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Criteria for independence of class 1E equipment and circuits in nuclear power plants

核电厂安全级电气设备和电路独立性准则

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Criteria for independence of class 1E equipment and circuits in nuclear power plants

1 Scope

This document specifies the independence criteria for physical separation and electrical isolation of safety-class electrical equipment and circuits.

This document applies to the safety class of nuclear power plants and their related electrical equipment and circuits.

This document does not apply to the determination of redundant equipment and circuits.

2 Normative references

The contents of the following documents constitute essential clauses of this document through normative references in the text. Among them, for dated references, only the version corresponding to that date applies to this document; for undated references, the latest version (including all amendments) applies to this document.

GB/T 5204 Periodic surveillance testing of the safety system of nuclear power plant

GB 8624 Classification for burning behavior of building materials and products

GB/T 12790 Method for identification of documents related to safety class 1E equipment and systems for nuclear power plants

GB 50016 Code for fire protection design of buildings

NB/T 20070 Criteria for design, installation, and qualification of raceway systems for class 1E circuits in nuclear power plants

NB/T 20213 Qualification procedure of safety-related electric cables and field splices for nuclear power plants

3 Terms and definitions

The following terms and definitions apply to this document.

3.1

The independence of safety-class electrical equipment and circuits shall not be compromised by the functional failure of auxiliary supporting features. For example, auxiliary supporting features (such as ventilation devices in safety-class switchgear rooms) shall be specified as belonging to the same division as the safety-class electrical system they support, to prevent the failure of a mechanical function in one division from causing the failure of an electrical function in another division.

4.5 Associated circuits

4.5.1 General

In addition to the exceptions mentioned in 4.6c), d), e), non-safety-class power supplies, control, instrumentation circuits may become associated circuits due to one or more of the following situations:

a) Electrically connected to the safety-class power supply without using an isolation device (see Figure 1);

b) Electrically connected to the related power supply without using an isolation device (see Figure 1);

c) Close to safety-class equipment and circuits without a physical separation or barrier that meets the requirements (see Figure 2);

d) Close to related equipment and circuits without a physical separation or barrier that meets the requirements (see Figure 2);

e) Sharing a safety-class or related signal source without using an isolation device (see Figures 3 and 8).

4.5.2 Guidelines

Associated circuits shall meet one of the following requirements.

a) They shall be marked according to the requirements of the associated circuit or safety class and can be traced back to the safety class division related to them, that is, they shall be physically separated in the same way as the safety class circuits related to them. Unless it is proved by analysis or test that it will not cause the performance of the safety class circuit to be reduced to an unacceptable level, they shall meet the requirements of the safety class circuit.

b) All associated circuits, including safety class equipment and isolation devices, shall comply with the requirements of 4.5.2a). If the circuit behind the isolation device is no longer related to the safety class system, it is not necessary to comply with the requirements of this document.

c) It shall be proved by analysis or test that these associated circuits will not cause

2) Through analysis, it is proved that the non-safety circuit will not cause the performance of the safety circuit to be degraded to an unacceptable level. The analysis shall evaluate the category of the non-safety circuit and its possible energy.

e) Non-safety fiber optic loops do not need to be physically isolated from safety circuits or associated circuits. Electrical isolation is an inherent characteristic of fiber optic loops. Because fiber optic loops do not cause the safety circuit to degrade, they can be treated as non-safety circuits rather than associated circuits.

4.7 Mechanical system

Safety-class circuits shall be laid or protected in a manner that prevents failure of a division of mechanical equipment from causing failure of safety-class circuits or equipment necessary for redundant systems or equipment to perform their safety functions. When safety-class equipment or circuits are used to mitigate the consequences of a mechanical system failure or misoperation, the impact of these failures or mis-operations on the division itself shall be evaluated. At the same time, the impact of pipe swing, jet impact, water spray, flooding, radiation, pressurization, temperature rise or moisture on redundant electrical systems, as caused by mechanical system failure, misoperation or operation, shall be evaluated. In addition, the potential hazards of flying objects caused by rotating equipment or high-energy system failures shall also be evaluated.

4.8 Structures and equipment

Safety-class electrical systems shall maintain their independence and redundancy during and after the failure of structures and equipment that have not been identified for design basis events.

4.9 Fire protection system

When redundant division equipment and circuits are arranged within the range of the same fixed fire protection system, the design of these equipment and circuits shall be coordinated with the fire protection system, so that the independence of the safety-class electrical system is not impaired; the impact of false operation of the fire protection system on equipment rooms and cable channels shall be evaluated.

