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REVISION HISTORY

Issue	Description	Date
00	First issue for INSA information.	11/12/2007
01	Integration of technical and co-applicant review comments	28/04/2008
02	PCSR June 2009 update: – Integration of references. – Integration of material sent within TQ EPR000043 regarding electromagnetic effects due to lightning or other sources of interference. (No modification due to design freeze)	27/06/2009
03	Consolidated Step 4 PCSR update: - Minor editorial changes - Update and addition of references - Text updated regarding the use of the earth fault monitoring system to identify the origin of a 10 kV earth fault (§3.1) - Text added on the level of immunity of the electrical distribution system to lightning strikes (§3.2) - Text added on fast transients / overvoltage risks on 10 kV IT system and insulation coordination (new §3.3 “Insulation coordination” added)	27/03/2011
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 for consistency and clarity - Previous sub-section 1.1 deleted, subsequent sub-section numbers revised accordingly - New material added for consistency with report 17074-709-000-RPT-0002, Issue 03 (CAE Document) (§1.1.1, §1.2.1, §2.2.1, §3.1.1, §3.1.2, §3.2 and §3.3) - Titles and content of sections 3.1.1 and 3.1.2 revised to clarify that the uninterruptible 400V systems are in TN-S configuration	21/08/2012

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SUB-CHAPTER 8.4 - SPECIFIC DESIGN PRINCIPLES

The design of electrical system equipment, including its architecture design ranges, thresholds and margins, complies with the requirements of the AFCEN RCC-E code [Ref-1] and its supporting documents and standards.

1. CABLING DESIGN PRINCIPLES

The cabling design principles comply with the rules for electrical equipment separation in chapter D7000 of the AFCEN RCC-E code [Ref-1].

1.1. CABLING DESIGN PRINCIPLES, MAIN CABLEWAYS

1.1.1. General Cabling Design Principles

The Nuclear and Conventional Island electrical distribution systems are installed in separate buildings: those on the Conventional Island are located in a non-classified electrical building and those on the Nuclear Island are mainly located in electrical equipment rooms within the Safeguard Auxiliary Buildings and Diesel Buildings (see Sub-chapter 8.4 – Figure 1).

The cableways between the Conventional Island and the Safeguard Auxiliary Buildings are installed in underground galleries.

The Nuclear Island electrical distribution systems are mainly located in the electrical equipment rooms of the Safeguard Auxiliary Buildings: however, locally, sub-distribution systems may be located in other buildings.

Cable decks are provided under the switchboard rooms and the instrumentation and control rooms in each division of the Safeguard Auxiliary Buildings and under the main control room in divisions 2 and 3.

Locating the electrical switchboards in the upper part of the Safeguard Auxiliary Buildings enables the length of the cables between the switchboards and the actuators of the safeguard systems that are located in the lower part of the building to be reduced. The cables are routed to the different buildings via cable decks on horizontal and vertical raceways. The cables to the Reactor Building are routed via the cable floor, the annulus, the electrical penetration and the raceways located in the Reactor Building.

The Diesel Generator Buildings are connected to the Safeguard Auxiliary Buildings by separate underground galleries.

The Nuclear Auxiliary Building receives its power supply from all four divisions. The Fuel Building receives its power supply mainly from divisions 1 and 4.

The cables between the Safeguard Auxiliary Buildings 1 and 4 and the Fuel Building use the junction towers located between the Safeguard Auxiliary Buildings and the Fuel Building. The cables between the Safeguard Auxiliary Building 1 and the Nuclear Auxiliary Building are installed at the lower level of the containment annulus. Those between the Safeguard Auxiliary Building 4 and the Nuclear Auxiliary Building are installed in the space between these two buildings. Those between the Safeguard Auxiliary Building 2 and the Nuclear Auxiliary Building are in the upper part of the containment annulus. Those between the Safeguard Auxiliary Building 3 and the Nuclear Auxiliary Building are installed at the upper level of the containment annulus.

During the site licensing, an assessment of electrical cables will be carried out to verify the loading of the cable routes.

Low voltage and instrumentation and control cables of the four divisions are required in each of the four bunkers where the main steam valves are installed. The cables are located to meet the segregation requirements between the divisions.

The power supply principles for the containment isolation valves are shown in Sub-chapter 8.3 – Figure 4.

1.1.2. Design Principles for Instrumentation and Control Cables

Instrumentation and control cables use the same routing as the power cables but are installed on separate trays.

