Safety Standards

of the
Nuclear Safety Standards Commission (KTA)

KTA 2206 (2022-11)

Design of Nuclear Power Plants against Damaging Effects from Lightning Strikes

(Auslegung von Kernkraftwerken gegen Blitzeinwirkungen)

Previous versions of this safety standard
were issued in 1992-06, 2000-06, 2009-11 and 2019-11

Editor:
KTA-Geschaeftsstelle
c/o Bundesamt fuer die Sicherheit der nuklearen Entsorgung (BASE)
Willy-Brandt-Str. 5 • 38226 Salzgitter • Germany
Telephone +49 (0) 30 184321-2907
Email: kta-gs@base.bund.de

KTA SAFETY STANDARD

November 2022	**Design of Nuclear Power Plants against Damaging Effects from Lightning Strikes**	KTA 2206

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2009-11 (BAnz No. 3a of January 7, 2010)
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Contents

PLEASE NOTE: Only the original German version of this safety standard represents the joint resolution of the 35-member Nuclear Safety Standards Commission (Kerntechnischer Ausschuss, KTA). The German version was made public in the Federal Gazette (Bundesanzeiger) on July 25, 2023. Copies of the German versions of the KTA safety standards may be mail-ordered through the Wolters Kluwer Deutschland GmbH (info@wolterskluwer.de). Downloads of the English translations are available at the KTA website (http://www.kta-gs.de).

All questions regarding this English translation should please be directed to the KTA office:

KTA-Geschaeftsstelle c/o BASE, Willy-Brandt-Strasse 5, D-38226 Salzgitter, Germany or kta-gs@base.bund.de

Comments by the Editor:

Taking into account the meaning and usage of auxiliary verbs in the German language, in this translation the following agreements are effective:

shall	indicates a mandatory requirement,
shall basically	is used in the case of mandatory requirements to which specific exceptions (and only those!) are permitted. It is a requirement of the KTA that these exceptions - other than those in the case of **shall normally** - are specified in the text of the safety standard,
shall normally	indicates a requirement to which exceptions are allowed. However, exceptions used shall be substantiated during the licensing procedure,
should	indicates a recommendation or an example of good practice,
may	indicates an acceptable or permissible method within the scope of the present safety standard.

Basic Principles

(1) The safety standards of the Nuclear Safety Standards Commission (KTA) have the task of specifying those safety-related requirements which shall be met with regard to precautions to be taken in accordance with the state of science and technology against damage arising from the construction and operation of the plant (Sec. 7, para. (2), subpara. (3) Atomic Energy Act - AtG) in order to attain the protective goals specified in the AtG, the Radiation Protection Act (StrlSchG) and the Radiation Protection Ordinance (StrlSchV) as well as further detailed in the Safety Requirements for Nuclear Power Plants (SiAnf) and the Interpretations of the SiAnf.

(2) In accordance with Sec. 2.4 SiAnf ("Protection concept against internal and external hazards as well as against very rare human induced external hazards"), protection measures are required with respect to natural external events. Appendix 3 SiAnf specifies the extent of required lightning protection measures in so far as stating that equipment-related protection measures shall be taken against this event. This is achieved by properly designing the lightning protection of the plant and by installing suitable lightning protection systems.

(3) The present safety standard is established under the presumption that the requirements from conventional standards and regulations (e.g., building regulations of the individual German states, the German Accident Prevention Regulations, DIN standards and VDE regulations, EN standards, IEC standards) are observed taking the nuclear power plant specific safety requirements into consideration.

(4) This safety standard specifies additional requirements for the lightning protection of nuclear power plants. The objective of this safety standard is to specify these additional requirements regarding the Exterior and the Interior Lightning Protection System such that the influence of lightning strikes on electrical facilities will not lead to impermissibly adverse effects on plant safety.

(5) The foundation of the present safety standard is based on

a) deriving, and then specifying, lightning strike characteristics from the measurement results of actual lightning strikes,

b) evaluating specific experiments with pulse generators that simulate lightning strikes by inducing voltage pulses into cables and conductors of existing nuclear power plants which were already protected by defined and relevant lightning protection measures,

c) specifying analytical procedures for determining that portion of the lightning current that must be considered for the voltage induction,

d) evaluating results from analytical and numeric procedures regarding the lightning-based voltage induction into cables of cable ducts and into buried cables (cf. **Appendix F** [1], [2]).

(6) The general requirements regarding quality assurance are specified in safety standard KTA 1401.

(7) The present safety standard specifies the protection measures against lightning-strikes required in accordance with Secs. 4.1.2.3 and 4.2.2 of safety standard KTA 3501.

(8) The present safety standard does not specify any analytical procedures regarding the induction of lightning strike based voltages into the instrumentation and control circuitry inside the power plant buildings. Various analytical procedures have been published in technical literature relating to the calculation of induced voltages in buildings of power plants. However, due to the differences between power plants with respect to geometric arrangement of the electrical equipment and the instrumentation and control equipment and due to the various induction possibilities, no single easily applicable analytical procedure is available that would suit all individual cases.

Note:

Further information on the voltages coupled into buildings can also be obtained from measurements of building shielding effectiveness and measurements on models (cf. **Appendix E**).

1 Scope

This safety standard applies to the protection of the electrical facilities in stationary nuclear power plants against impermissibly adverse effects from a lightning strike.

2 Definitions

Note:

Some of the terms used in the present safety standard, e.g. "lightning protection system", are differently defined from the terms in DIN EN 62305, and, therefore, identical terms may be associated with differing contents.

(1) Lightning protection

Lightning protection is the entirety of all measures and equipment for the prevention of damaging effects from a lightning strike.

(2) Lightning protection system

The lightning protection system comprises the Exterior Lightning Protection system and the Interior Lightning Protection system.

(3) Exterior Lightning Protection system

Exterior Lightning Protection system is the entirety of all measures and equipment provided for catching and grounding the lightning current.

(4) Interior Lightning Protection system

Interior Lightning Protection system is the entirety of all measures and equipment provided against the effects of the lightning strike on conductive installations and electrical facilities inside buildings and structures. This includes all measures for the reduction and limitation of surge-voltages.

(5) Grounding, decentralized

Decentralized grounding is the multiple, low-impedance connection of the reference potential lead of the instrumentation and control systems to the voltage equalization system.

(6) Grounding, centralized

Centralized grounding is the stellate connection of the reference potential lead to the central ground point.

(7) Robustness

Robustness indicates the ability of a system to be able to withstand events going beyond the design specifications without losing its functionality. In the present safety standard, robustness means the ability of the safety-related electrical systems associated with the lightning protection system to withstand lightning strikes beyond the design specifications.

3 Design Parameters

3.1 General Requirements

(1) The lightning protection and the electrical facilities shall be designed and coordinated with each other such that no electrical facilities will suffer impermissibly adverse effects from lightning strikes.

Note:

Impermissibly adverse effects are, e.g., the blocking or erroneous initiation of protective actions by the safety systems as well as the loss of function of safety-related plant components.

(2) Type and extent of the electrical facilities that must be protected by lightning protection measures shall be specified before beginning with the construction of the buildings and structures.

Note:
Requirements regarding modifications are specified in Section 7.

3.2 Assignment of Protection Categories

(1) The requirements with respect to dimensioning the lightning protection of the buildings and structures of the nuclear power plant shall be specified with regard to the electrical facilities contained in these buildings. The individual buildings and structures shall therefore be assigned to the following protection categories:

a) Level 1 protection category
Buildings and structures that contain electrical facilities relevant to safety shall be assigned to the Level 1 protection category.

Note:
The Level 1 protection category also applies to buildings and structures that contain facilities of plant-operation related instrumentation and controls if their malfunction might lead to impermissibly adverse effects in safety-related plant components.

b) Level 2 protection category
The Level 2 protection category applies to all buildings and structures not assigned to item a).

Note:
No requirements are specified in the present safety standard regarding buildings in the Level 2 protection category.

(2) It shall be prevented that electrical facilities in buildings and structures in the Level 2 protection category have any impermissible feedbacks to electrical facilities in buildings and structures in the Level 1 protection category.

Note:
Impermissible feedbacks can be prevented by, e.g., spatial separation, galvanic decoupling, use of shielded cables whose shield is able to conduct currents, or by protective circuitry. A combination of multiple measures may be necessary.

3.3 Lightning Current Parameters

The lightning current parameters specified in **Tables 3-1** and **3-2** shall be used as basis for demonstrating the protection against lightning-based surge voltages (cf. Section 5).

3.4 Lightning Strike Protected Areas of Buildings and Structures in the Level 1 Protection Category

(1) The lightning strike locations and the lightning strike protected areas shall normally be determined by the rolling sphere method in accordance with DIN EN 62305-1 using a radius of 20 m.

Note:
Electrical equipment located outside of the thus determined lightning strike protected area might be subject to direct lightning strikes with a reduced crest value of the current.

(2) The design of protective measures with respect to their maximum current conductivity may be based on the crest value of the current of the initial lightning strike at the radius of the rolling sphere in accordance with Equation (3-1) touching at this location.

$$R = 10 \cdot I^{0,65} \qquad (3\text{-}1)$$

Nomenclature:

R	in m	rolling sphere radius
I	in kA	crest value of the current

Note:
According to DIN EN 62305-1 and the electro-geometrical model, the rolling sphere radius, R (maximum striking distance), correlates to the crest value of the first current pulse.

Type of Lightning	***Parameter***	***Formula Symbol***	***Unit***	***Value***
Positive initial lightning strike	crest value of current	I_B	kA	200
	average current gradient	I_B / T_1	kA/µs	20
	front time	T_1	µs	10
	time of half-value	T_2	µs	350
	impulse charge	Qi	C	100
	specific energy	W/R	MJ/Ω	10
Negative initial lightning strike	crest value of current	I_B	kA	100
	average current gradient	I_B / T_1	kA/µs	100
	front time	T_1	µs	1
	time of half-value	T_2	µs	200
Negative subsequent lightning strike	crest value of current	I_B	kA	50
	average current gradient	I_B / T_1	kA/µs	200
	front time	T_1	µs	0.25
	time of half value	T_2	µs	100

Table 3-1: Lightning current parameters of the current pulses

Height of Structure (Type of Lightning)	***Parameter***	***Formula Symbol***	***Unit***	***Value***
$h \geq 60$ m	charge of the longtime current	Q_I	C	400
	duration of the longtime current	t	s	0.5
$h < 60$ m	charge of the longtime current	Q_I	C	200
	duration of the longtime current	t	s	0.5

Table 3-2: Lightning current parameters of the long-duration currents

4 Design and Construction

4.1 Design and Construction Documents

(1) Prior to erecting the grounding devices and the lightning protection system it shall be shown on the basis of the design specifications how the requirements under the present safety standard are being met.

Rolling Sphere Radius	*Corresponding Crest Value of the Current of the Initial Lightning Strike*
20 m	3 kA
30 m	6 kA
45 m	10 kA
60 m	16 kA

Table 3-3: Example for the **c**orrelation between the crest values of currents and the rolling sphere radii in accordance with Equation (3-1)

(2) The buildings and structures to be protected may be subdivided into lightning protection zones.

Note:

This may be necessary in order to be able to realize a graded protection concept. The basics and details for a concept of these lightning protection zones are contained in DIN EN 62305-4.

4.2 Exterior Lightning Protection System

4.2.1 General requirements

The spacing specified in Sections 4.2.2 through 4.2.6 as well as in **Figures 4-1** through **4-4** are only general approximations. It is permissible to use deviating spacing values in order to adjust for the geometry of the buildings and structures. However, the specified spacing shall normally not be exceeded by more than 20 %. A reduction of the spacing is permissible.

Note:

Requirements regarding materials and corresponding cross-sections for the capture devices, down conductors and grounding systems are specified in DIN EN 62305-3.

4.2.2 Capture devices

(1) All roof surfaces and wall parts that can be struck by lightning shall be provided with capture devices.

(2) The positions of the capture devices shall normally be determined by the rolling sphere method using a radius of 20 m.

(3) In case the capture meshing lies directly on top of the building roof, the mesh width shall normally not exceed 5 meters (cf. **Figure 4-1**).

(4) Metallic structures on top of the roof may be used as capture devices. They shall be connected to the other capture devices.

4.2.3 Down conductors

4.2.3.1 Buildings without metal fronts

(1) A meshing of vertical down conductors and horizontal transverse connectors shall be placed into or onto the walls in order to distribute the conducted lightning current over as large a surface as possible. The spacing of the down conductors and of the transverse connectors shall not exceed 5 meters.

(2) If the meshing is placed within or onto the reinforcement steel rods, it shall itself be manufactured from round or flat bar steel with a minimum cross-section of 50 mm². The intersecting points of the meshing shall be welded or securely clamped or bolted together such that the connecting cross-section is at least equal to the cross-section of the meshing. The rods of the meshing shall be tie-wire connected to the reinforcement steel rods at intervals of 1 meter (cf. **Figure 4-1).**

(3) If a conductive interconnection of the reinforcement steel rods, e.g. by welding, is permissible these rods may be used as down conductors and transverse connectors, provided a continuous interconnection is ensured. These reinforcement steel rods shall have a diameter of at least 10 mm.

