

# **Electrical engineering in general: Design and construction. Earthing**

## **1 Purpose and scope**

The purpose with a separate chapter of grounding in “felles elektro” is to ensure that earthing in all installations is planned and built to avoid impermissible touch voltages and fulfilling all functions of the facilities.

The chapter deals with earthing for all electrotechnical disciplines at Jernbaneverket and set requirements for planning and building to ensure the functionality of the facilities, and to ensure a cost effective and sensible planning and building process. The chapter contain requirements to earthing facilities both within and outside the contact line or current collector zone (clause 4) and non-electric railways (clause 5). In addition there are requirements for earth electrodes (clause 6) and requirements to documentation (clause 7).

### **1.1 Special arrangements for station areas and workshops where the rolling stock is parked below the contact line**

Jernbaneverket has an objective liability to third party not to be exposed to danger, for instance with a live contact line. For planning and refurbishment of station area and workshops a risk assessment shall always be performed in advance. This risk assessment shall result in answers to the following items:

- shall the area be separated by a fence?
- shall there be limitations to what kind of vehicles (with easy access to the roof) that may be parked
- shall the contact line be live or not? - by sectioning? - by conditional locking to shore supply?
- shall the area have a local caretaker engaged by Jernbaneverket or another company?
- shall the area be illuminated? - to what extent?
- shall the area have supervision by video? - to what extent? - with recording?
- shall the area have remote monitoring?

In the risk assessment information should be collected, such as:

- the need for parking and relevant vehicles to be parked
- the capacity for the area (parking positions)
- train movements per hour/day for ordinary traffic and parking
- the neighbourhood – indications of homes, schools, sport fields, shops and other service facilities
- registered (unauthorised) traffic crossing tracks
- registered traffic in the parking area

# 2 Installations within or outside the contact line and current collector zone

## 2.1 General

Earthing in an electrical installation shall be performed to avoid impermissible touch voltages and step voltages and to facilitate electromagnetic compatibility between different facilities, systems and equipment. Earthing shall also be performed to protect the different parts from over-voltages.

The traction return circuit shall be maintained separate from other electrical circuits and earthing systems. The isolation level should be coordinated with the isolation level for the contact line.

1. On sections with continuous parallel earth conductor and low voltage supply with TN system the requirement for separation shall be maintained with galvanic isolation, see [Chapter 8](#).

Exception:

The requirement is not applicable for buildings where the connection to the return circuit is present, such as substation, supply point, switching station etc., and circuit directly attached to the track (track circuits).

For impermissible touch voltages (with fault duration  $t \leq 0,5$  s), temporary available voltages in operation (duration  $0,5 < t \leq 300$  s) and continuous available voltages ( $t > 300$  s) the values in [NEK EN 50122-1] shall be observed.

c) the flow diagram in annex 6.a may be used as a tool for planning of an earthing system.

## 2.2 Refurbishment of electrical installations

a) For major changes in facilities related to either contact line system, safety system (track circuits), the traction return circuit or other circuits impact the earthing system, an assessment shall be undertaken in advance to check the earthing system with regards to relevant requirements to:

- voltage potential and touch voltages in [NEK EN 50122-1]
- compatibility between the different electrical facilities (in particular track circuits, earthing system and return circuit)
- sufficient protection against over-voltages

The documentation can include theoretical calculations or references to measurements on similar facilities.

Examples on major changes with impact on the earthing system may be:

- enhancement of the traction feeding (feeders, reinforcing feeder, new substations etc.) which impact short-circuit currents in the facilities.
- refurbishment of the contact line system, substitution of poles with metal masts.
- installation of return conductor.
- refurbishment of existing track circuit (change from single insulated to double insulated, change of insulation).
- new track circuits.
- addition of parallel earthing conductor.
- new facilities or change in existing facility with significantly increased number of

(conductive) parts.

b) If the facility do not satisfy the requirements in a) the earthing system shall be fully planned and rebuilt.

## 2.3 Combined overhead contact line and current collector zone

Combined overhead contact line and current collector zone is defined in accordance with [EN 50122-1]. Different definitions are contained in:

- [Combined overhead contact line and current collector zone](#)

a) Exposed conductive parts within the combined overhead contact line and current collector zone shall have bonds to the traction return circuit (in accordance with EN 50122-1:2010 or later). The conductor cross-section area shall be selected according to Tabell [1](#).

Exception:

1. Other conductive part (without electrical supply or electrical circuit) with dimensions less than 3 m along the track or 2 m perpendicular to the track.

E.g. Signs, mast with sign, garbage containers, ash trays, manhole lids etc.

2. Partly conductive part with dimensions up to 15 m along the track or 2 m perpendicular to the track.
  3. Loose, moveable part without any electrical supply or electrical equipment that is parked partly within the overhead contact line zone in a stand fitted with bonds to the return circuit (for instance ramp for wheel chair)
  4. Insulated section, neutral section and lines for tensioning devices, including anchoring wire beneath the anchoring insulator
- Coaxial cable antennas in tunnels, provided that the requirements in [Radio systems in tunnels](#) are satisfied.