The various instrumentation and control systems require different types of independent buses as defined by the instrumentation and control architecture (see Sub-chapter 7.2).

Generally, the control or instrumentation cables are installed alongside the power supply cables when they come close to the sensors.

1.2. REQUIREMENTS FOR SEPARATION BETWEEN CABLEWAYS

1.2.1. General

The power supply system to the Nuclear Island auxiliaries is divided into a normal power supply system and an emergency power supply system.

The emergency electrical boards and non-emergency electrical boards are installed in the same rooms. Physical separation between the cableways that supply power to the non-emergency and emergency systems is not required. The safety classified and non-safety classified cables (power cables or instrumentation and control cables) run on the same trays and cable decks recognising that each of the cables of the Nuclear Island is strictly assigned to a single train.

The power supplies to the various safeguard trains are installed in separate divisions. This separation into divisions ensures protection against propagation of failure due to hazards. The cables belonging to the various trains are physically separated from one another. Each electrical train is considered as having an individual fire volume and is physically separated from adjacent trains by devices protecting against fire, such as protective barriers or other appropriate means. The spaces used for the interconnections between the divisions are also considered as different fire volumes.

Cables from different trains that pass through common rooms are separated by anti-fire screens, protecting walls, sufficient separation distances or other suitable means. Cables from different trains that terminate in the same room are separated as much as possible on a case by case basis. The loss of all functions performed by equipment in the same room as a result of fire is considered in the system design.

The instrumentation and control equipment and electrical boards are installed in different rooms. Their cables follow the same main routes but are arranged on different trays (see section 1.3 for differentiation between cable categories).

During site licensing, an assessment of electrical cables will be carried out to verify the segregation of the cable routes.

1.2.2. Installation of Interconnection Cables

The interconnection cables between two divisions that go through a third one must satisfy the divisions' separation requirements. They are separated from the cables of the third division. The cableway requirements and the principles for separating cable categories described in section 1.3 are met.

When not constructed of optical fibre, the instrumentation and control cables linking two divisions are equipped with galvanic isolation devices, one in each division.

1.2.3. Installation and Separation Close to the Main Control Room

The main control room cabling must be separated from that of the remote shutdown station in order to protect against common cause failure due to internal hazards. Cables linking redundant systems with the main control room are separated (e.g. installed on different trays).

1.2.4. Requirements for Network Cabling

Redundant networks or ring networks located in the cable decks are arranged on different trays (also see Sub-chapter 7.2).

1.2.5. Separation of the Conventional and Nuclear Island Cables

Electrical cables from the Conventional Island are installed with Nuclear Island cables on the same trays.

Instrumentation and control cables from the Conventional Island may run on the same trays as cables from the Nuclear Island. To avoid any disturbance to the Nuclear Island networks, cables from the Conventional Island are provided with earthed shielding at the entry point to each building.

1.3. INSTALLATION OF CABLEWAYS

Cables of various voltages are installed on trays according to their type to avoid electromagnetic interference, as set out in the table below:

Category	Types of cables	Numbers of layers
1	Medium voltage cables > 1 kV	Single-layer or in trefoil groups
2	Low voltage cables (< 1 kV) with power greater than 25 kW	Preferably single layer, but multi layers possible
3	Low voltage cables (< 1 kV) with power less than 25 kW Cables for control with voltage more than 60 V Cables for lighting systems	Multi layers up to height of cables trays
4	Cables for control with voltage of 60 V or less I&C cables for instrumentation Telecommunication cables Bus cables, glass fibre optic cables	Multi layers up to height of cables trays
5	Neutron flux and radiation monitoring cables	Single layer

Provision is made for adhering to the minimum distances between trays that support different electrical cables specified in chapter D7000 of the AFCEN RCC-E code [Ref-1].

Control cables can be laid on the same tray as the low voltage power cables or instrumentation cables for the same item of equipment when they are close to this equipment. Measurement cables run in covered raceways if they are close to a low voltage cable.

Cables of categories 2 and 3 can be installed together on termination trays (that support a small number of cables on the final approach to the equipment). Exceptions to the above rules are possible when close to powered drives.

Main cableways in the controlled nuclear zone are installed in rooms with a low dose rate.

For protection against electrical risks, all metallic or metallised components that make up cableways and their supports are earthed by a conductor connected at each end to the building's ground electrode. All the instrumentation and control cables are equipped with shielding that is earthed at both ends.