Note:

Requirements regarding the welding of reinforcement steel rods are contained in DIN EN ISO 17660.

(4) The terminal lugs for connecting the capture devices and the grounding system shall be corrosion protected wherever these lugs are routed through the ground or through concrete. The meshing within or outside on the wall shall be welded or securely clamped or bolted to the mesh in the foundation such that the connecting cross-section is at least equal to the cross-section of the meshing. In the case of buildings with an external structural seal cf. **Figure 4-2** and in case of buildings without an external structural seal cf. **Figure 4-1.**

(5) For the purpose of testing, a connection to the external grounding system shall be achievable by accessible and disconnectable terminals. These disconnect terminals shall be unambiguously and durably marked. Their markings shall be identical to the corresponding markings used in the surveillance plans of the buildings.

4.2.3.2 Buildings with metal fronts

(1) Metal fronts may be used as down conductors and electromagnetic shielding, thus, replacing the measures specified under Sections 4.2.3.1 and 4.2.4. If used as down conductors, the metal fronts shall be conductively interconnected such that they are capable of vertically carrying the current of a lightning strike. If used as electromagnetic shielding, additional electrically conductive connections are required.

(2) The metal fronts shall be connected to the capture devices. If the metal fronts are used as down conductor, vertical interconnections capable of conducting the current of a lightning strike are required and shall be spaced no more than 5 meters apart from each other. If the metal fronts are also used as electromagnetic shielding, additional vertical and horizontal electrically conductive interconnections of the individual metal sheets are required and shall be spaced no more than 1 meter apart from each other.

(3) In case the lower part of the building has steel reinforced walls, then the metal fronts shall normally be interconnected with the reinforcement steel rods and these interconnections shall be spaced no more than 10 meters apart from each other. If there are no steel reinforced walls, the metal fronts shall be connected to the grounding system and these connections shall be spaced 10 meters apart from each other if the lower lip of the metal front is lower than 1 meter above ground. If the lower lip of the metal front is higher than 1 m above ground, either the connections to the grounding system shall be spaced no more than 5 meters apart from each other or the fronts shall be connected to a meshing as specified under Section 4.2.3.1.

(4) The metal fronts used as down conductors shall be interconnected to the meshing in the roof, and these connections shall be spaced as specified under Section 4.2.4.1 (cf. **Figure 4-3**).

(5) In the case of buildings provided with an external structural seal, the connections of the foundation grounding devices shall be designed as shown in **Figure 4-2** and, in case of buildings without an external structural seal, as shown in **Figure 4-3**. For the purpose of testing, the connection to the external grounding system shall be achieved by accessible and disconnectable terminals. These disconnectable terminals shall be unambiguously and durably marked. Their markings shall be identical to the corresponding markings used in the surveillance plans of the buildings.

4.2.4 Electromagnetic building shield

4.2.4.1 Outer walls and roofs of buildings

(1) For the protection of the electrical facilities a shield shall be formed inside the buildings by interconnecting all electrically conductive parts of the building structure.

(2) In the case of structural components made of reinforced concrete, the reinforcement steel rods shall be used for the electromagnetic shielding. Thus, a meshing shall be created, either, by interconnecting the existing reinforcement steel rods or by interconnecting additional steel rods with the reinforcement steel rods. The mesh spacing shall not exceed 5 meters. To ensure a true contact, all parts of the meshing shall be welded or securely clamped or bolted together such that the connecting cross-section is at least equal to the cross-section of the meshing. The added rods shall be tie-wire connected at intervals of 1 meter to the reinforcement steel rods.

(3) Expansion joints within a building shall normally be bridged in intervals of 2 meters ± 1 meter.

(4) If the actual building construction does not deliver a sufficient shielding, it is permissible to create a shielding effect for the electrical facilities located within this building by a suitable electromagnetic shield of the individual component (e.g., electromagnetic shielding of the cable ways). In case of insufficient shielding, e.g., due to the use of prefabricated steel-reinforced components, additional measures shall be taken (cf. Section 4.3).

4.2.4.2 Building penetrations

All conducting non-electrical components leading into the buildings shall normally be connected to the building shield.

Note:

For example, pipelines are interconnected by low-impedance connections to the reinforcement steel rods at the point of entry into the building. In this context, corrosion protection shall be provided.

4.2.5 Grounding

4.2.5.1 Grounding of the buildings

(1) In the case of buildings not provided with an external structural seal (non-insulated foundation), grounding shall be achieved using the reinforcement steel rods of the foundations. Beneath the grounding connection within the foundation and the walls, an additional meshing shall be embedded with a mesh spacing of 10 meters; the rods of the meshing shall be tie-wire connected at intervals of 1 meter to the reinforcement steel rods. The intersecting points of the meshing shall be welded or securely clamped or bolted such that an electrically conducting connecting cross-section at least equal to the cross-section of the meshing is achieved. Inside the walls this meshing and the down conductors shall be welded or securely clamped or bolted together as specified in Section 4.2.3.1 (cf. **Figure 4-1**).

Note:

Additional requirements with regard to grounding systems outside of the buildings are specified in, e.g., DIN VDE 0100-410, DIN VDE 0100-540, DIN EN 61936-1 VDE 0101-1 and DIN EN 50522 VDE 0101-2.

(2) For the connection to the external grounding system, terminal lugs shall be led to the outside of the wall from the meshing connected to the reinforcement steel rods. In this context, corrosion protection shall be provided. The terminal lugs shall be permanently connected to the reinforcement steel rods or to the metal building fronts; the connection to the grounding system shall be achieved through accessible and disconnectable terminals (cf. **Figure 4-2**).

(3) In the case of buildings provided with an external structural seal (insulated foundation), a grounding mesh with a mesh spacing of 10 meters shall be embedded in the ground outside of the structural seal. If this grounding mesh is fabricated from reinforcement steel, the diameter of the rods shall normally not be smaller than 10 mm and the mesh shall be embedded in a concrete layer of a thickness no smaller than 10 cm consisting of at least a grade B 15 concrete. The interconnection between the concrete reinforcement steel rods and the copper cable shall be protected against corrosion. This interconnection does not have to be detachable (cf. **Figure 4-2**). The interconnections of the grounding mesh shall be as specified under Section 4.2.5.3.

4.2.5.2 External grounding between the buildings

(1) In the direct vicinity of buildings in the Level 1 protection category a close-meshed grounding net of surface ground devices (ground rings and grounding meshes) shall be installed (cf. **Figure 4-4**).

(2) Each building complex that builds a unit with regard to lightning protection shall be provided with a surrounding ground ring which shall be connected every 10 meters to the down conductors or, in the case of metal building fronts whose lower lip is higher than 1 meter above ground, shall be connected above the disconnect terminals at intervals of 5 meters (cf. Section 4.2.3). Starting out from the ground ring, surface ground devices shall be provided at intervals of 10 meters (mesh width) and such that a maximum mesh length of 30 meters is formed. The meshing of neighboring buildings shall be correlated to each other. The mesh of the surface ground devices connecting to these meshes shall not exceed 30 meters in width and 90 meters in length; further meshes interconnected to theses surface ground device meshes may be increased up to twice this dimension. The overall expanse of the grounding mesh shall be specified in each individual case.

(3) The ground rings of buildings in the Level 2 protection category shall also be connected to the grounding mesh.

(4) In the case of multi-unit power plants, the grounding meshes of the individual plant units as well as those of the mutually used buildings shall be interconnected to each other.

4.2.5.3 Corrosion resistance of the grounding mesh

All parts of the grounding mesh embedded in soil shall be constructed using corrosion resistant materials. Non-detachable connections (e.g., welds, crimp connections) shall be used exclusively.

Note:

The required minimum cover of reinforcement steel is specified in DIN EN 1992-1-1.

4.2.6 Connections between the buildings

4.2.6.1 Cable ducts and cable bridges

(1) Cable ducts and cable bridges running between buildings in the Level 1 protection category shall be electromagnetically shielded throughout. The reinforcement steel rods of the ducts may be used as the electromagnetic shield.

(2) The duct ends and the expansion joints shall be provided with electrically conductive ring connections of steel rods or steel bars with a minimum cross-section of 100 mm², and these ring connections shall be tie-wire connected to the reinforcement steel rods and shall be welded or securely clamped or bolted to the meshing in the walls.

(3) Provisions shall be taken at the expansion joints and the anchor points to the building walls to ensure that the reinforcement steel rods are interconnected with each other such that it becomes possible to bridge the expansion joints by a low-impedance connection (cf. **Figure 4-5**).

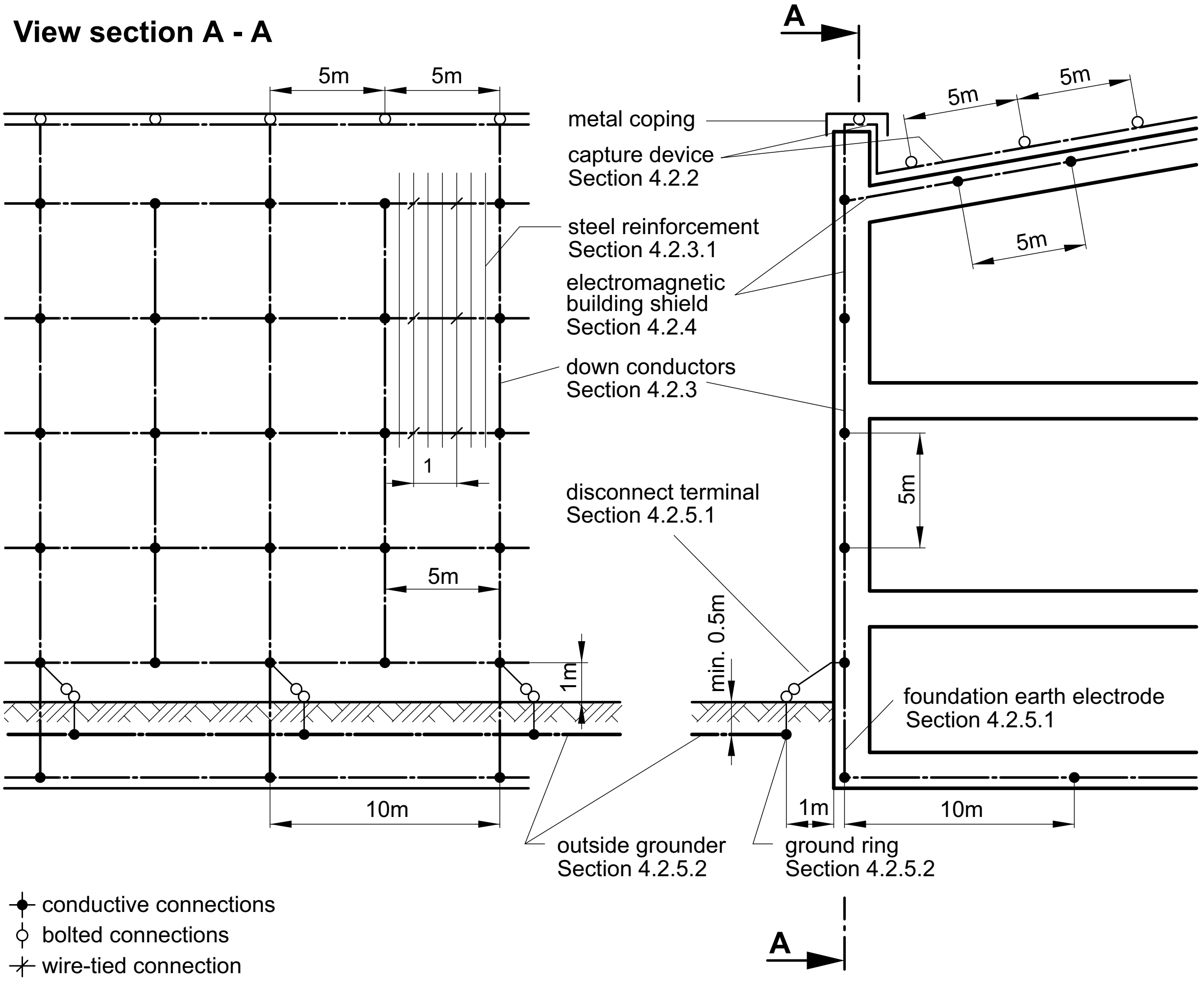
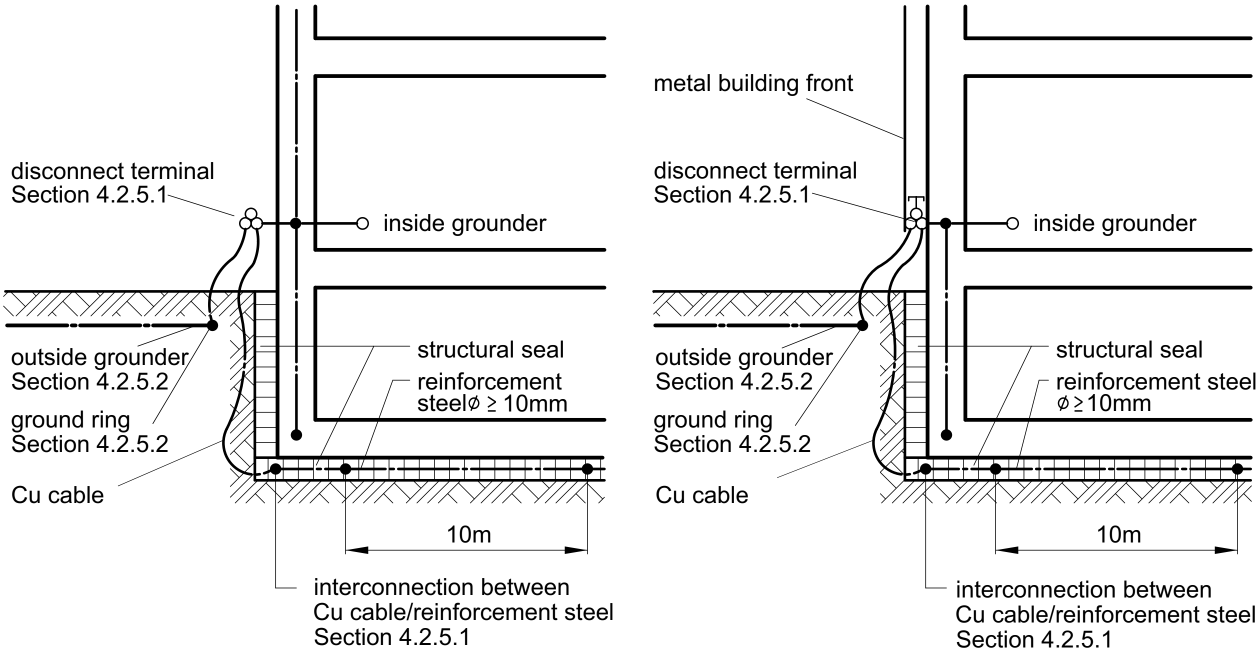


