transformers (TS) with two secondary windings, so as to retain a four train structure with regard to electrical independence.

- installation of the unit step-down transformers on a common TP/TS platform and separation of the cable race from each TS to the conventional island's non-classified electrical building. This minimises the risk of losing external power in the Electrical Building in the event of fire.

Furthermore, a high voltage step-down scheme (HTB) is used to provide energy for the normal operating needs of the unit. A design study of the above [Ref-1] [Ref-2] led to the definition of the following requirements:

- the possibility to connect the alternator to the grid during normal operation,
- the possibility to disconnect the alternator from the grid in the case of an incident affecting the unit, while keeping the unit auxiliaries supplied by the grid,
- the possibility to disconnect the unit from the grid in the case of a grid incident; with the unit auxiliaries continuing to be supplied by the alternator,

Finally, the high voltage switchgear and unit transformers (TS) are sized taking into account the grid performance (minimum and maximum short-circuit powers).

The main design parameters are the switching capacities of the circuit-breakers, and the rated reactance and power of each transformer.

3.3. SYSTEM DESCRIPTION

The high voltage step-down scheme includes the main energy transmission connection and the unit transformer (TS) step-down connection. These two connections form the main connection.

The main energy transmission connection starts at the alternator's outlet point. It comprises a main transformer (TP), a coupling circuit-breaker and a line circuit-breaker. It is then connected to the grid.

The roles of each element of the connection are, respectively:

- for the main transformer (TP), to raise the alternator's voltage to that of the 400 kV grid in order to transmit electrical energy,
- for the coupling circuit-breaker, to carry out coupling and decoupling the unit, to clear alternator faults, to clear high voltage station faults with the line circuit-breaker, and to supply the unit auxiliaries in the event of load shedding.
- for the line circuit-breaker:
  - to assist in clearing high voltage station faults with the help of the coupling circuit-breaker,
  - to assist in clearing transmission line faults using the circuit-breaker in the grid switchyard (for the proposed option of a long line grid connection scheme),
  - to ensure unit load shedding and recoupling following operation on house load,
  - to supply the unit auxiliaries during shutdown.

The unit transformers (TS) are connected to the main connection between the coupling circuit-breaker and the line circuit-breaker.

3.4. PHYSICAL PHENOMENA DETERMINING OPERATION

The main power supply is the main electricity source for supplying the unit from the grid. This source is used in the majority of unit operating regimes.

The main switching events involved in the transition between the various operating regimes are outlined below:

- Putting the main connection into service: the main line is energised by closing the line circuit-breaker. This enables the unit's auxiliaries to be supplied through the unit step-down transformers (TS). The transfer of energy is in the grid to plant direction.

- Taking the main connection out of service: the main line is de-energised by opening the line circuit-breaker.

- Coupling/decoupling of the alternator to the grid through the main connection: this operation is performed by the coupling circuit-breaker. When the unit is coupled and draws power from the grid, the alternator provides the energy supply to the unit auxiliaries.

- House load operation: in the case of a grid disturbance on the main line, the unit must be disconnected from the grid by means of the line circuit-breaker to avoid serious damage. The unit resupplies the auxiliaries through the alternator. The requirements for house load operation (islanding) are mainly derived from consideration of electrical faults on the grid, which manifest themselves as low voltage or frequency. Recoupling the unit to the grid after load shedding is achieved with the line circuit-breaker as soon as the grid has returned to normal operation.

3.5. TESTS, INSPECTIONS AND MAINTENANCE

To be specified as part of the site licensing.

4. AUXILIARY CONNECTION

4.1. OPERATING ROLE

The auxiliary connection is used as a back-up to the main connection and is used in the following situations:

- Unit initially at power, entering the shutdown phase,

- Unit in normal shutdown phase, when it supplies the unit required auxiliaries from the grid.

4.2. DESIGN BASIS

The main connection is complemented by an auxiliary connection whose characteristics are:

- the auxiliary transformer (TA) is identical to the unit step-down transformers (TS),
- the auxiliary transformer (TS) is supplied from a 400 kV source which is physically separated from the unit step-down transformer's (TS) supply line from the grid switchyard,
- the auxiliary transformer is sited well away from the TS,
- the cable race from each TA winding to the conventional island's non-classified electrical building are separated.

Protective compartments enclosing the various transformers ensure that a fire on one transformer does not affect its neighbours.

The design minimises the risk of a Loss Of Off-site Power (LOOP) on the nuclear island in the event of fire.

The design of the switchgear and the auxiliary connection's transformers is identical to that of the unit high voltage step-down equipment.

The characteristics of the auxiliary transformer are identical to those of the unit step-down transformer, thereby allowing them to share a common replacement. The design of the TA enables recovery of the unit auxiliaries after switching supplies.

4.3. SYSTEM DESCRIPTION

The auxiliary connection consists of a transformer and a circuit-breaker. It is connected to the 400 kV grid through an auxiliary connection which differs from the one that supplies the unit step-down transformers.