4.10 Fire

4.10.1 An electrical fire occurring within a safety class division shall not cause the loss of function of its redundant division.

4.10.2 Redundant safety class equipment and circuits shall maintain independence; a fire in a fire hazardous area shall not prevent its redundant equipment and circuits from performing safety functions.

4.11 Electromagnetic interference/Radio frequency interference

The possibility of electromagnetic interference/radio frequency interference affecting the independence of redundant safety class equipment and circuits shall be evaluated. Corrective measures to mitigate electromagnetic interference/radio frequency interference interactions may include the following: grounding, use of low-voltage components, physical separation, isolation devices, shielding of susceptible equipment or circuits, shielding of electromagnetic interference sources, etc., see Appendix B of GB/T 13284.1-2008.

The following interactions of EMI/RFI shall be evaluated:

a) EMI/RFI generated by a safety class division shall not reduce the ability of redundant safety class equipment or circuits to perform safety functions;

b) EMI/RFI generated outside the safety class circuit (such as non-safety class circuits and equipment, broadcasting, telephone) shall not reduce the ability of safety class equipment and circuits to perform safety functions.

5 Physical separation criteria

5.1 Cable and wiring channels

5.1.1 General

5.1.1.1 Grading of areas

The cable laying and equipment areas of the safety class and its associated circuits shall be reviewed, to find out whether there are potential hazards such as high-energy pipelines, flying objects, flammable materials, ignition sources and flooding. These areas shall be divided as follows:

a) Non-hazardous areas (see 5.1.3);

b) Low-hazard areas (see 5.1.4);

c) Hazardous areas (see 5.1.5).

In the early stages of design, a separation equivalent to the degree of potential hazardous damage shall be provided through separate rooms, barriers and other facilities. If there is sufficient heat dissipation capacity, the sides of the room or area can also be used as a partition.

5.1.1.2 Minimum separation distance

5.1.1.2.1 Subject to the following criteria, the minimum separation distances specified in 5.1.3 ~ 5.1.5 and 5.1.9 can be used to obtain a physical separation that meets the

the consequences (such as spraying devices) shall be evaluated.

5.1.2 Marking

Exposed safety-class and associated circuit cable wiring channels shall be permanently marked at the entrances and exits of the enclosed area and at intervals of no more than 5 m on the channel. The marking shall be set before the cable is installed. Cables laid in the wiring channel shall be permanently marked at intervals of no more than 3 m, so that it can be verified from the beginning whether their laying meets the separation criteria. The marking shall be set before or during the cable laying.

Cables of safety class and associated circuits shall be permanently marked at each end in accordance with the requirements of the design drawings or cable lists.

To meet the above requirements, the marking method adopted shall be able to easily distinguish between redundant safety class divisions, safety class and non-safety class divisions, associated cables of different redundant safety class divisions. If no separation is required between optical fiber loops, a single method can be used for identification.

5.1.3 Non-hazardous area

5.1.3.1 Area requirements

The basis for determining the minimum separation distance applicable to this area is limited to internal faults of electrical equipment and cables.

The area that meets the following requirements is defined as a non-hazardous area:

a) There are no high-energy equipment (such as switchgear, transformers, rotating equipment) in this area, nor are there any potential hazards such as missiles, pipeline damage or fire;

b) The circuits in this area shall be limited to instrumentation and control functions, as well as power equipment and cables that only serve the equipment in this area;

c) The power cables in this area shall be installed in closed wiring channels;

d) The introduction of potential hazards shall be limited and controlled through administrative measures for operation and maintenance activities.

5.1.3.2 Boundary of non-hazardous areas

The boundary of non-hazardous areas meets the following requirements:

a) The area shall be separated from other adjacent areas by a fire barrier, which shall have a fire resistance equivalent to the possible fire hazard, or shall have a fire resistance rating of 3 h;

In the hazardous area, comprehensive measures such as restrictions on cable laying or special physical separation shall be adopted according to the requirements of 5.1.6 ~ 5.1.8, to keep the independence of the redundant division of the safety class system within an acceptable level.

The minimum distance between the non-safety class and the safety class or associated circuits shall meet the requirements of 5.1.4.

5.1.6 Pipeline damage hazardous area

5.1.6.1 Area requirements

If there are pipelines operating normally at high or medium energy in a certain area, the area shall be defined as a pipeline damage dangerous area.