Figure 4-1: Reinforcement steel rods for the electromagnetic building shield in the case of buildings without a metal building front, and connection of the foundation earth electrode in the case of buildings not provided with an external structural seal



a) without a metal building front

b) with a metal building front

Figure 4-2: Connection of the foundation earth electrode in the case of buildings provided with an external structural seal

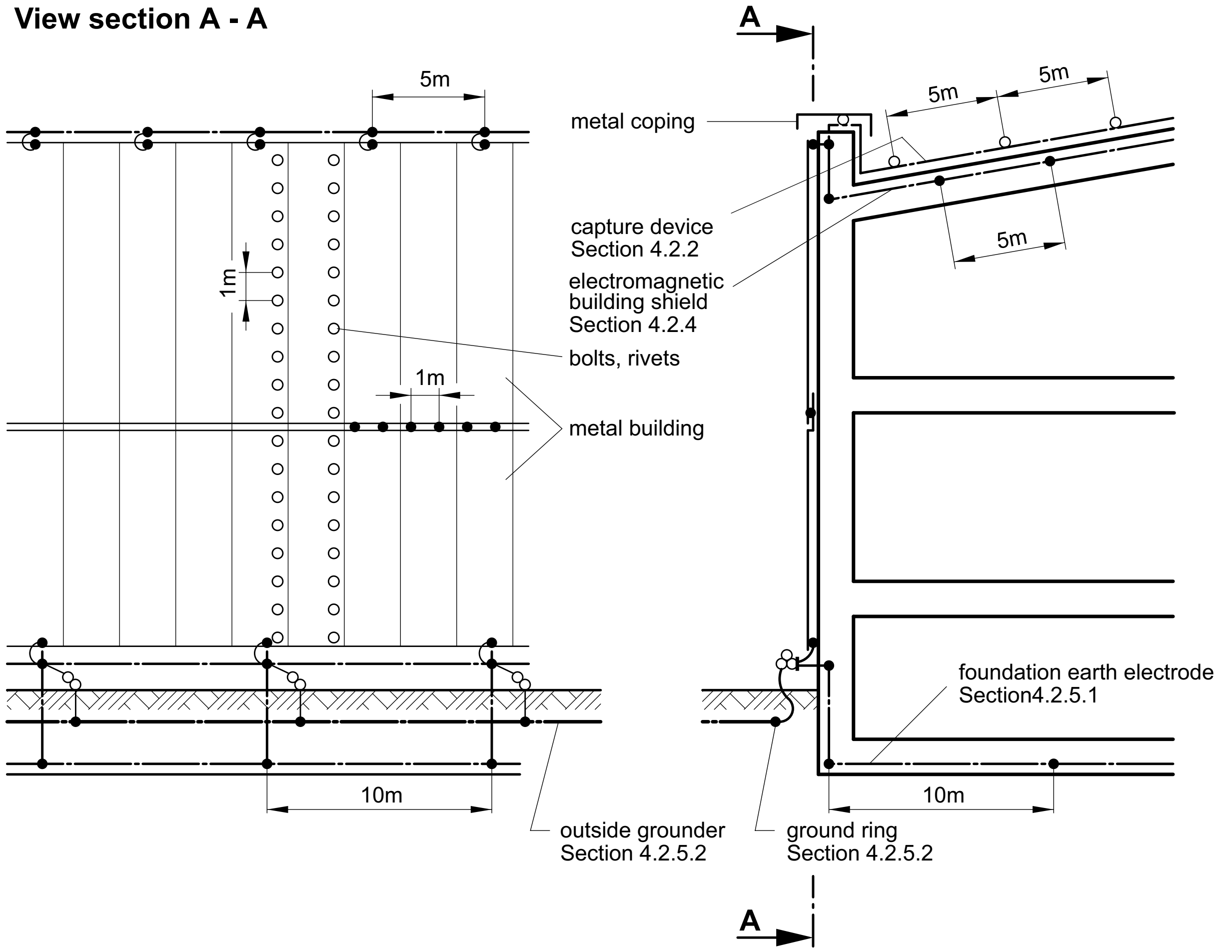


Figure 4-3: External Lightning Protection system in the case of buildings with metal building fronts (height of lower lip less than 1 meter above ground) and without an external structural seal

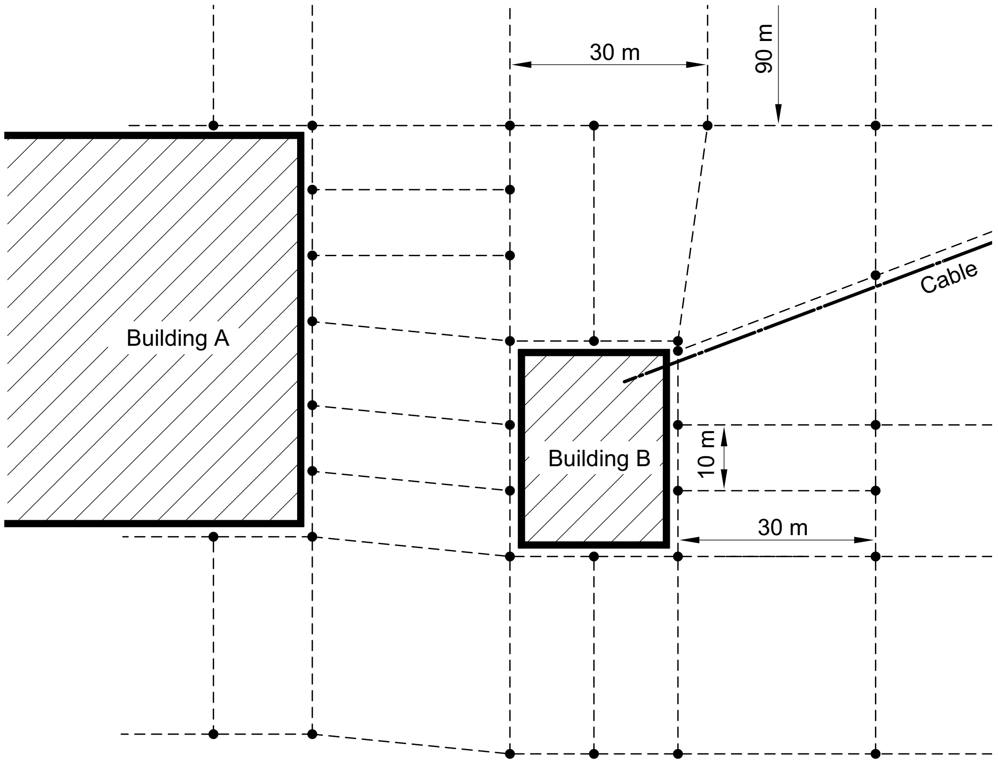
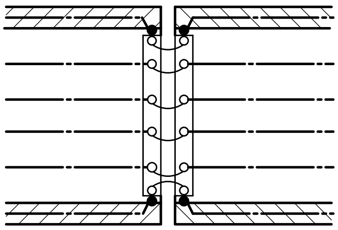
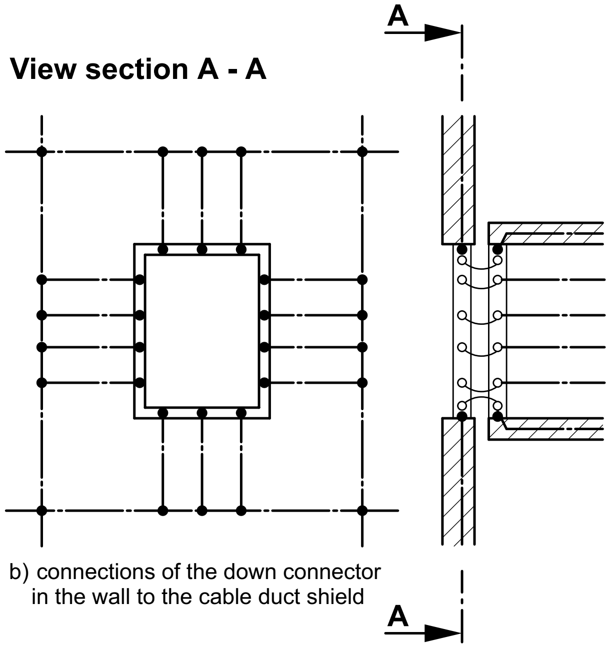


Figure 4-4: External grounding between buildings



a) connections at expansion joints



b) connections of the down connector in the wall to the cable duct shield

Figure 4-5: Cable ducts and cable bridges

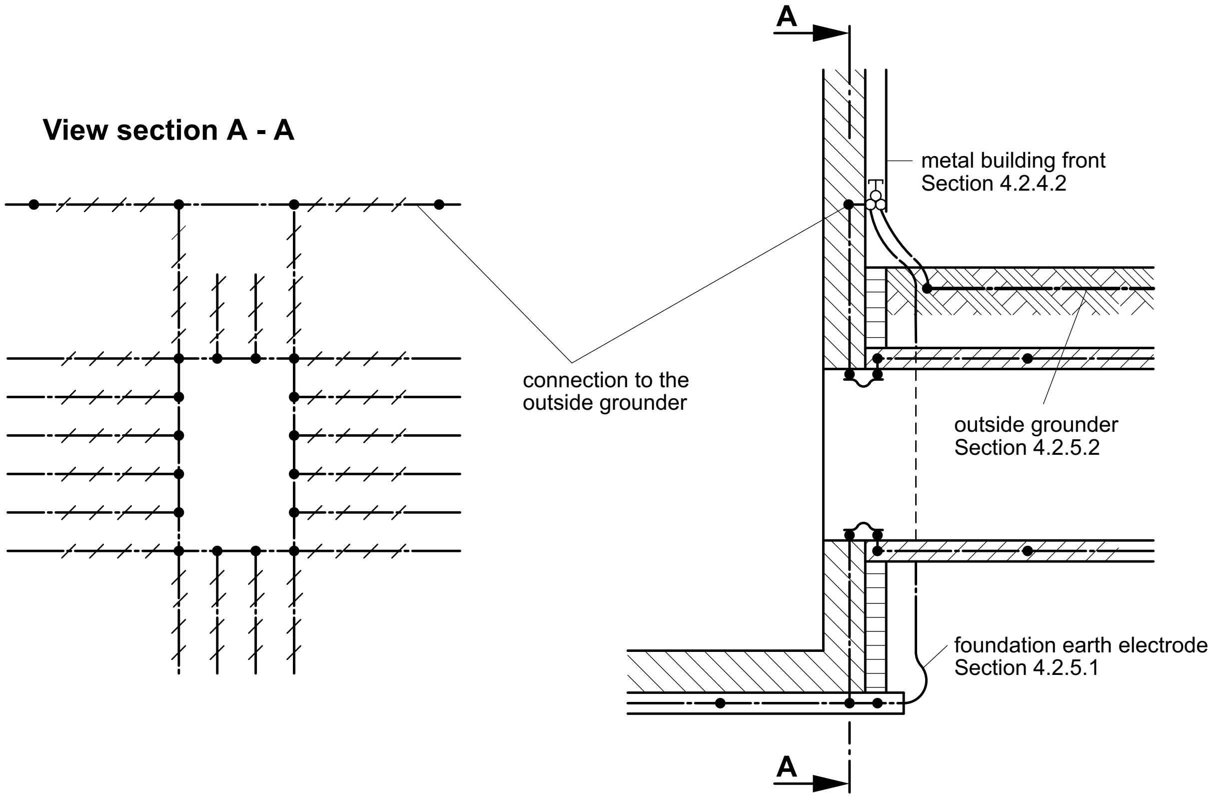


Figure 4-6: Cable duct, connection of the cable duct shielding to the metal building fronts and to the foundation earth electrode in the case of an insulated foundation

(4) At the connecting points to the building walls, reinforcement steel rods shall be embedded in the wall with the same spacing as that of the bridging of the expansion joints; these reinforcement steel rods shall extend as far as the nearest down conductor or grounding mesh (cf. **Figure 4-5**).

