

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

If there is any doubt regarding the information contained in this translation, the German wording shall apply.

Editor:

KTA-Geschaefsstelle

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

Previous versions of the present safety standard: 1992-06 (BAnz No. 36a of February 23, 1993)
2000-06 (BAnz No. 159a of August 24, 2000)
2009-11 (BAnz No. 3a of January 7, 2010)
2019-11 (BAnz AT 14.01.2020 B4)

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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-Geschaftsstelle 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.

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

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/ μ s	20
	front time	T_1	μ s	10
	time of half-value	T_2	μ s	350
	impulse charge	Q_i	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/ μ s	100
	front time	T_1	μ s	1
	time of half-value	T_2	μ s	200
Negative subsequent lightning strike	crest value of current	I_B	kA	50
	average current gradient	I_B / T_1	kA/ μ s	200
	front time	T_1	μ s	0.25
	time of half value	T_2	μ s	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_1	C	400
	duration of the longtime current	t	s	0.5
$h < 60$ m	charge of the longtime current	Q_1	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.

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

Table 3-3: Example for the correlation 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 $\pm$ 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 these 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**).

View section A - A

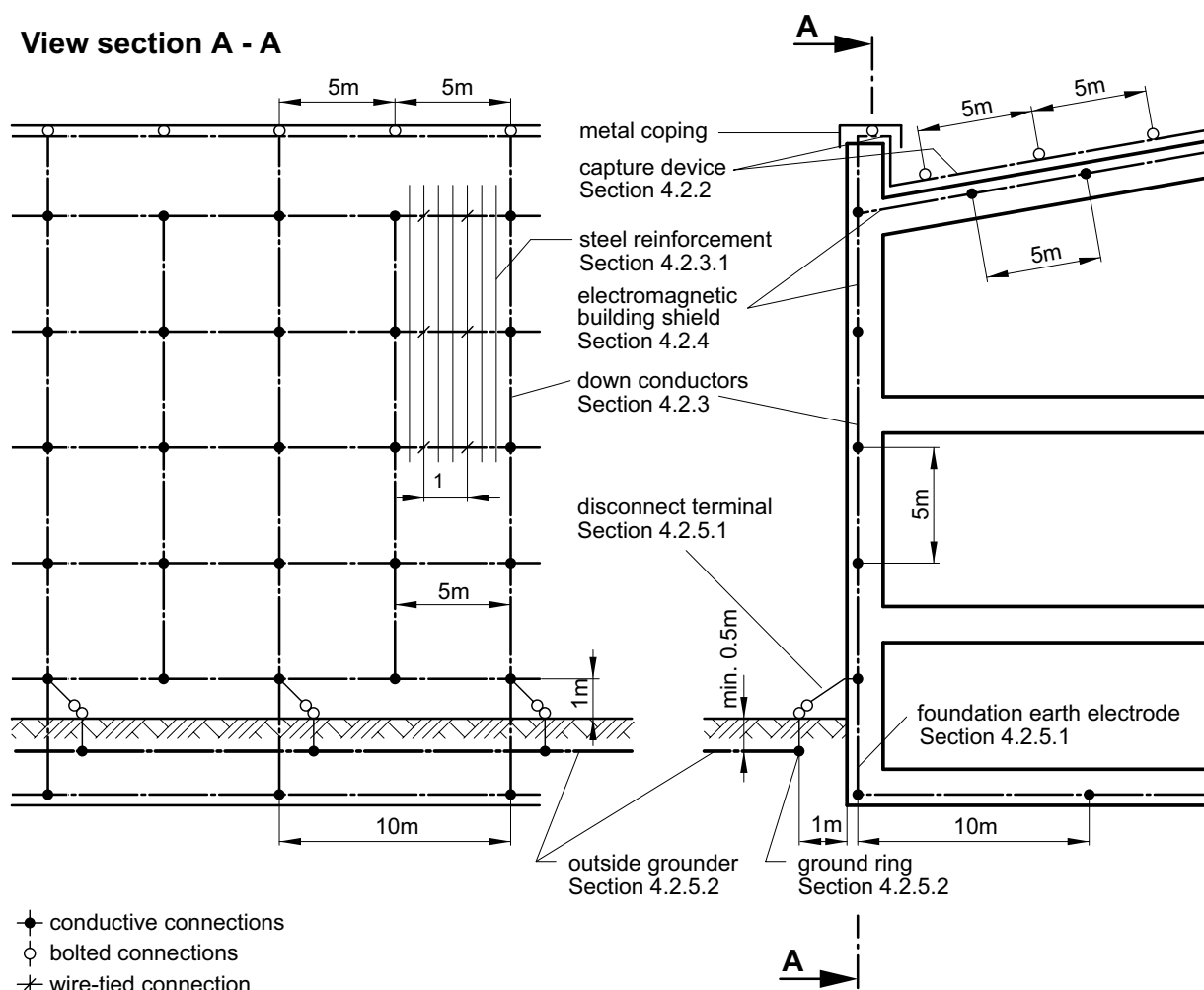


Figure 4-1: Reinforcement steel rods for the electromagnetic building shield in the case of buildings without a metal building front, and connection of the foundation earth electrode in the case of buildings not provided with an external structural seal

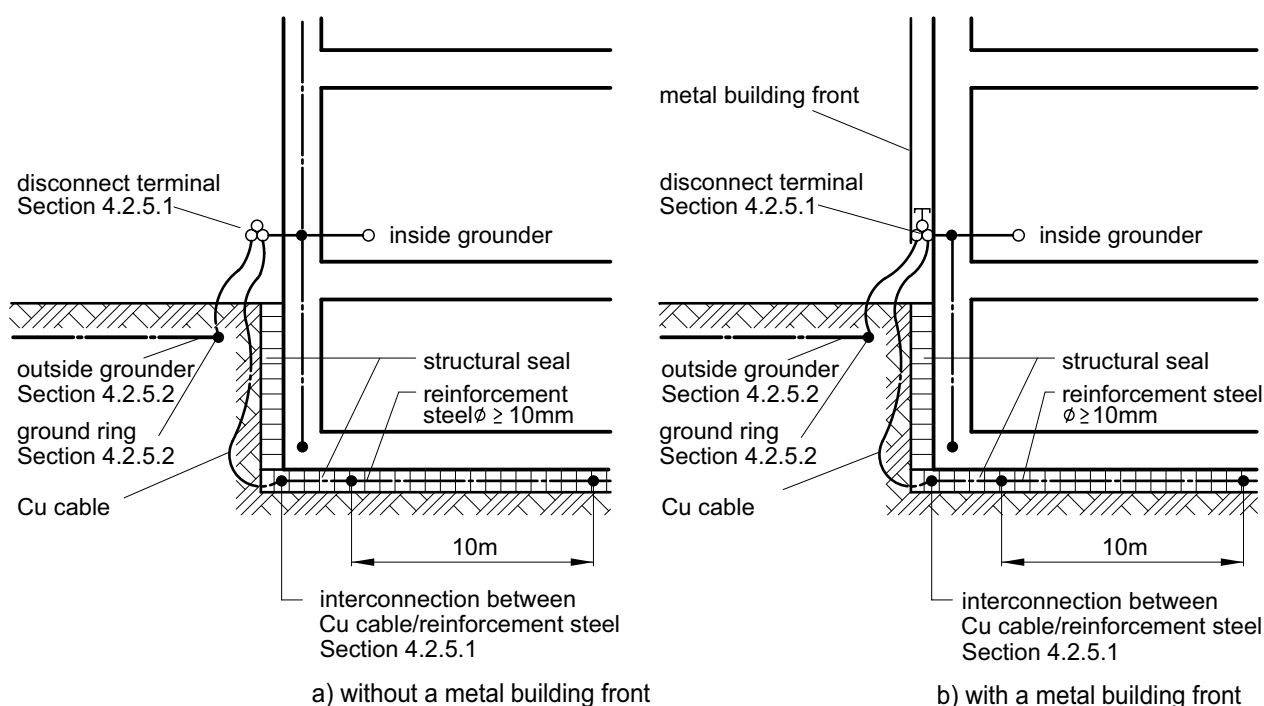


Figure 4-2: Connection of the foundation earth electrode in the case of buildings provided with an external structural seal