4.4. UK EPR SITE-SPECIFIC DESIGN

The point of connection of the auxiliary connection to the grid will be site-dependent: the chosen option will ensure adequate independence of supply from the main connection.

4.5. OPERATIONAL REQUIREMENTS

Energisation and de-energisation of the auxiliary transformer takes place through the transformer's supply circuit-breaker.

The supply to the auxiliary transformer always remains live, ready to act as a back-up to supply the unit auxiliaries in the event of loss of the main grid connection.

4.6. TESTS, INSPECTIONS AND MAINTENANCE

To be specified as part of the site licensing.

5. TS/TA TRANSFER

5.1. OPERATING ROLE

As set out in section 1 of this sub-chapter, the purpose of automatically switching from the unit transformer (TS) to the auxiliary transformer (TA) is to ensure a continuity of electricity supply from the grid to the unit auxiliaries. This source change-over is slow. It results in the modification of the unit's status as the two sources, TS and TA, are not of the same design. In fact, some unit auxiliary loads need to be shed to remain within the design capability of the TA, resulting in an automatic reactor shutdown. A maximum voltage dip of 5 seconds is related to the TS to TA transfer. There is also a manual switch from TS to TA to isolate the main connection during a unit shuts down stage. The unit auxiliaries are switched over to TA prior to the isolation of the main connection. As long as the manual switch is voluntary and the unit is already shut down, the supplied unit auxiliaries remain in service.

The conditions necessitating a TS to TA transfer are described in [Ref-1].

5.2. OPERATIONAL REQUIREMENTS

Source change-over is generally the direct result of a failure to establish house load operation. When the grid is disrupted, the unit attempts to protect itself by disconnecting itself from the grid. House load operation fails when the turbine does not run through the transient. The opening of the line circuit-breaker followed by the tripping of the turbine leads to an automated TS/TA change-over, which must take place in less than 5 seconds (beyond this time-delay the emergency diesel generator set starts).

The other type of transient which leads to automatic change-over of TS to TA is a fault on the 400kV switchgear. Such a fault will lead to the simultaneous opening of the line circuit-breaker and the coupling circuit-breaker which requires a change-over to the TA.

Following supply change-over, the unit moves from power operation to shutdown. The transient is analysed on the basis of the following requirements which determine the high power loads to be retained or shed during the transient:

- retention of the availability of the secondary side as a source of make-up for the steam generators, enabling the dissipation of the core residual heat. The operating requirement specifies that an extraction pump, circulating pump and a start-up pump must be kept available. A feedwater pump must also be able to be restarted,

- stabilisation of the primary system by operating the reactor coolant pump of loop Nº3 to enable spray to the pressuriser.

SUB-CHAPTER 8.1 – REFERENCES

External references are identified within this sub-chapter by the text [Ref-1], [Ref-2], etc at the appropriate point within the sub-chapter. These references are listed here under the heading of the section or sub-section in which they are quoted.

1. ROLE OF EXTERNAL SUPPLY

[Ref-1] System Design Manual – 10 kV Normal Power Supply System (Conventional Island) (LGi), Part 2 – System operation. ETDOFC080180 Revision A1. EDF. September 2009. (E)

[Ref-2] System Design Manual – 10 kV Normal Power Supply System (Conventional Island) (LGi), Part 3 – System sizing. ETDOFC080274 Revision A1. EDF. September 2009. (E)

[Ref-3] System Design Manual – 10 kV Normal Power Supply System (Conventional Island) (LGi), Part 4 – Flow diagrams.ETDOFC080275 Revision A1. EDF. September 2009. (E)

[Ref-4] System Design Manual – 10 kV Normal Power Supply System (Conventional Island) (LGi), Part 5 - Instrumentation and Control. ETDOFC070285 Revision B1. EDF. November 2009. (E)

[Ref-5] Design and Construction Rules for Electrical Components of Nuclear Islands. RCC-E. AFCEN Edition. December 2005. (E)

3. MAIN CONNECTION

3.2. DESIGN BASIS

[Ref-1] Detailed design of the conventional island - Study of electrical transients. ENSEMD090232 Revision A. EDF. September 2009. (E)

ENSEMD090232 Revision A is the English translation of ENSEMD060315 Revision A.

[Ref-2] Detailed design for the conventional island. Calculation of three-phase short-circuit currents for the HVA and LV switchboards. ENSEMD090233 Revision A. EDF. September 2009. (E)

ENSEMD090233 Revision A is the English translation of ENSEMD070136 Revision A

5. TS/TA TRANSFER

5.1. OPERATING ROLE

[Ref-1] System Design Manual – 10 kV Normal Power Supply System (Conventional Island) (LGi), Part 2 – System operation. ETDOFC080180 Revision A1. EDF. September 2009. (E)