(5) In the case of buried ducts that have to be connected to buildings provided with an external structural seal, 2 meter long reinforcement steel rods shall be embedded in the walls starting from the bridging of the expansion joints, and these rods shall be tie-wire connected to the reinforcement steel rods and shall be welded or securely clamped or bolted to the meshing in the walls (cf. **Figure 4-6**).

(6) Cable bridges shall either be constructed in the same way as the cable ducts or shall be provided with a closed metal cladding that is interconnected by a low-impedance connection to the metal building front or to the reinforcement steel rods via the shortest route. The connections between the cable bridges and the buildings shall be spaced in intervals of no more than 1 meter (cf. **Figure 4-5**).

(7) In case metal building fronts are used as down conductors, structural measures shall be taken to connect the meshing in the cable bridges to the metal fronts with the same number of connections as for bridging the expansion joints (evenly distributed over the circumference).

4.2.6.2 Buried cables and outside routed cables

(1) As protection against a direct lightning strike accompanying earth wire ropes shall be routed above the buried cables.

(2) If instrumentation and control cables are not routed through steel-reinforced cable ducts, these cables shall be provided with suitable protection measures, e.g., electromagnetic shielding. This electromagnetic shielding shall be interconnected by a low-impedance connection to the electromagnetic building shield.

Note:

Examples for such an electromagnetic shielding are:

a) Cables inside a current conductive shield, where this shield is interconnected by a low-impedance connection to the reinforcement steel rods of the building either at, or directly after, the point of entry of the cable into the building.
b) Cables routed inside continuous metal pipes, where the pipes are interconnected by low-impedance connections to the steel reinforcement of the building.

(3) In the case of electrical facilities located outside of buildings, the same measures shall be applied as specified under paragraph (1), and the electromagnetic shielding shall be interconnected by a low-impedance connection to the grounded housing.

(4) In the case of electrical facilities located outside of buildings where the possibility for a direct lightning strike exists, the cables leading from these facilities into buildings shall, at the point of entry into the respective building, be equipped with surge-voltage protection devices that would be capable of carrying the current of a lightning strike.

4.3 Interior Lightning Protection System

4.3.1 General requirements

In addition to the measures specified under Section 4.2 for the Exterior Lightning Protection system, the measures specified under Sections 4.3.2 through 4.3.5 are required for the electrical facilities specified under Section 3.2 that are located within buildings in the Level 1 protection category. In addition, the measures specified under Section 4.3.6 shall be applied to any electrical facilities

a) in which the maximum permissible voltage would be exceeded in case of a lightning strike, or
b) which are connected to electrical facilities outside of the buildings or to grounding facilities and which cannot be protected by other measures.

4.3.2 Voltage equalization (internal grounding)

4.3.2.1 Collective ground conductor

(1) All rooms inside the buildings in Level 1 protection category shall be provided with collective ground conductors in the form of ground cable rings or with collective ground tracks (voltage equalization track). The collective ground conductors shall be connected to the meshing via low-impedance connections providing connections to the reinforcement steel rods. The meshing in the reinforcement steel rods may be used as the collective ground conductor.

(2) All cabinets or related groups of cabinets shall be connected to these collective ground conductors, provided, their function so allows. However, it is permissible to use other connections to the meshing connected to the reinforcement steel rods than the connection to the collective ground conductor.

4.3.2.2 Cable racks and cable troughs

(1) Inside the buildings and structures, the cable racks and cable troughs shall normally be conductively interconnected in order to enhance voltage equalization. They shall be connected at least at both ends to the meshing or to the reinforcement steel rods in the walls or to the collective ground conductor.

Note:

The present safety standard considers as conductively interconnected also a bolt connection to construction elements secured against self-loosening, or a copper cable connection between joints of those cable racks and cable troughs not otherwise interconnected through construction elements.

(2) Cable ways inside buildings that run directly along the outside walls shall normally be additionally shielded from the outside wall if an induction of voltages is not reduced to permissible values by other means, e.g., by metal building fronts.

(3) All cable racks and cable troughs for instrumentation and controls cables in those connecting channels and cable bridges to which design requirements for buildings in the Level 1 protection category apply shall be conductively interconnected over their entire length between the buildings and shall be connected to the collective ground conductors inside the buildings. This also applies to the connections of cable racks and cable troughs traversing physical partitions or expansion joints.

4.3.3 Grounding of the reference potential lead of the power supply

(1) The reference potential lead of the power supply of functionally related instrumentation and control systems shall be connected to the voltage equalization system. Whether this is achieved by a decentralized (planar, intermeshed) or by a centralized connection (stellate connection to a central ground point) shall be decided primarily on the basis of the requirements of the instrumentation and control system. In the case of instrumentation and control systems with a large-area reference potential system, decentralized grounding shall be given preference from the standpoint of lightning protection.

Note:

Instrumentation and control systems are considered functionally related if they are galvanically connected to each other. In the case of a centralized grounding of the reference potential system, high transient voltage differences, caused by the coupling of lightning currents or by switching as well as equalization procedures, may occur in the reference potential lead system. Furthermore, electromagnetic compatibility (EMC) tests (tests performed in accordance with DIN EN 61000-4-4) have shown that several instrumentation and control systems with a centralized grounding of the reference potential lead system were not sufficiently immune to fast electric transients (bursts).

(2) If the power supplies of the individual systems are operated isolated from each other and no galvanic couplings exist between the systems, then each system may be connected at the most convenient location to the voltage equalization system.

(3) It shall be ensured that low frequency effects from the electrical power supply have no impermissibly adverse effects on the instrumentation and control systems.

Note:

Low frequency effects may be caused by, e.g., ground shorts or short-circuits.

(4) With regard to the search for ground shorts, the connection of the reference potential lead to the central ground point shall be unambiguously and permanently marked and shall be constructed to be easily accessible and disconnectable.

(5) In case of a decentralized voltage equalization of functionally related instrumentation and control systems, the reference potential lead of the power supply in each of the concerned cabinets, control desks and control panels shall be interconnected with low-impedance connections to the housings and frames. The housings and frames, in turn, shall be interconnected with low-impedance connections to the reinforcement steel rods.

(6) To avoid any cross-interference of a lightning strike in the case of multi-unit power plants, the signaling lines between the units or between the units and mutually used facilities shall be galvanically separated with regard to their operation.

Note:

A galvanic separation excludes using high-resistance connections.

4.3.4 Cable shields

(1) The instrumentation and control cables shall be provided with a shielding that shall be grounded in order to reduce undue capacitive or inductive interferences. With regard to lightning protection, it is advantageous to ground at least the two ends of the cable shield.

Note:

In the case of short cable connections and branch cable connections between sub-distributors and transducers, a single grounding of the cable shield within the sub-distributor is usually sufficient, provided the requirements under Section 3.1 para. (1) are met.

(2) The cable shield shall be grounded in the cabinets, at the central ground point or at other points provided specifically for shield grounding.

(3) If the shield of an instrumentation and control cable is grounded at more than one point In order to reduce the axial lightning-based voltage components, it shall be ensured that any other coupled interference voltages will also not lead to impermissible signal distortions and that the cable shield is not subjected to undue thermal effects from possible equalization currents.

Note:

In the case of multiple grounding of the cable shield, care shall be taken that the coupling impedance of the cable is sufficiently low.

(4) Cable wires of the same circuits, e.g. power supply wires and signal wires, shall be contained within the same electromagnetic shielding.

(5) Within a building, the signal cables and corresponding supply cables (power supply cables of the electronics cabinets) shall be led in cable racks or cable troughs that are interconnected by low-impedance connections.

(6) If additional shielding measures are required, e.g., pipes around cable ways or routing cables in metal sheet channels, then the signal cables and supply cables along the respective stretch of the cables shall be equivalently shielded.

(7) To reduce the axial voltage components, unused cable wires may be grounded at both ends. It shall be ensured that the radial voltage components in the other wires do not exceed the permissible limit values.

4.3.5 Routing of cables

(1) Cables coming from buildings and structures in the Level 2 protection category or from the external area of the power plant into buildings and structures in the Level 1 protection category shall be routed apart from the local cables or shall be shielded unless it is ensured that no induction of impermissible voltages can occur.

(2) The minimum separation distance in case of a separate routing of cables from buildings and structures in the Level 1 and Level 2 protection categories shall be specified on the basis of the relevant influencing parameters.

Note:

Relevant influencing parameters can be, e.g., the length of parallel routing, the wire arrangement within the cables as well as the interference parameters (voltage slope, current slope, frequency spectrum) from the cables in the Level 2 protection category

4.3.6 Surge-voltage protection devices

(1) The instrumentation and control equipment shall be protected against lightning-based surge voltages. If this requires surge-voltage protection devices, they shall be provided with low-impedance connections to ground.

Note:

The surge-voltage protection devices employed can be, e.g., spark gaps, Zener diodes varistors or a combination of these components. It may be necessary to install a system of graduated and coordinated surge-voltage protection devices. The graduation occurs in accordance with discharge capacity and response behavior. To increase the input resistance, opto-electrical signal connections, buffer transmitters, buffer amplifiers and coupling relays or coupling switches can be employed. The surge-voltage protection devices employed depend on the type of instrumentation or control equipment to be protected, i.e., on the type of effective signal transmission and processing.

(2) It shall be possible to test the surge-voltage protection devices installed for limiting lightning-based surge voltages. The testing shall normally be possible without any changes to the circuitry. The surge-voltage protection devices shall, preferably, be designed as plug-in units. The surge-voltage protection plug-in devices shall be constructed such that no mix-up is possible. In the case of hardwired surge-voltage protection devices, built-in testing aids (e.g. disconnect terminals, testing jacks) shall be provided.

5 Proof of the Protection against Lightning-Based Surge Voltages

5.1 General Requirements

(1) It shall be demonstrated that the permissible voltages of the employed instrumentation and control equipment and systems are not exceeded in case of a lightning strike (cf. Section 5.3).

Note:

In order to be able to determine the induced voltages it is necessary to know the lightning current that would flow through the individual cable duct or cable way in case of a lightning strike. This current can be calculated from the characteristics of the lightning current specified under Section 3.3 by taking the impedances of the ducts, ground cables and the ground itself into consideration and distributing the entire lightning current over these respective paths.

(2) The present safety standard does not specify any analytical procedures regarding the induction of lightning strike based voltages into instrumentation and control cables inside the power plant buildings. With the electromagnetic shielding of

buildings as well as the routing and electromagnetic shielding of cables as specified in the present safety standard, no impermissibly high lightning-based voltage induction into the cable ways inside buildings needs to be considered.

(3) In designing the lightning protection system, it is permissible to use the results from previous measurements or calculations for nuclear power plants whose dimensions and arrangements of the buildings and cable ducts are comparable.

(4) In this analysis it is permissible to neglect those currents induced into cables routed in channels or in the ground that would be caused by close-vicinity lightning strikes.

(5) In addition to the general design, a robustness analysis as specified under **Appendix C** shall be performed.

5.2 Calculation of the Expected Voltages

Note:

The following calculations apply to the measures specified under Sections 4.2 through 4.3.5.

5.2.1 General requirements

(1) Regarding the calculation of occurring voltages, the critical lightning strike locations shall be specified.

Note:

Those possible lightning strike locations are considered as being critical that would lead to a large voltage induction into the cables. These are, above all, lightning strike locations on buildings at the end of a longer cable duct and there, essentially, on the smaller building. For cables in cable ducts, the critical lightning strike locations would be the ones in the emergency feed building and the emergency diesel building. The critical lightning strike locations with regard to voltage induction in buried cables are the smaller buildings at the edge or outside of the nuclear power plant site.

(2) The calculations shall be based on the lightning current parameters specified under Section 3.3.

(3) The pulse currents shall be modeled in accordance with the analytical lightning current function given by Equation 5-1:

$$i_B = \frac{I_B}{\eta} \cdot \frac{\left(\frac{t}{\tau_1}\right)^{10}}{1+\left(\frac{t}{\tau_1}\right)^{10}} \cdot \exp\left(-\frac{t}{\tau_2}\right) \qquad (5\text{-}1)$$

Nomenclature:

i_B	in kA	lightning current
I_B	in kA	crest value of the current
t	in µs	time
η	(dimensionless)	correction factor
τ_1	in µs	front end response time
τ_2	in µs	back end response time

The parameters to be employed in this context are listed in **Table 5-1**.

Note:

Using the parameters listed in **Table 5-1**, the Equation 5-1 will result in a lightning current function that corresponds to the lightning current parameters specified under Section 3.3.