On the Nuclear Island, cableways only contain cables from one train. Fire protection devices are installed if a cableway defines a fire zone (see ETC-F). Generally, the trays are interrupted either side of a fire barrier. In all cases, the trays are interrupted where cables pass through a penetration between two buildings.

2. EARTHING AND LIGHTNING PROTECTION SYSTEM

2.1. SYSTEM FUNCTION

The main function of the earthing and lightning protection systems is to limit the risks of over voltage on the electrical systems. Consequently, the following items are taken into consideration:

- over voltage amplitude and frequency; and
- safety of both personnel and equipment.

2.2. SYSTEM BOUNDARY

These measures apply to the Nuclear Island, the Conventional Island and to the Balance of Plant.

2.2.1. System Description

This section details the basic design concepts applicable to all types of offsite and onsite lightning protection facilities and onsite and offsite earthing facilities, as well as additional Electro Magnetic Compatibility (EMC) requirements [Ref-1] imposed to minimise electromagnetic interference to electrical and electronic facilities.

The offsite lightning protection facilities consist of lightning arrestors, earthing conductors and a buried grid electrode. Their objective is to conduct the atmospheric discharge into the ground.

From the Book of Technical Specifications (BTS) [Ref-2] the lightning arresters are provided at the Power Transformer (TP). They connect to each phase terminal inside the electrical sub-station and the TP earth connection is in parallel with the lightning arresters. Also from the BTS [Ref-2], the rated lightning impulse withstand voltage and rated operating impulse withstand voltage for the TP High Voltage (HV) winding will be specified in a Book of Specific Technical Clauses (BSTC).

The lightning protection facilities include additional measures to reduce the electromagnetic effects of currents induced by lightning in locations to be protected, such as building structures, cableways, aerial cables, etc.

The earthing facility ensures personnel protection from unacceptable contact voltages.

Details on the requirements for lightning protection [Ref-3] and details on the earthing system are given in section 7 of Sub-chapter 13.1, in chapter D 4000 of the AFCEN RCC-E code [Ref-4] and in [Ref-5] to [Ref-7].

In order to reduce electromagnetic effects due to lightning or other sources of interference, EPR electrical and I&C equipment are designed according to the requirements detailed in the EMC (immunity) standards and requirements for electrical equipment [Ref-1]. The electromagnetic environment of power stations is defined in the IEC 61000-6-5 Standard [Ref-8]. This document sets immunity requirements for equipment and systems, for which reliable operation is required in the presence of actual electromagnetic conditions.

Compliance with these standards gives a high level of confidence in the protection of equipment against Electro Magnetic Interference (EMI): the first ensures that installed equipment will be able to withstand the specified industrial environment and the second ensures that following best practice installation rules will enable satisfactory overall operation of equipment and systems.

Chapter D 5000 of the AFCEN RCC-E code [Ref-4] and amendment to RCC-E (Modification Sheet 73) [Ref-9] gives details on the type of EMI perturbations encountered and the means required to prevent EMI: these include electrical separation, meshed earthing systems, cabinet protection for certain systems and cable shielding.

2.2.2. System Classification

The classification of the system is described in section 7 of Sub-chapter 13.1.

3. ELECTRICAL PROTECTION MEASURES

3.1. HIGH VOLTAGE AND LOW VOLTAGE NEUTRAL POINT ARRANGEMENT

3.1.1. 10 kV AC and 220 V DC Systems

From [Ref-1] and commensurate with chapter C 2333 of the AFCEN RCC-E code [Ref-2], the neutral points of the 10 kV AC systems and the poles of the DC systems are isolated from earth (IT configuration). With this type of neutral point arrangement, it is possible to continue operation for some time after a phase earthing fault has occurred.

This configuration includes:

- an earth fault monitoring system; and,
- an automatic power disconnection device for use when a second earth fault occurs.

The IT system allows the Nuclear Island loads to continue to operate in the case of a 10 kV earth fault. In this situation, the Nuclear Island process is not disturbed and the operator can identify the origin of the earth fault using the appropriate earth fault monitoring system. The IT system is recommended by the European Utility Requirements for Light Water Reactors and this arrangement is used in French and German NPPs with good operating experience feedback.

An earth fault monitor is installed on each source (e.g. Auxiliary step-down Transformer, TA, incoming, diesel incoming, etc.). These are designed to detect any current leakage to the earth by continuous measurement of the resistance to the earth. Two thresholds are used to monitor the fault. Upon reaching the lower threshold, a visual alarm is sent to the local display. Upon reaching the higher threshold, i.e. detection of a first phase-to-earth fault, the system triggers an alarm (locally and in the control room).