For medium energy pipelines, it is not necessary to consider pipeline swing and jet impact, but the impact on the surrounding area and the environment shall be evaluated.

5.1.6.2 Area boundary

Barriers, constraints, separation distances or appropriate combinations thereof shall be used to protect non-hazardous areas and low-hazardous areas from the hazards of pipeline damage hazardous areas.

5.1.6.3 Laying requirements

In the pipeline damage hazardous area, it shall be possible to prove that the pipeline damage does not affect the ability of the safety-class equipment and circuits to perform their safety functions. Otherwise, the laying of cables or wiring channels for safety-class or associated circuits shall meet the following requirements.

a) If the relevant pipeline does not belong to a single division and has been qualified by the design basis event, meanwhile no protective action is required for the impact caused by its damage, the cables or wiring channels for the safety-class or associated circuits laid in the area shall be limited to a single division.

b) If protective action is required for the impact caused by the damage to the pipeline, except for the cables that shall be terminated to the devices or loads in the area [special measures (such as increasing redundancy or diversity) may be required for these cables to meet the single failure criterion], cables or wiring channels for other safety-class or associated circuits shall not be laid in the area.

c) If the relevant pipeline belongs to a single division and has been qualified by the design basis event, meanwhile no protective action is required for the impact caused by its damage, the cables or wiring channels for the safety-class or associated circuits laid in the area shall be limited to the same division as the pipeline.

d) If the relevant pipeline has not been identified for design basis events, cables or wiring channels of other safety-class or associated circuits shall not be laid in the area, except for cables that shall be terminated to devices or loads in the area. When the area where safety-class or associated circuits or wiring channels are laid is designated as a hazardous area due to the presence of pipelines that have not been identified for design basis events, these cables or wiring channels shall be protected in accordance with the methods specified in 5.1.6.2, to avoid the impact of the area; otherwise, the relevant pipeline shall be qualified after design basis event identification.

5.1.7 Missile hazardous area

5.1.7.1 Area requirements

If there is a missile source with sufficient kinetic energy in a certain area under design basis event conditions, which will damage the safety-class redundant circuits separated according to the requirements of 5.1.4 and laid in the area, then the area shall be designated as a missile hazardous area.

5.1.7.2 Area boundary

Barriers, orientation, separation distance or appropriate combination thereof shall be adopted to protect non-hazardous areas and low-hazard areas from the hazards of missile hazard areas.

5.1.7.3 Laying requirements

The cables or wiring channels for safety-class or associated circuits laid in this area shall meet the following requirements.

a) If the relevant missile source does not belong to a single division and has been qualified by the design basis event, meanwhile no protective action is required for the impact caused by its damage, the cables or wiring channels for safety-class or associated circuits laid in this area shall be limited to a single division.

b) If protective action is required for the impact caused by the missile source, except for the cables that shall be terminated to the devices or loads in this area [special measures (such as increasing redundancy or diversity) may be required for these cables to meet the single failure criterion], cables or wiring channels for other safety-class or associated circuits shall not be laid in this area.

c) If the relevant missile source belongs to a single division and has been qualified by the design basis event, meanwhile the impact of its damage does not require protective action, the cables or wiring channels of the safety class or associated circuits laid in the area shall be limited to the same division as the missile source.

d) If the relevant missile source has not been qualified by the design basis event,

In the fire hazardous area, the cables or wiring channels for laying safety-class or associated circuits shall meet the following requirements.

a) If the relevant fire hazard source does not belong to a single division and is qualified by the design basis event, meanwhile the impact of its damage does not require protective action, the cables or wiring channels for the safety-class or associated circuits laid in the area shall be limited to a single division.

b) If protective action is required for the impact caused by the fire hazard source, except for the cables that shall be terminated to the devices or loads in the area [special measures (such as increasing redundancy or diversity) may be required for these cables to meet the single fault criterion], cables or wiring channels for other safety-class or associated circuits shall not be laid in the area.

c) If the relevant fire hazard source belongs to a single division and has been qualified by the design basis event, meanwhile the impact of its damage does not require protective action, the cables or wiring channels of the safety class or associated circuits laid in the area shall be limited to the same division as the fire hazard source.

d) If the relevant fire hazard source has not been qualified by the design basis event, except for the cables that shall be terminated to the devices or loads in the area, other cables or wiring channels of the safety class or associated circuits shall not be laid in the area. When the area where the cables or wiring channels of the safety class and associated circuits are laid is designated as a hazardous area due to the presence of fire hazards not related to nuclear safety, these cables or wiring channels shall be protected in accordance with the methods specified in 5.1.8.2, to avoid the impact of the area.