(4) In case of twisted-wire pairs, the transverse voltage may be neglected.

Note:

The transverse voltages are influenced by the input impedances of the connected component groups, transducers, etc., and by the type of cable routing. The transverse voltages amount to about 1/5 to 1/3 of the axial voltages, at the most.

Parameter	*Symbol*	*Unit*	*Value of*		
			positive initial lightning strike	*negative initial lightning strike*	*negative subsequent lightning strike*
Crest value of the current	I_B	kA	200	100	50
Correction factor	η	-	0.930	0.986	0.993
Front end time constant	τ_1	µs	19.0	1.82	0.454
Back end time constant	τ_2	µs	485	285	143

Table 5-1: Parameters for calculating the lightning current function

Type of Cable Duct, *Type of Soil-Contacting Cable*	*Weighting Factor, p_K, for the relative portion of the lightning current*
Cable duct (approx. 2 m × 2 m)	3
Threefold or fourfold cable duct (each approx. 2 m × 2 m)	6
Soil-contacting cable: Ø < 0.1 m (e.g., accompanying earth wire ropes)	1
Soil-contacting cable: 0.1 m ≤ Ø ≤ 1 m (e.g., pipeline)	2
Soil-contacting cable: Ø > 1 m (e.g., pipeline)	3

Table 5-2: Weighting factors, p_K

Type of Lightning	*Lightning Type Factor K in $(\Omega/m)^{-1/2}$*
Positive initial lightning strike	3
Negative initial lightning strike	1
Negative subsequent lightning strike	0.5

Table 5-3: Lightning type factor, K

5.2.2 Cables routed in cable ducts

5.2.2.1 Determination of the current distribution

(1) When determining the distribution of the lightning current, it shall be assumed for all lightning types that 1/3 of the lightning current flows to ground through the grounding system of the lightning struck building via the foundation earth electrode. The remaining 2/3 of the lightning current shall be proportionately distributed among all cable ducts and soil-contacting conductors (pipes, accompanying earth wire ropes) leading away from the lightning struck building.

$$I_{ab} = \frac{2}{3} \cdot I_B \qquad (5\text{-}2)$$

Nomenclature:

I_{ab}	in kA	crest value of the partial lightning current conducted into the ground via the cable ducts and soil-contacting conductors of the building struck by lightning
I_B	in kA	crest value of the current from Equation 5-1

(2) The relative portions, p_K (weighting factor), for the various partial lightning currents conducted by the cable ducts and soil-contacting conductors of the building struck by lightning shall be chosen as listed in **Table 5-2**.

(3) The crest value of the partial lightning current, I_K, via the respective cable duct shall be calculated using Equation 5-3.

$$I_K = \frac{p_{KK}}{\sum\limits_{\nu=1}^{n} p_{K\nu}} I_{ab} \qquad (5\text{-}3)$$

Nomenclature:

I_K	in kA	crest value of partial lightning current via the respective cable duct
p_{KK}	(dimensionless)	relative portion of the lightning current through the respective cable duct
$\Sigma p_{K\nu}$	(dimensionless)	sum of the relative portions of the partial lightning currents through all cable ducts and soil-contacting cables
n	dimensionless	number of considered parallel conducting plant components
ν	dimensionless	running index of considered parallel conducting plant components

5.2.2.2 Fictive length of the cable duct

(1) When calculating the induced voltage it may be assumed that the partial lightning current along the cable duct remains constant for a fictive length, ℓ_f and then falls off to zero.

(2) The fictive length, ℓ_f, of the cable duct shall be calculated from Equation 5-4:

$$\ell_f = K\sqrt{\rho_e} \qquad (5\text{-}4)$$

Nomenclature:

ℓ_f	in meters	fictive length of the cable duct to be applied when determining the induced voltage
K	in $(\Omega/m)^{-1/2}$	lightning type factor
ρ_e	in Ωm	specific resistance of ground soil

(3) The lightning type factor, K, to be employed in this context is listed in **Table 5-3**.

(4) If the actual cable duct length ℓ_K is smaller than the length calculated from Equation 5-4, then the fictive length shall be set equal to the actual length:

$$\ell_f = \ell_K \qquad (5\text{-}5)$$

5.2.2.3 Calculation of the induced axial voltage component

(1) The induced axial voltage component, U_L, shall be calculated from Equation 5-6:

$$U_L = Z'_M \cdot I_K \cdot \ell \qquad (5\text{-}6)$$

Nomenclature:

U_L	in V	crest value of induced axial voltage component
Z'_M	in V/kAm	coupling impedance overlay
ℓ	in meters	to be assumed length (cf. Equation 5-7)

(2) The influence of the expansion joints along the course of a cable duct and to the buildings shall be accounted for by assuming a fictive extension, ℓ_{DF}, of the cable duct. The values for ℓ_{DF} shall be chosen from **Table 5-6**. Only those expansion joints shall be considered that are located within reach of the fictive length, ℓ_f, of the cable duct.

$$\ell = \ell_f + \sum_{\nu=1}^{N} \ell_{DF\nu} \qquad (5\text{-}7)$$

Nomenclature:

ℓ_{DF}	in meters	influence of an expansion joint
N	dimensionless	number of expansion joints to be considered
ν	dimensionless	running index

(3) The values for the coupling impedance overlay, Z'_M, needed in calculating the induced axial voltage component to be employed are listed in **Table 5-5**; deviations from these values shall be substantiated.

5.2.3 Buried cables

5.2.3.1 Determination of the current distribution

(1) The current distribution in buried cables shall be determined for the case of a positive initial lightning strike.

Note:

In buried cables the highest induced voltages are caused by currents from positive initial lightning strikes.

(2) In the case of buildings with a steel reinforced foundation it shall be assumed, with regard to determining the lightning current distribution, that 1/3 of the lightning current of the lightning struck building flows to ground through the grounding system. The remaining 2/3 of the lightning current shall be proportionately distributed to the cables leading away from the lightning struck building.

$$I_{ab} = \frac{2}{3} I_B \qquad (5\text{-}8)$$

Nomenclature:

I_{ab}	in kA	crest value of the partial lightning current led through all conductors (soil-contacting and non-soil-contacting conductors) of the building struck by lightning
I_B	in kA	crest value of the current from Equation 5-1

(3) If the building struck by lightning has only a single ground ring or only one or more ground rods then the entire lightning current shall be proportionately distributed as listed in **Table 5-4** to all conductors leading away from the building (pipelines, accompanying earth wire ropes, cable ducts):

$$I_{ab} = I_B \qquad (5\text{-}9)$$

(4) If buried cables are laid together in a single duct (buried cable duct), the partial lightning current shall be determined for the entire duct.

(5) The relative portions, p_E (weighting factor), of the various partial lightning currents conducted by the buried cables leading away from the building struck by lightning as well as for the soil-contacting or insulated conductors shall be employed are listed in **Table 5-4**.

(6) The crest value of the partial lightning current, I_E, flowing through the respective buried cable duct shall be calculated from Equation 5-10.

Type of Ground Cable, Type of Soil-Contacting or Insulated Conductor	***Weighting Factor, pE, for the partial lightning current***
Single cable (instrumentation and control equipment)	1
Buried cable duct with from 2 up to 10 instrumentation and control cables	2
Buried cable duct with more than 10 instrumentation and control cables	3
Cable duct (approx. 2 m x 2 m)	3
Threefold or fourfold cable duct (each approx. 2 m x 2 m)	6
Soil-contacting or insulated conductor: Ø < 0.1 m (e.g., accompanying earth wire ropes)	1
Soil-contacting or insulated conductor: 0.1 m ≤ Ø ≤ 1 m (e.g., pipeline)	2
Soil-contacting or insulated conductor: Ø > 1 m (e.g., pipeline)	3

Table 5-4: Weighting factor, p_E

$$I_E = \frac{p_{EE}}{\sum_{\nu=1}^{n} p_{E\nu}} I_{ab} \qquad (5\text{-}10)$$

Nomenclature:

I_E	in kA	crest value of partial lightning current flowing through the respective buried cable duct
p_{EE}	dimensionless	relative portion of the lightning current flowing through the respective buried cable duct
$\Sigma p_{E\nu}$	dimensionless	sum of the relative portions of the partial lightning currents flowing through all buried cables and soil-contacting conductors
n	dimensionless	number of all parallel conducting plant components considered
ν	dimensionless	running index of the parallel conducting plant components considered

(7) The crest value of the partial lightning current, I_E, flowing through the respective buried cable duct shall be evenly distributed over the crest values of the partial lightning currents, I_{KS}, flowing through the current conductive shields of all parallel cables in the individual buried cable duct.

Equation 5-11 shall be applied to single cables:

$$I_{KS} = I_E \qquad (5\text{-}11)$$

Nomenclature:

I_{KS}	in kA	crest value of partial lightning current flowing through the buried cable

Equation 5-12 shall be applied to a buried cable duct:

$$I_{KS} = \frac{1}{q} \cdot I_E \qquad (5\text{-}12)$$

Nomenclature:

q	dimensionless	number of instrumentation and control cables in the buried cable duct. (This count may include all soil-contacting accompanying cables of the duct and the voltage equalization cable in the cable-drawing tubes.)

5.2.3.2 Calculation of the crest value of the induced axial voltage component

(1) The crest value of the induced axial voltage component, U_L, shall be calculated from Equation 5-13:

$$U_L = Z'_M \cdot I_{KS} \cdot \ell_E \qquad (5\text{-}13)$$

Nomenclature:

ℓ_E	in meters	actual length of the buried cable

(2) The direct-current resistance, R'_{DC}, specified by the cable manufacturer, shall be used as the coupling impedance overlay, Z'_M.

5.3 Testing for Permissible Voltages

(1) The test for the permissible voltages of the devices and systems interconnected to the cables as specified under Sections 5.2.2 and 5.2.3 shall be based on the maximum dielectric strength against voltage pulses.

Note:

DIN EN 61000-4-5 describes a hybrid voltage generator for testing the immunity against disturbance and destruction of devices and systems in the case of lightning-based voltage pulses. This hybrid voltage generator creates an idling voltage with a pulse shape of 1.2/50 µs and a short-circuit current with a pulse shape of 8/20 µs. The test setup takes the employed standard surge-voltage protection devices into consideration.

(2) In the case of devices with a decoupling function, e.g. measuring transducers or high-resistance separation modules, the resistance against axial voltage components shall also be determined.

Note:

Axial voltages are the voltage loads between decoupled connections and between the connections and the housing.

(3) If the voltages determined as specified under Section 5.2 exceed the permissible voltage, then these cables shall be provided with surge-voltage protection devices as specified under Section 4.3.6.

5.4 Certification in Case of Design Deviations

In case the calculation specified under Section 5.2 cannot or should not be performed due to a deviating plant concept, then the induced axial voltage, U_L, shall be determined either

a) by other suitable analytical procedures,

b) by modeling tests,

c) by lightning simulation,

or by a combination of these methods. The requirements specified under Section 5.2.1 para. (2) shall remain unaffected.

Note:

Typical deviating plant concepts are, e.g.:

a) shielding housings of buried cable ducts of a different design than specified in the present safety standard (non-accessible lean-concrete ducts; copper cable meshing);

Arrangement	Type of Lightning	***Front Time, T1 (µs)***	***Coupling Impedance Overlay, Z'_M (V/kAm)***
Cable duct (approx. 2 m × 2 m)	Negative subsequent lightning strike	0.25	0.50
	Negative initial lightning strike	1.0	0.30
	Positive lightning strike	10	0.08

Note:

1. The values specified apply to cable ducts designed in accordance with the present safety standard.
2. The same values apply to multi-channel cable ducts. For the calculation in this case, the entire current through the multi-channel cable duct is split up into partial currents and distributed over the individual cable ducts.

Table 5-5: Guide values for the coupling impedance overlay, Z'_M, for calculating the axial voltage component as a function of the front time, T1, of the current pulse

Type of Lightning	***Front Time, T1 (in µs)***	***Fictive Extension, l_{DF}, per Expansion Joint (in meters)***			
		for 16 expansion joint bridgings	for 8 expansion joint bridgings	for 4 expansion joint bridgings	for 2 expansion joint bridgings
Negative subsequent lightning strike	0.25	15	30	50	70
Negative initial lightning strike	1.0	10	20	35	55
Positive lightning strike	10	5	10	20	30

Note:
The values specified apply to a single-channel cable ducts designed in accordance with the present safety standard.

Table 5-6: Fictive extension, l_{DF}, of a cable duct per expansion joints as a function of the front time, T_1, of the lightning current pulse

b) accessible cable ducts with dimension other than the standard dimensions specified in the present safety standard and, therefore, with other than specified coupling impedance overlay;

c) cable support systems in cable ducts with a higher value for electromagnetic shielding than considered in the present safety standard.

6 Tests and Inspections

6.1 Design Review

(1) Prior to the construction of the lightning protection system, it shall be verified on the basis of documents (e.g., design specifications, building survey plans) that the requirements under the present safety standard are met.