During site licensing, the licensee will provide consistent insulation coordination evidence for all electrical equipment. Analysis will demonstrate the suitability of the insulation control system of the 10 kV and DC networks.

The switching devices are capable of interrupting the duty in the event of a double earth fault.

Commensurate with chapter C 2350 of the AFCEN RCC-E code [Ref-2], the DC power supplies are equipped with earth fault-monitoring devices to monitor the insulation resistance between the live conductors and earth [Ref-3].

3.1.2. 400 V and 690 V AC Systems

The neutral points of the 400 V and 690 V systems are directly earthed and the N (neutral) and PE (earth) conductors are separated (so-called TN-S configuration). Any earth fault causes a short circuit that trips the protection devices. Earthing requirements for the converters, comprising inverters and the Uninterruptible Power Supply (UPS) are described in the BTS [Ref-1].

3.2. ELECTRICAL PROTECTION DEVICES

Electrical protection devices are addressed in [Ref-1], chapter D 5000 of the AFCEN RCC-E code [Ref-2], [Ref-3] and the GPA (Generator and Power Transmission Protection System) System Design Manual [Ref-4].

The GPA provides protection from short circuits from external sources, where the action in response to the fault is to trip the line breaker.

For 10 kV power feeds or connections between 10 kV switchboards, only a short circuit protection device is installed.

The 10 kV motor outgoing sections are protected against short circuits and against overloads.

Protection for outgoing feeders to the HV/LV transformers occurs via independent time threshold detectors. This protection device can be completed by a zero-phase sequence protection device for the detection of phase/ground faults on the secondary winding of the transformer.

The low voltage equipment is protected by:

- fuse-contactor combinations;
- circuit breakers; and
- fuse-disconnect switch combinations.

The electrical protection devices are designed in such a manner that only the upstream protection devices closest to the fault are triggered when a short circuit or overload occurs, so as only to trip the faulty part of the electrical system.

3.3. INSULATION COORDINATION

The overall coordination of insulation is specified in chapter C 2132 of the AFCEN RCC-E code [Ref-1], and chapter D 4000 of [Ref-1] describes requirements applicable to earthing and grounding networks.

To accommodate the neutral point arrangement (see section 3.1.1), the electrical equipment is rated for a phase-to-earth withstand voltage equal to the phase-to-phase voltage [Ref-2].

EMI immunity and susceptibility levels are specified via chapter D 5000 of the AFCEN RCC-E code [Ref-1].

Protective measures to mitigate against over voltage, such as switching impulses generated by operation of the circuit breaker (External High Voltage, EHV, and 10 kV) include:

- provision of surge arresters as the first line of defence (on the TP and 10 kV switchboards, etc.);
- coefficient of transient over-voltage transmission of transformers, as characteristics are specified within the equipment technical specification;
- capacity of the network; and
- equipment insulation strength in accordance with the RCC-E D5000 and modification sheet 73.

Requirements for the EHV surge arrestors, including the rated operating impulse withstand voltage, their location and the means of substantiating the design of the surge arrestors, will be specified in a BTS and/or BSTC. These specifications will also address the following for protection against switching impulses generated by the EHV network:

- limit on over voltage to be achieved by the surge protection on the TP and TA; and
- coefficient of transient over voltage transmission of both the Step-down Transformer (TS) and TA.

Requirements for the surge arrestors on the LGi and LHi switchgear, including the rated operating impulse withstand voltage, their location and the means of substantiating the design of the surge arrestors, will be specified in a BTS and/or BSTC. These specifications will also address the following for protection against switching impulses:

- limiting over voltages;
- transient recovery voltage; and
- insulation performance criteria for the 10 kV equipment.

The coefficient of transient over voltages transmission of 10 kV to Low Voltage (LV) step-down transformers will be defined in the BTS and/or BSTC.

The LV equipment specifications BTS and/or BSTC will address the insulation performance criteria for over voltage protection.