5.1.9 Optical fiber loop

5.1.9.1 General

Optical fiber loops will not cause degradation of other optical fiber loops or live circuits. Therefore, if the optical fiber loop is used as a fault source cable, there is no isolation requirement. If the optical fiber loop is used as an affected cable, it shall meet the isolation criteria requirements of 5.1.9.2. For more discussion on optical fiber loops, see Appendix A.

5.1.9.2 Separation distance

In non-hazardous areas, there is no isolation distance requirement between the optical fiber circuit of the safety-class division and the optical fiber circuit of its redundant division. There is no isolation distance requirement between the safety-class optical fiber circuit and the non-safety-class optical fiber circuit.

If the optical fiber circuit is used as the affected cable and the live circuit is used as the

The auxiliary equipment and local control devices of the redundant standby generator set shall be arranged in a structure with the same safety class as the unit; otherwise, they shall be physically separated in accordance with the requirements of Chapter 4.

5.3 DC system

5.3.1 Batteries

Redundant safety-class batteries shall be arranged in separated safety-class structures.

5.3.2 Battery chargers

The chargers of safety-class redundant batteries shall be physically separated in accordance with the requirements of Chapter 4.

5.4 Power distribution system

5.4.1 Switchgear

The division of redundant safety-class distribution switchgear shall be physically separated in accordance with the requirements of Chapter 4.

5.4.2 Motor control center

Redundant safety-class motor control center shall be physically separated in accordance with the requirements of Chapter 4.

5.4.3 Switchboard

Redundant safety-class switchboards shall be physically separated in accordance with the requirements of Chapter 4.

5.5 Containment electrical penetrations

Redundant safety-class containment electrical penetrations shall be physically separated in accordance with the requirements of Chapter 4; redundant penetrations are generally required to be widely distributed around the circumference of the containment. The minimum physical separation distance of redundant penetrations shall meet the requirements of 5.1.4 and 5.1.5 for cables and wiring channels.

Non-safety-class circuits passing through safety-class circuit penetrations shall be handled in accordance with the requirements of 4.5 for associated circuits.

5.6 Control cabinets

5.6.1 Location and layout

The main control cabinet shall be arranged in a non-hazardous area within the safety-

class structure. The local control cabinet shall be arranged in accordance with the requirements of 5.1.

Redundant safety-class equipment and circuits may be arranged in a control cabinet physically separated in accordance with the requirements of 5.1 to be separated. From the operational perspective, when redundant safety-class equipment or safety-class equipment is placed in the same control cabinet or box with non-safety-class equipment, the requirements of 5.6.2 ~ 5.6.6 shall be met.

5.6.2 Internal separation

5.6.2.1 In the control cabinet, the minimum separation distance required by Chapter 4 can be determined based on the analysis of the proposed installation method. This analysis shall be based on tests, the purpose of which is to determine the flame retardant properties of the wiring method, wire materials, equipment and other materials inside the control switch cabinet. Considering the overall safety function of the circuit, sufficient separation distance can be determined when the impact of the source cable on the target cable is acceptable.

If the above analysis is not performed and the material of the control switch cabinet is flaming retardant, when only live circuits are involved, the minimum horizontal separation distance is 2.5 cm and the minimum vertical separation distance is 15.0 cm. The minimum vertical separation distance can be reduced to 2.5 cm, if the wiring can withstand the following worst transient conditions:

a) Heating of non-safety-class wires will not cause the wires to sag and touch safety-class wires or components;

b) Heating of safety-class wires will not cause the wires to sag and touch safety-class wires or components of redundant divisions.

Acceptable wire fixing methods include using stainless steel ties or other metal brackets to fix the wires every 15.0 cm along the wires.

5.6.2.2 When fiber optic circuits are involved, the following isolation guidelines must be followed:

a) There is no isolation distance requirement between the fiber optic circuit of the safety-class division and the fiber optic circuit of its redundant division;

b) There is no isolation distance requirement between the safety-class fiber optic circuit and the non-safety-class fiber optic circuit;

c) The isolation distance between the fiber optic circuit and the live circuit shall meet the isolation distance requirements of Table 3.

If the above isolation distance cannot be maintained, partitions shall be installed

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