(2) The design of the lightning protection system shall be reviewed to verify that the components and operating media meet the requirements under the present safety standard with regard to the materials employed, their dimensions and corrosion behavior.

(3) The measures provided by the Interior Lightning Protection system shall be reviewed to verify that they meet the requirements under the present safety standard. Descriptions, arrangement drawings, circuit diagrams and data sheets shall be used to check, e.g., the correct design and arrangement of the intended surge-voltage protection devices.

6.2 Tests and Inspections during Construction

During construction of the buildings and structures, those parts of the lightning protection system that will not be accessible at a later time (e.g. connections of the meshing, of the terminal points, the anchor plates and the foundation earth electrodes as well as the connections to the reinforcement steel rods) shall be inspected before concreting or refilling to verify that they conform with the design reviewed construction documents.

6.3 Acceptance Tests

(1) After completion of the lightning protection system and prior to beginning the nuclear commissioning, the following acceptance tests of the Exterior Lightning Protection System shall be performed:

a) The accessible parts of the Exterior Lightning Protection system shall be visually inspected with respect to fabrication quality, required dimensions, spacings and materials.

b) The conductive resistances via the ground ring, via down conductors and via connections to the ground rings of neighboring buildings shall be measured. This requires that the disconnect terminals are individually opened. The two resistance values to the two corresponding neighboring disconnect terminals shall be measured and the measurement results documented. In each case these measurements shall be used to verify the low-impedance connection to the grounding system.

(2) Prior to beginning the nuclear commissioning, the following acceptance tests of the Interior Lightning Protection system shall be performed:

a) A visual inspection shall be performed with regard to the fabrication quality of the collective ground conductor (voltage equalization tracks), to the grounding of the instrumentation and control system, to the connection between the collective ground conductor and the grounding system, and to the electrical connections of the cable racks and cable troughs.

b) Regarding the centralized grounding, the insulation resistance of the reference potential lead to ground shall be measured and the measurement results documented. A random check shall be performed of the insulation of the reference potential lead at the transducer

   Note:
   An exemplary measurement procedure is presented in **Appendix B**.

c) The devices of the surge-voltage protection shall be tested.

(3) Prior to nuclear commissioning, a testing schedule for the acceptance tests shall be set up and shall be agreed upon by the authorized expert (under Sec. 20 AtG). This testing schedule shall list the systems or system components to be tested, the tests to be performed, the test instructions and the participation of the authorized expert (under Sec. 20 AtG).

(4) The acceptance tests shall be performed by qualified personnel assigned by the licensee. If the testing schedule so provides, authorized experts (under Sec. 20 AtG) shall be asked to participate in these tests.

6.4 Inservice Inspections

(1) The Interior Lightning Protection system shall be subjected to inservice inspections in approximately annual intervals (e.g., during refueling), and the Exterior Lightning Protection system in three-year intervals (e.g., annually one third of the overall test volume). The following tests shall be performed:

a) The accessible parts of the Exterior Lightning Protection system shall be visually inspected with respect to their physical condition.

b) The conductive resistances via the ground ring, via down conductors and via connections to the ground rings of neighboring buildings shall be measured. This requires that the disconnect terminals are individually opened. The two resistance values to the two corresponding neighboring disconnect terminals shall be measured and the measurement results documented and compared to previous measurement values.

c) The surge-voltage protection devices shall normally be inspected in intervals of one year. An extension of the testing intervals is permissible on the basis of reliability data of the individual surge-voltage protection devices under consideration of their location of installation.

Note:

The evaluation of operating experience indicates that, for certain components, an extension of the testing interval to four years can be permissible.

(2) In the case of instrumentation and control systems with a central ground point, the insulation resistance of the reference potential lead shall be inspected at the central ground point in approximately one-year intervals (e.g. during refueling); the results shall be documented and compared to the respective previous measurement values. The measurement procedures used for these measurements shall be equivalent to those used in the course of the acceptance tests.

(3) The inservice inspections shall be performed by qualified personnel assigned by the licensee. If the testing schedule in accordance with safety standard KTA 1202 so provides, authorized experts (under Sec. 20 AtG) shall be consulted in these tests.

6.5 Test Certification

The acceptance tests and the inservice inspections performed shall be recorded in test certificates. In accordance with safety standard KTA 1202, these test certificates shall contain all data required for the assessment and evaluation of the individual tests.

7 Requirements regarding Modifications

(1) It shall be ensured that the requirements under the present safety standard are fulfilled in case of any modifications of instrumentation and control equipment, of the electrical, mechanical and structural components. The modifications shall not have any impermissibly adverse effects on the existing lightning protection system.

(2) In the case of modifications, it is required that the tests specified under Section 6 are performed. The extent of these tests shall be specified in each individual case.

(3) After completion of any modifications of the instrumentation and control equipment with a central ground point, the insulation of the reference potential lead as well as of the static shields of the instrumentation and control cables shall be checked on the modified device.

8 Documentation

The extent of the documentation shall be as specified in safety standard KTA 1404.

Appendix A

Examples for Calculating the Occurring Voltages

A 1 Determination of the Induced Voltages for One Cable in a Cable Duct

(1) These calculations are based on the following assumptions:

a) The lightning strike occurs in a building with a foundation earth electrode.

b) The specific resistance of the soil is ρ_e = 500 Ωm.

c) The following conductors lead away from the building struck by lightning:

- ca) two soil-contacting pipelines, 0.1 m < Ø < 1 m;
- cb) two soil-contacting pipelines, Ø > 1 m;
- cc) ten accompanying earth wire ropes (soil-contacting conductors, Ø < 0.1 m);
- cd) one single channel cable duct (approx. 2 m x 2 m).

d) The respective cable duct has a length of ℓ_K = 50 meters and has a total of four expansion joints (two between the connecting buildings and two additional joints after every 16.7 meters). The expansion joints are each bridged eight times.

(2) Calculation for the negative subsequent lightning strike (I_B = 50 kA)

a) Based on Equation 5-2, the crest value of the partial lightning current leaving the building is calculated to be

$$I_{ab} = \frac{2}{3} \cdot I_B = 33.3\ \text{kA}.$$

b) Based on Equation 5-3 and **Table 5-2**, the crest value of the partial lightning current through the respective cable duct is calculated, with p_{KK} = 3 and $\sum p_{K\nu}$ = 23, to be

$$I_K = \frac{p_{KK}}{\sum_{\nu=1}^{n} p_{K\nu}} \cdot I_{ab} = 4.34\ \text{kA}.$$

c) Based on Equation 5-4 and **Table 5-3**, the fictive length of the cable duct is calculated to be

$$\ell_f = K \cdot \sqrt{\rho_e} = 11.2\ \text{m}.$$

d) **Table 5-5** lists the coupling impedance overlay for a negative subsequent lightning strike as Z'_M= 0.50 V/kAm, and **Table 5-6** lists the fictive extension of this cable duct for one expansion joint to be ℓ_{DF} = 30 meters. Only one expansion joint needs to be considered (ℓ_f = 11.2 m). Based on Equations 5-6 and 5-7, the induced axial voltage component is calculated to be

$$U_L = Z'_M \cdot I_K \cdot \left(\ell_f + \sum \ell_{DF}\right)$$

$$= 0.50 \frac{\text{V}}{\text{kAm}} \cdot 4.34\ \text{kA} \cdot (11.2\ \text{m} + 30\ \text{m}) = 89.4\ \text{V}.$$

(3) Calculation for the negative initial lightning strike (I_B = 100 kA)

a) Based on Equation 5-2, the crest value of the partial lightning current leaving the building is calculated to be

$$I_{ab} = \frac{2}{3} \cdot I_B = 66.7\ \text{kA}.$$

b) Based on Equation 5-3 and **Table 5-2**, the crest value of the partial lightning current through the respective cable duct is calculated, with p_{KK} = 3 and $\sum p_{K\nu}$ = 23, to be

$$I_K = \frac{p_{KK}}{\sum_{\nu=1}^{n} p_{K\nu}} \cdot I_{ab} = 8.70\ \text{kA}.$$

c) Based on Equation 5-4 and **Table 5-3**, the fictive length of the cable duct is calculated to be

$$\ell_f = K \cdot \sqrt{\rho_e} = 22.4\ \text{m}.$$

d) **Table 5-5** lists the coupling impedance overlay for a negative subsequent lightning strike as Z'_M= 0.30 V/kAm, and **Table 5-6** lists the fictive extension of this cable duct for one expansion joint to be ℓ_{DF} = 20 meters. In this case, two expansion joints must be considered (ℓ_f = 22.4 m). Based on Equations 5-6 and 5-7, the induced axial voltage component is calculated to be

$$U_L = Z'_M \cdot I_K \cdot \left(\ell_f + \sum \ell_{DF}\right)$$

$$= 0.30 \frac{\text{V}}{\text{kAm}} \cdot 8.70\ \text{kA} \cdot (22.4\ \text{m} + 2 \cdot 20\ \text{m}) = 162.8\ \text{V}.$$

(4) Calculation for the positive lightning strike (I_B = 200 kA)

a) Based on Equation 5-2, the crest value of the partial lightning current leaving the building is calculated to be

$$I_{ab} = \frac{2}{3} \cdot I_B = 133\ \text{kA}.$$

b) Based on Equation 5-3 and **Table 5-2**, the crest value of the partial lightning current through the respective cable duct is calculated, with p_{KK} = 3 and $\sum p_{K\nu}$ = 23, to be

$$I_K = \frac{p_{KK}}{\sum_{\nu=1}^{n} p_{K\nu}} \cdot I_{ab} = 17.3\ \text{kA}.$$

c) Based on Equation 5-4 and **Table 5-3**, the fictive length of the cable duct is calculated to be

$$\ell_f = K \cdot \sqrt{\rho_e} = 67.1\ \text{m}.$$

d) **Table 5-5** lists the coupling impedance overlay for a negative subsequent lightning strike as Z'_M= 0.08 V/kAm, and **Table 5-6** lists the fictive extension of this cable duct for one expansion joint as ℓ_{DF} = 10 meters. In this case, all four expansion joints must be considered ($\ell_f > \ell_K$). Based on Equations 5-6 and 5-7, the induced axial voltage component is calculated to be

$$U_L = Z'_M \cdot I_K \cdot \left(\ell_f + \sum \ell_{DF}\right)$$

$$= 0.08 \frac{\text{V}}{\text{kAm}} \cdot 17.3\ \text{kA} \cdot (50\ \text{m} + 4 \cdot 10\ \text{m}) = 124.6\ \text{V}.$$

A 2 Determination of the Induced Voltage for a Buried Cable with a Current Conductive Shield

(1) These calculations are based on the following assumptions:

a) The lightning strikes a building surrounded by a ground ring.

b) The following conductors lead away from the building struck by lightning:

- ba) one buried cable duct containing eight instrumentation and control cables;

bb) three accompanying earth wire ropes (soil-contacting conductors, Ø < 0.1 m).

c) The respective buried cable duct considered has a length ℓ_E = 160 m.

d) The coupling impedance overlay is Z'_M = 1.2 mΩ/m.

(2) The calculations are performed only for the positive lightning strike (I_B = 200 kA):

a) Based on Equation 5-9, the crest value of the partial lightning current leaving the building is calculated to be

$$I_{ab} = I_B = 200 \text{ kA} .$$

b) Based on Equation 5-10 and **Table 5-4**, the crest value of the partial lightning current through the respective buried cable duct is calculated with p_{EE} = 2 and $\sum p_{E\nu}$ = 5 to be

$$I_E = \frac{p_{EE}}{\sum_{\nu=1}^{n} p_{E\nu}} \cdot I_{ab} = 80.0 \text{ kA} .$$

c) Based on Equation 5-12, the crest value of the partial lightning current through a buried cable (instrumentation and control cable) is calculated to be

$$I_{KS} = \frac{1}{8} \cdot I_E = 10.0 \text{ kA} .$$

d) Based on Equation 5-13, the induced axial voltage component is calculated to be

$$\begin{aligned} U_L &= Z'_M \cdot I_{KS} \cdot \ell_E \\ &= 1.2 \frac{\text{m}\Omega}{\text{m}} \cdot 10.0 \text{ kA} \cdot 160 \text{ m} = 1920 \text{ V} . \end{aligned}$$

Appendix B

Example for Measuring the Insulation Resistances to Ground of the Reference Potential Lead and of the Static Shield at the Central Ground Point

B 1 General Requirements

The measurement of the insulation resistances at the central ground point (ZEP) refers to the ± 24 V facility of a typical nuclear power plant unit. Three tracks come together at the ZEP, as well as the static shield (S), the central or reference potential lead (M) and the local ground (E) and, possibly, two additional tracks, the plus pole conductor (P) and the minus pole conductor (N). Here at this location are also the terminal lugs that have to be opened for making measurements. **Figure B-1** shows the simplified schematic of a ±24 V facility with the ZEP and the four resulting insulation resistances to ground of the tracks S, P, M, and N as well as a possible mutual galvanic induction between tracks S and M (resistance R_3). Generally, these five resistances are caused by the parallel connection of many various size individual insulation resistances. The result is an active network consisting of five resistances and the two voltage sources U_1 and U_2. With respect to the terminals E-M and E-S, the individual equivalent schematics each consist of one equivalent voltage source and one series-connected equivalent resistance. In order to determine these equivalent resistances, the two terminal lugs must both be opened and, as shown in **Figure B-2**, a separate adjustable voltage source must be sequentially connected to the terminals E-M and then E-S, while recording the resulting voltage-current-characteristics (U/I-characteristic).