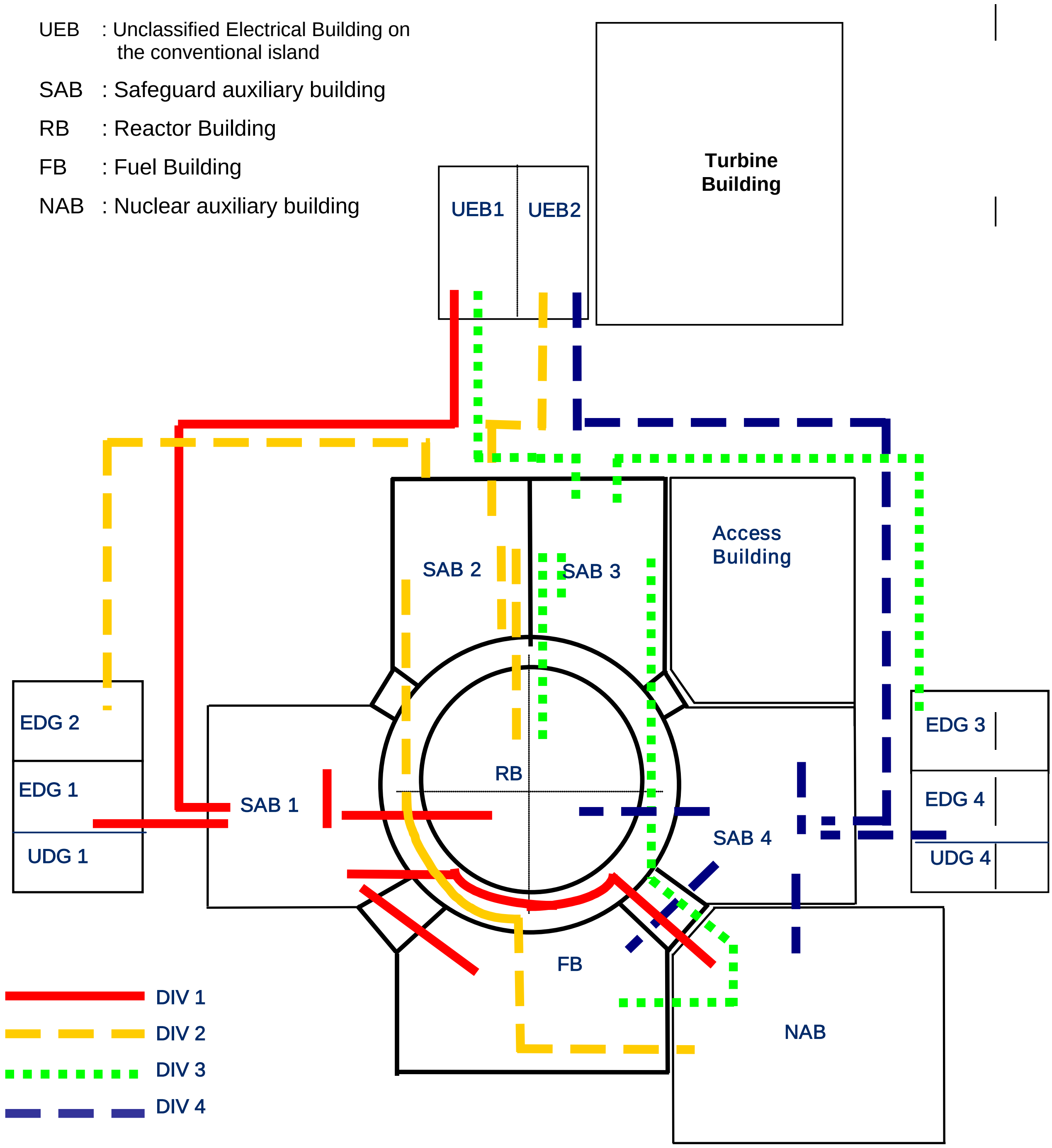
The assumed lightning characteristics are related to Level 1 protection as defined by sections 1 to 4 of IEC 62305 standard [Ref-3] (see Sub-chapter 13.1). Protective measures to mitigate against lightning are described in section 7 of Sub-chapter 13.1.

Other over voltage phenomena are addressed in PCSR Sub-chapter 8.6.

During site licensing, the licensee will assess the consequences throughout the electrical distribution system of the failure of a level of defence in the insulation coordination (e.g. loss of a surge arrestor on the 400 kV system).

SUB-CHAPTER 8.4 - FIGURE 1

Main cableways



SUB-CHAPTER 8.4 – 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.