B 2 Calculation of the U/I-Characteristics

(1) A measurement circuit consisting of an adjustable direct current source, K, an ampere meter, I, and a voltmeter, U, is sequentially connected (as shown in **Figure B-2**) to the terminals E-M and then E-S. The voltage, U, and current, I, are related as follows:

a) Connection to terminals E-M (cf. **Figure B-3**):

$$I = \frac{1}{R_{EM_o}} \cdot \left(U - U_{EM_o}\right) \qquad \text{(B 2-1)}$$

b) Connection to terminals E-S (cf. **Figure B-4**):

$$I = \frac{1}{R_{ES_o}} \cdot \left(U - U_{ES_o}\right) \qquad \text{(B 2-2)}$$

(2) In accordance with the theory of equivalent voltage sources, the terms in Equations B 2-1 and B 2-2 signify the following:

U_{EM_o} and U_{ES_o}	equivalent voltages of the circuit shown in **Figure B-2** relative to the terminals E-M or E-S, respectively, in the idling condition, i.e., both terminals are open.
R_{EM_o} and R_{ES_o}	equivalent resistances of the circuit shown in **Figure B-2** with short-circuited voltage sources U_1 and U_2 as seen from the terminals E-M or E-S, respectively.

(3) With the help of **Figure B-2 t**he quantities specified in paragraph (1) are calculated to be:

$$U_{EM_o} = \frac{\frac{U_1}{R_1} - \frac{U_2}{R_2}}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_M} + \frac{1}{R_S + R_3}} \qquad \text{(B 2-3)}$$

$$U_{ES_o} = U_{EM_o} \cdot \frac{R_S}{R_S + R_3} < U_{EM_o} \qquad \text{(B 2-4)}$$

$$\frac{1}{R_{EM_o}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_M} + \frac{1}{R_S + R_3} \qquad \text{(B 2-5)}$$

$$\frac{1}{R_{ES_o}} = \frac{1}{R_S} + \frac{1}{R_3 + \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_M}}} < \frac{1}{R_{EM_o}} \qquad \text{(B 2-6)}$$

(4) Equation B 2-6 is exactly true if

$$\frac{1}{R_S} < \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_M}$$

which is the case after completion of the search for shorts to ground (cf. Section B 4).

(5) Equations B 2-5 and B 2-6 show that the insulation resistances R_M and R_S cannot be measured individually and are always larger than the measurable equivalent resistances R_{EM_o} and R_{ES_o}.

B 3 Interpretation of the Results

(1) **Figure B-3** and **Figure B-4** show that the insulation resistance can, generally, only be determined based on the gradient of the U/I-characteristic and not based on individual values on this characteristic. This gradient, however, corresponds to the parallel connection of many individual insulation resistances (cf. Equations B 2-5 and B 2-6) and not to the significant resistances, R_M or R_S, during a lightning strike.

(2) Even without specific numeric values, Equations B 2-3 and B 2-6 show that

$U_{EM_o} > U_{ES_o}$ (superimposed voltage) (B 3-1)

$R_{EM_o} < R_{ES_o}$ (very important) (B 3-2)

(3) Even in the case that R_3 is very large relative to the other resistances, the following applies:

$U_{EM_o} \neq 0$

$R_{EM_o} < R_M$ or (B 3-3)

$R_{EM_o} = \frac{R_M}{3}$ (if $R_1 = R_2 = R_M$)

and

$U_{ES_o} = 0$

$R_{ES_o} = R_S$ (B 3-4)

(4) Apart from the design details of the nuclear power plant and from actual numeric values, it shall be noted that a measurement at the terminals E-M does not deliver R_M but, rather, a result that is approximately one third of this value, and that this measurement result is always smaller than when the measurement is carried out at the terminals E-S. This fact shall be considered from the start by specifying a smaller target value for R_{EM_o} than the target value specified for R_{ES_o} .

B 4 Performing the Measurements and Evaluation of the Measurement Results

(1) Prior to the final measurement of the insulation resistances, any shorts-to-ground shall be located and eliminated. The shorts-to-ground can be detected with a 5 Hz locating equipment.

(2) After elimination of any detected shorts-to-ground, the equivalent resistances in accordance with **Figures B-3** and **B-4** shall be determined by the U/I-procedure using an adjustable direct current source. This requires that both terminal lugs are opened simultaneously and that the measurement circuit is sequentially connected to each of the terminal pairs. The voltage of the measurement circuit shall be varied between $-U_2$ and $+U_1$; the voltage steps shall normally be smaller than or equal to 5 V and the maximum current shall be limited to a value that is safe for the electronics involved (approx. 0.5 A). Experience shows that the insulation resistances R_{EM_o} may reach values larger than 100 Ohm and R_{ES_o} larger than 1000 Ohm.

(3) Furthermore, experience shows that, in case of a measurement with both terminal lugs simultaneously open, the pulsation of the electronics can lead to fluctuating ambiguous measurement values, in particular, at the terminals E-S. In this case, the terminals E-M shall normally be kept closed when measuring at terminals E-S, and vice versa.

(4) Connecting peripheral equipment irrelevant to safety (e.g. clocks, transient recorders, computers) to the 24 V facility will result in a reduction of the equivalent insulation resistance even if the actual – not measurable – resistance, e.g., R_M, is considerably higher. Therefore, in case of lower values of the equivalent insulation resistance than specified in paragraph (2), the measurement of the equivalent insulation resistance shall normally be performed only after disconnection of the peripheral equipment or by evaluating each existing short-to-ground separately.

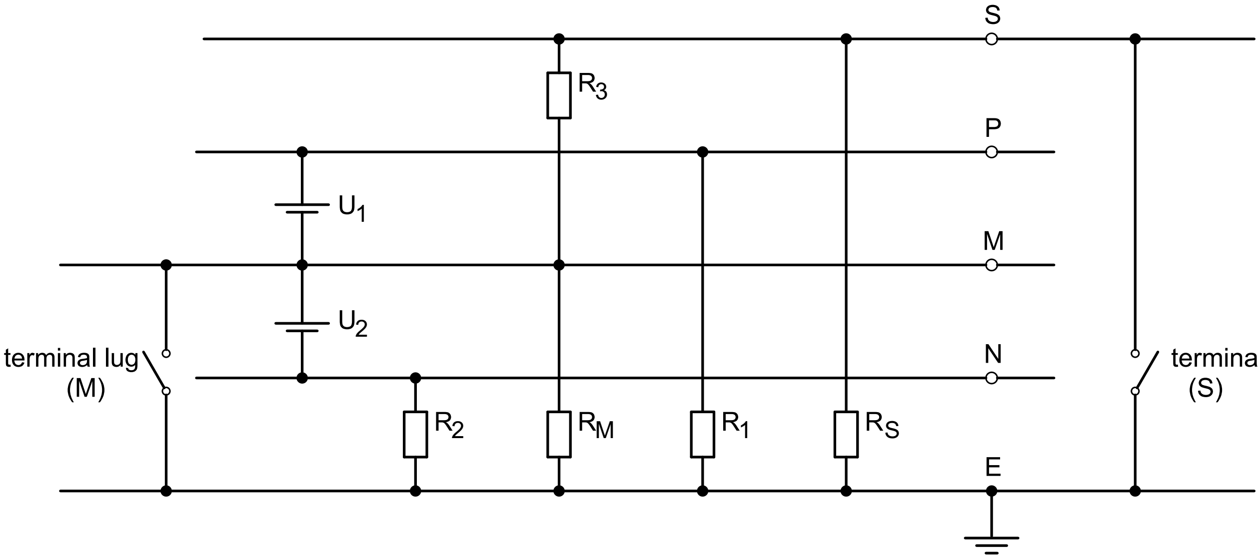


Figure B-1: Simplified circuitry of a 24-volt facility with a central grounding point, ZEP

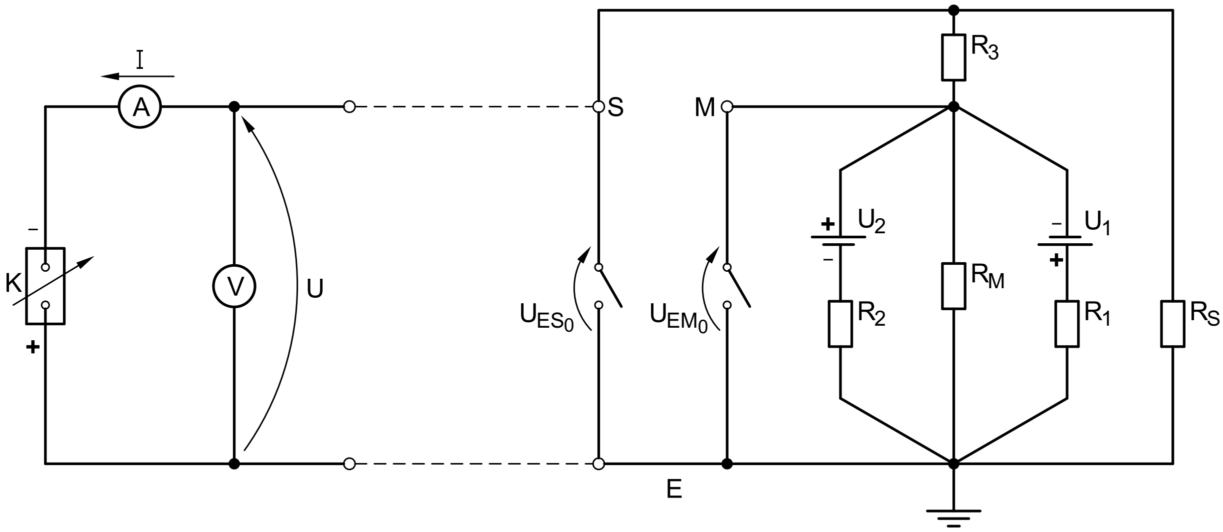
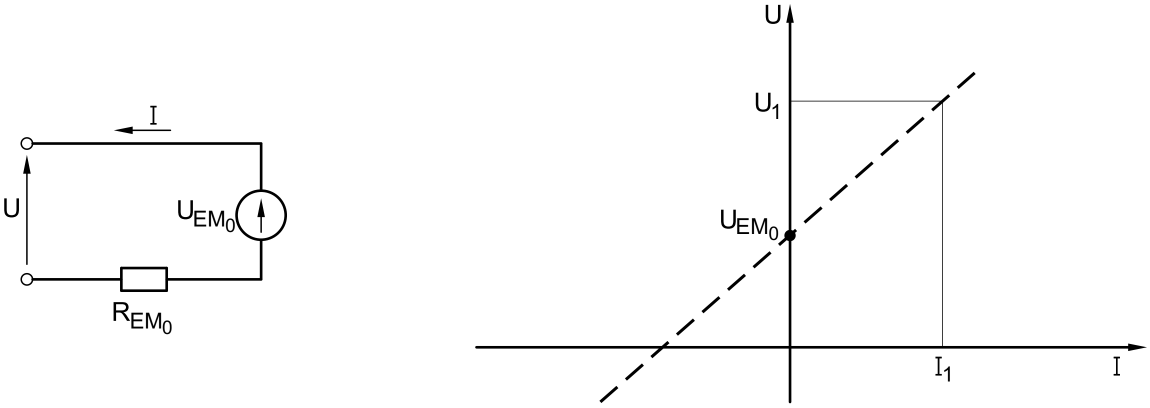


Figure B-2: Connection of a measurement circuit to the circuitry shown in **Figure B-1**

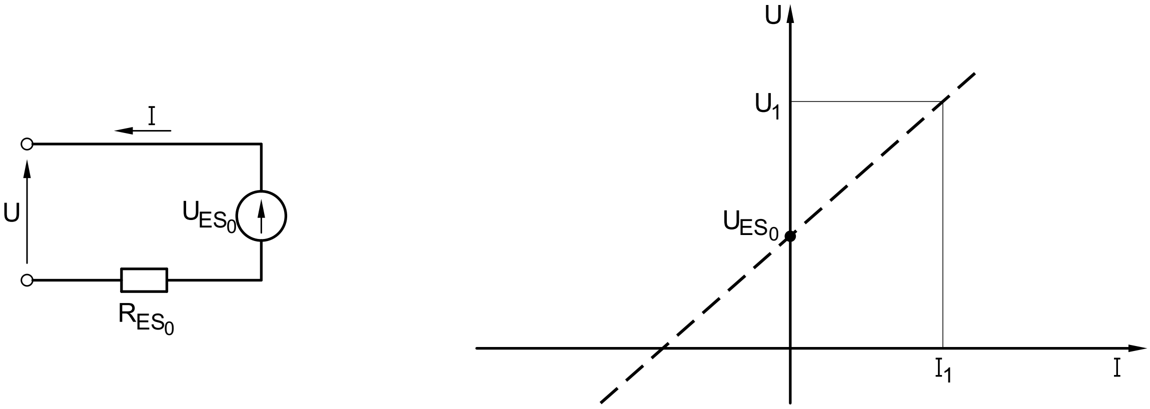


State 0: terminal lug E - S closed,
terminal lug E - M open,
induced current $I = 0$:
voltage E - M equals U_{EM_0}

Stage 1: terminal lug E - S closed,
terminal lug E - M open,
induced current $I = I_1$:
voltage E - M equals U_1

The resistance R_{EM_0} is calculated as $R_{EM_0} = \frac{U_1 - U_{EM_0}}{I_1}$

Figure B-3: Measurement results in case of the connection of the measurement circuit at terminals E-M



State 0: terminal lug E - M closed,
terminal lug E - S open,
induced current $I = 0$:
voltage E - M equals $U_{ES\,0}$

Stage 1: terminal lug E - M closed,
terminal lug E - S open,
induced current $I = I_1$:
voltage E - M equals U_1

The resistance $R_{ES\,0}$ is calculated as $R_{ES\,0} = \frac{U_1 - U_{ES\,0}}{I_1}$

Figure B-4: Measurement results in case of the connection of the measurement circuit at terminals E-S

Appendix C

Procedure for the Robustness Analysis regarding Lightning Exposure with Increased Current Parameters

Note:

The requirements for the performance of a robustness analysis is based on the RSK-Statement (cf. **Appendix F** [7]).