[Ref-1] Design and Construction Rules for Electrical components of nuclear islands. RCC-E. AFCEN Edition. December 2005. (E)

1. CABLING DESIGN PRINCIPLES

[Ref-1] Design and Construction Rules for Electrical components of nuclear islands. RCC-E. AFCEN Edition. December 2005. (E)

1.3. INSTALLATION OF CABLEWAYS

[Ref-1] Design and Construction Rules for Electrical components of nuclear islands. RCC-E. AFCEN Edition. December 2005. (E)

2. EARTHING AND LIGHTNING PROTECTION SYSTEM

2.2. SYSTEM BOUNDARY

2.2.1. System Description

[Ref-1] D. Soaret. EMC (immunity) standards and requirements to be specified for electrical equipment. ENSECC090082. Revision A. EDF. June 2009. (E)

ENSECC090082 Revision A is the English translation of ENSECC060193 Revision A.

[Ref-2] Book of Technical Specifications (BTS). Main Single Phase Transformers for Three-Phase Assemblies, Main Three-Phase Transformers And Three-Phase Ancillary Power Supply Transformers of Nuclear Power Stations. General Clauses. 72.C.042.02 Final. EDF. April 2004. (E)

[Ref-3] Lightning safety reference base applicable to the EPR. ENSEMD090183 Revision A. EDF. August 2009. (E)

ENSEMD090183 Revision A is the English translation of ENSEMD060324 Revision A.

[Ref-4] Design and Construction Rules for Electrical components of nuclear islands. RCC-E. AFCEN Edition. December 2005. (E)

[Ref-5] System Design Manual Grounding System (LTR), Part 1. ECEIG081012 Revision A1. EDF. November 2009. (E)

[Ref-6] System Design Manual Grounding System (LTR), Part 2 – System operation (Stage 2). ECEIG081018 Revision A1. EDF. November 2009. (E)

[Ref-7] System Design Manual Grounding System (TR), Part 3 – System sizing (Stage 2). ECEIG081035 Revision A1. EDF. November 2009. (E)

[Ref-8] Electromagnetic compatibility (EMC) – Part 6-5: Generic standards – Immunity for power station and substation environments. IEC TS 61000-6-5-2001. (E)

[Ref-9] RCC-E Modification Sheet 73. Protection rules to increase the immunity of receptors to disturbance. Volume D Chapter D 5500 (and A1300). AFCEN. December 2005. (E)

3. ELECTRICAL PROTECTION MEASURES

3.1. HIGH VOLTAGE AND LOW VOLTAGE NEUTRAL POINT ARRANGEMENT

3.1.1. 10 kV AC and 220 V DC Systems

[Ref-1] System Design Manual – 10 kV Normal Power Supply System (Nuclear Island) (LGF/G/H/I), Part 2 – System operation (Stage 2). EZE/2008/en/0003 Revision D. EDF. October 2008. (E)

[Ref-2] Design and Construction Rules for Electrical components of nuclear islands. RCC-E. AFCEN Edition. December 2005. (E)

[Ref-3] Low-voltage switchgear and control gear assemblies. Type-tested and partially type-tested assemblies. BS EN standard 60439-1:1999. (E)

3.1.2. 400 V and 690 V AC Systems

[Ref-1] Book of Technical Specifications (BTS). Converters (Inverters and Uninterruptible Power Supplies) for Nuclear Power Plants. General Clauses. 81.C.004.03 Final. EDF. June 2004. (E)

3.2. ELECTRICAL PROTECTION DEVICES

[Ref-1] Principle of selectivity and coordination of HVA and LV electrical protection systems for the EPR. ENSEMD090015 Revision A. EDF. February 2009. (E)

ENSEMD090015 Revision A is the English translation of ENSEMD080064 Revision A.

[Ref-2] Design and Construction Rules for Electrical components of nuclear islands. RCC-E. AFCEN Edition. December 2005. (E)

[Ref-3] RCC-E Modification Sheet 73. Protection rules to increase the immunity of receptors to disturbance. Volume D Chapter D5500 (and A1300). AFCEN. December 2005. (E)

[Ref-4] System Design Manual. GPA: Electrical Protections for the Generator and Transformers. Part 2: System Operation. ETDOFC080364 Issue B1. EDF. January 2010. (E)

3.3. INSULATION COORDINATION

[Ref-1] Design and Construction Rules for Electrical components of nuclear islands. RCC-E. AFCEN Edition. December 2005. (E)

[Ref-2] Detailed design for the conventional island – Calculation of three-phase short-circuit currents for the HVA and LV switchboards. ENSEMD090233 Revision A (appendix 6.2). EDF. September 2009. (E)

[Ref-3] International Standard. International Electrotechnical Commission – Protection against lightning. IEC 62305. 2010. (E)