C 1 General Requirements

(1) The robustness analysis shall be performed plant-specifc regard to the individual power plant. The analysis shall be limited to the electrical equipment assigned to the Level 1 protection category. The analysis is independent of the requirements under Section 3 taking into consideration those lightning strike effects (surge voltages) the lightning current parameters of which exceed the design parameters listed in **Table 3-1**).

(2) The robustness analysis shall consider the buildings of the site as well as the surrounding topography. In case of major changes (e.g., demolition or new construction of buildings) the previously existing analysis shall be reviewed.

C 2 Parameters and Performing of the Robustness Analysis

(1) The robustness analysis shall be based on increased lightning current parameters for the three lightning types that are defined as follows:

a) positive initial lightning strike:
   crest value of the current 300 kA

b) negative initial lightning strike:
   crest value of the current 150 kA

c) negative subsequent lightning strike:
   average current gradient 300 kA/µs.

Note:

In accordance with available measurements, observations in temperate geographical latitudes and theoretical analyses of lightning strikes, the robustness analysis can be based on a natural upper limit of 300 kA for the crest value of the current of the positive initial lightning strike in these temperate latitudes (cf. **Appendix F** [8]). This corresponds to a 1.5-fold value of the crest value of the current listed in **Table 3-1**. Such a natural upper limit for the average current gradient is not known. Analogous to the crest value of the current for the positive initial lightning strike, the crest value of the current for the negative initial lightning strike and the average current gradient for the negative subsequent lightning strikes are also increased by 50 % relative to the values listed in **Table 3-1**. These values are considered as being the natural upper limits of the individual lightning current parameters. According to the current state of the art in lightning science it can be precluded that no higher values will occur.

(2) The electro-geometrical model of a building shall normally be used for determining the maximum crest value of the lightning current. The maximum crest value of the lightning current is a function of the maximum radius of the rolling sphere (cf. Equation C-1) that still touches anywhere on the building.

$$I_{max} = 28.9 \cdot 10^{-3} \cdot R^{1.54} \qquad \text{(C-1)}$$

Nomenclature:

I_{max}	in kA	crest value of the lightning current
R	in meters	radius of the rolling sphere (= maximum striking distance)

Notes:

(1) The maximum radius of the rolling sphere that still touches the building can be determined by a suitable graphic procedure that takes the fundamentals of the electro-geometrical model in accordance with DIN EN 62305-1 into account. The dynamic electro-geometrical model (cf. **Appendix F** [9]) is such a procedure.

(2) A comparable unrestricted reduction of the lightning current parameters for subsequent lightning strikes is not possible with the electro-mechanical model because the reduction only addresses the crest values of the initial lightning strike current and, not the lightning current gradients. Therefore, in the robustness analysis only the crest values of currents for the positive and negative initial lightning strikes may possibly be correspondingly reduced if applicable and not the lightning current gradients for the negative subsequent lightning strikes.

(3) The calculation of the surge voltages occurring in safety related electrical devices shall be performed by the procedures specified under Section 5.2.2 (for cables and cable ducts) and under Section 5.2.3 (for buried cables). The calculation shall normally consider representative, conservatively assumed cases for the cables routed in cable ducts and buried cables.

(4) The present safety standard does not specify any analytical procedures regarding the induction of lightning strike based voltages into instrumentation and control cables inside the power plant buildings (cf. Basic Principles, para. (8), and Section 5.1, para. (2)). If such an analysis becomes necessary, the analysis shall be based on the increased lightning current parameters as specified under paragraph (1) of this Section C 2.

C 3 Documentation

The robustness analysis regarding lightning strikes with the parameters as specified under Section C 2, para. (1) shall be documented in a comprehensible way.

Appendix D

Regulations Referred to in the Present Safety Standard

(Regulations referred to in the present safety standard are valid only in the versions cited below. Regulations which are referred to within these regulations are valid only in the version that was valid when the latter regulations were established or issued.)

AtG		Act on the Peaceful Utilization of Atomic Energy and the Protection against its Hazards (Atomic Energy Act) Atomic Energy Act in the version promulgated on July 15, 1985 (BGBl. I, p. 1565), most recently changed by article 1 of the act dated December 4, 2022 (BGBl. I, p. 2153)
StrlSchG		Act on the Protection against the Harmful Effect of Ionising Radiation (Radiation Protection Act - StrlSchG) Radiation Protection Act of June 27, 2017 (BGBl. I, p. 1966), most recently changed by the promulgation of January 3, 2022 (BGBl. I, p. 15)
StrlSchV		Ordinance on the Protection against the Harmful Effects of Ionising Radiation (Radiation Protection Ordinance - StrlSchV) Radiation Protection Ordinance of November 29, 2018 (BGBl. I, p. 2034, 2036), most recently changed by article 1 of the ordinance dated October, 2021 (BGBl. I p. 4645)
SiAnf	(2015-03)	Safety Requirements for Nuclear Power Plants (SiAnf) of November 22, 2012, amended version of March 3, 2015 (BAnz AT 30.03.2015 B2), most recently changed as promulgated by BMUV on February 25, 2022 (BAnz AT 15.03.2022 B3)
Interpretions of SiAnf	(2015-03)	Interpretations of the safety requirements for nuclear power plants of November 22, 2012, of November 29, 2013 (BAnz AT 10.12.2013 B4), changed on March 3, 2015 (Banz AT of March 30, 2015 B3)
KTA 1202	(2017-11)	Requirements for the testing manual
KTA 1401	(2017-11)	General requirements regarding quality assurance
KTA 1404	(2022-11 Draft)	Documentation during the construction and operation of nuclear power plants
KTA 3501	(2015-11)	Reactor protection system and monitoring equipment of the safety system
DIN EN 1992-1-1	(2011-01)	Eurocode 2: Design of concrete structures - Part 1-1: General rules and rules for buildings; German version EN 1992-1-1:2004 + AC:2010
DIN EN ISO 17660-2	(2006-12)	Welding - Welding of reinforcing steel - Part 2: Non load-bearing welded joints (ISO 17660-2:2006); German version EN ISO 17660-2:2006
DIN EN 61000-4-4 (VDE 0847-4-4)	(2013-04)	Electromagnetic compatibility (EMC) - Part 4-4: Testing and measurement techniques - Electrical fast transient/burst immunity test (IEC 61000-4-4:2012); German version EN 61000-4-4:2012
DIN EN 61000-4-5 (VDE 0847-4-5)	(2019-03)	Electromagnetic compatibility (EMC) - Part 4-5: Testing and measurement techniques - Surge immunity test (IEC 61000-4-5:2014 + A1:2017); German version EN 61000-4-5:2014 + A1:2017
DIN EN 62305-1 (VDE 0185-305-1)	(2011-10)	Protection against lightning - Part 1: General principles (IEC 62305-1:2010, modified); German version EN 62305-1:2011
DIN EN 62305-1	(2012-03)	
DIN EN 62305-2 (VDE 0185-305-2)	(2013-02)	Protection against lightning - Part 2: Risk management (IEC 62305-2:2010, modified); German version EN 62305-2:2012

DIN EN 62305-2 Supplement 1 (VDE 0185-305-2 Supplement 1)	(2013-02)	Protection against lightning - Part 2: Risk management Supplement 1: Lightning threat in Germany
DIN EN 62305-2 Supplement 2 (VDE 0185-305-2 Supplement 2)	(2013-02)	Protection against lightning - Part 2: Risk management Supplement 2: Calculation assistance for assessment of risk for structures, with CD-ROM
DIN EN 62305-3 (VDE 0185-305-3)	(2011-10)	Protection against lightning - Part 3: Physical damage to structures and life hazard (IEC 62305-3:2010, modified); German version EN 62305-3:2011
DIN EN 62305-3 Supplement 1 (VDE 0185-305-3 Supplement 1)	(2012-10)	Protection against lightning - Part 3: Physical damage to structures and life hazard Supplement 1: Additional information for the application of DIN EN 62305-3 (VDE 0185-305-3)
DIN EN 62305-3 Supplement 2 (VDE 0185-305-3 Supplement 2)	(2012-10)	Protection against lightning - Part 3: Physical damage to structures and life hazard Supplement 2: Additional information for special structures
DIN EN 62305-3 Supplement 3 (VDE 0185-305-3 Supplement 3)	(2012-10)	Protection against lightning - Part 3: Physical damage to structures and life hazard - Supplement 3: Additional information for the testing and maintenance of lightning protection systems
DIN EN 62305-4 VDE 0185-305-4)	(2011-10)	Protection against lightning - Part 4: Electrical and electronic systems within structures (IEC 62305-4:2010); German version EN 62305-4:2011
	(2017-02)	
DIN VDE 0100-410	(2018-10)	Low-voltage electrical installations - Part 4-41: Protection for safety - Protection against electric shock (IEC 60364-4-41:2005, modified + A1:2017, modified); German implementation of HD 60364-4-41:2017 + A11:2017
DIN VDE 0100-540	(2012-06)	Low-voltage electrical installations - Part 5-54: Selection and erection of electrical equipment - Earthing arrangements and protective conductors (IEC 60364-5-54:2011); German implementation HD 60364-5-54:2011
DIN EN 50522 (VDE 0101-2)	(2011-11)	Earthing of power installations exceeding 1 kV a.c. German version EN 50522:2010
DIN EN 61936-1 (VDE 0101-1)	(2014-12)	Power installations exceeding 1 kV a.c. - Part 1: Common rules (IEC 61936-1:2010, modified + Cor.:2011 + A1:2014); German version EN 61936-1:2010 + AC:2011 + AC:2013 + A1:2014
DIN EN 61936-1 Corrigendum 1, (VDE 0101-1 Corrigendum 1)	(2017-05)	Power installations exceeding 1 kV a.c. - Part 1: Common rules (IEC 61936-1:2010, modified + Cor.:2011 + A1:2014); German version EN 61936-1:2010 + AC:2011 + AC:2013 + A1:2014, Corrigendum to DIN EN 61936-1 (VDE 0101-1):2014-12

Appendix E (informative)

Additional Relevant Standards

DIN EN 1991-1-4 /NA	(2010-12)	National Annex - Nationally determined parameters - Eurocode 1: Actions on structures - Part 1-4: General actions - Wind actions
DIN EN 62561-1 (VDE 0185-561-1)	(2017-12)	Lightning Protection System Components (LPSC) - Part 1: Requirements for connection components (IEC 62561-1:2017); German version EN 62561-1:2017
DIN EN 62561-2 (VDE 0185-561-2)	(2013-02)	Lightning Protection System Components (LPSC) - Part 2: Requirements for conductors and earth electrodes (IEC 62561-2:2012, modified); German version EN 62561-2:2012
DIN EN 62561-3 (VDE 0185-561-3)	(2018-02)	Lightning Protection System Components (LPSC) - Part 3: Requirements for isolating spark gaps (ISG) (IEC 62561-3:2017); German version EN 62561-3:2017

Appendix F (informative)

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[7] RSK-Stellungnahme:
Blitze mit Parametern oberhalb der genormten Blitzstromparameter. 488. Sitzung der Reaktorsicherheitskommission am 03.11.2016.

RSK Statement: Lightning with parameters exceeding the standardised lightning current parameters. 488th Meeting of the German Reactor Safety Commission on November 3rd, 2016

[8] CIGRE TB549:
Lightning Parameters for Engineering Applications (2013-08)

[9] Kern A., Schelthoff C., Mathieu M.
Das dynamische elektro-geometrische Modell - Ein neues Verfahren zur detaillierten Berechnung der Einfangwirksamkeit von Fangeinrichtungen. Elektropraktiker, Berlin (66), Heft 4/2012.

The dynamic electro-geometrical model – A new procedure for the detailed analysis of the capturing effectiveness of capture devices