1. Pre-constructed concrete elements, e.g. for platforms, TBM-elements (in drilled tunnels) etc., with a maximum dimension (length, width, height) up to 5,1 m and where the armouring is not exposed. (Observe: elements made at site should be bonded to the return circuit.)

b) All exposed conductive parts positions where the possibility to touch other parts connected to the return circuit (distances less than 2,5 m) shall also have bonds to the traction return circuit.

1. If live parts in the contact line system may touch a conductive part connected to the return circuit, the cross-section area of the bond conductor shall be selected according to Tabell [1](#).
2. If the bonded part are not likely to become live by the contact line, the conductor cross-section area may be selected according to relevant standard or codes for particular part ([NEK 400-5-54], or similar). Detached unprotected outdoor bonds shall not be less than 16 mm<sup>2</sup>.

c) Unnecessary bonds to the traction return circuit shall be avoided to limit unwanted paths for the traction return current, such as:

Earthing of such parts may be as well be relevant by other criteria (e.g. lightning protection).

1. Parallel conductive fence outside the overhead contact line zone is affected of the same earth potential rise as the contact line masts. Bonds to the return circuit or earthing is normally not necessary, however, refer to [Continuous conductive objects](#) for possible sectioning.
2. Other conductive part (not contained in b) above) on the platform and positioned outside the overhead contact line zone.

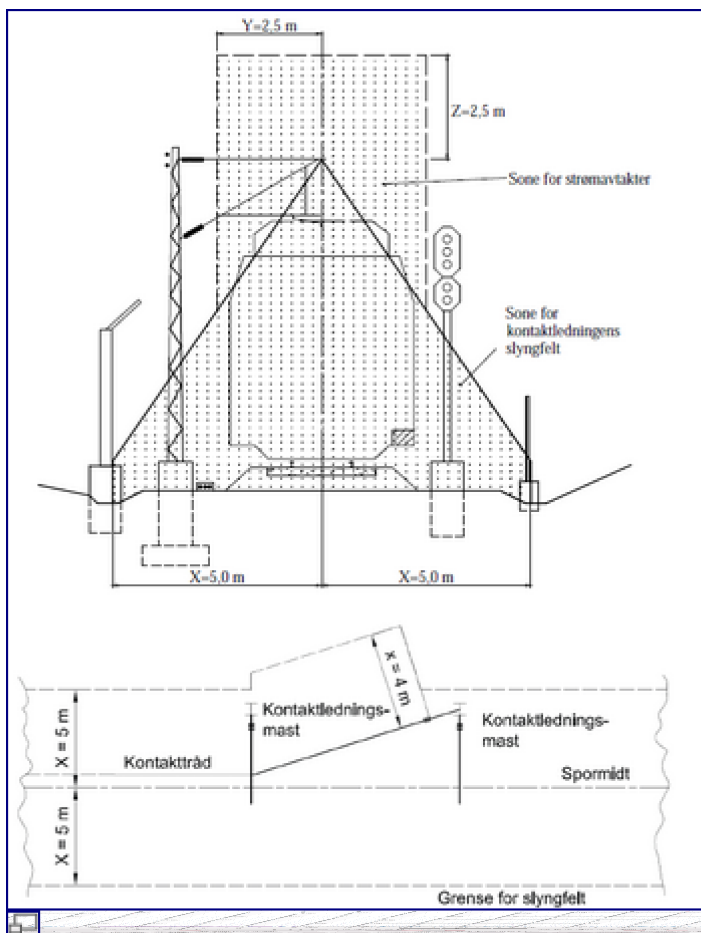
### 2.3.1 Combined overhead contact line and current collector zone for conventional contact line system

a) The combined overhead contact line and current collector zone is defined in Figur 1. Distances X, Y and Z shown in the figure shall have the following values: X=5,0 m, Y=2,5 m and Z=2,5 m.

1. At ground level the combined overhead contact line and current collector zone applies from and including the top of rails (SOK) and extends down to the ground.
2. On bridges the combined overhead contact line and current collector zone shall be extended to 10 m below the top of rail (SOK) (figure 8-2 in [FEF]).
3. For large conductive constructions (buildings, road bridges etc.) a border for the combined overhead contact line and current collector zone should be somewhat redefined as depicted in [Large conductive constructions](#).
4. At overlap spans the combined overhead contact line and current collector zone is extended based on the position of the wires, see Figur 1. The requirement for “4 m” in the figure extends from the earth point of the insulator perpendicular to the contact line to be tensioned.
5. The boarder of the combined overhead contact line and current collector zone in tunnels depends of the profile of the tunnel, and one of the following shall apply:

For planning and constructing of new tunnels the combined overhead contact line and current collector zone defined above shall be used.

By refurbishment of tunnels with less profile than given in [Underbygning](#) the combined overhead contact line and current collector zone shall be extended to the whole profile of the tunnel.



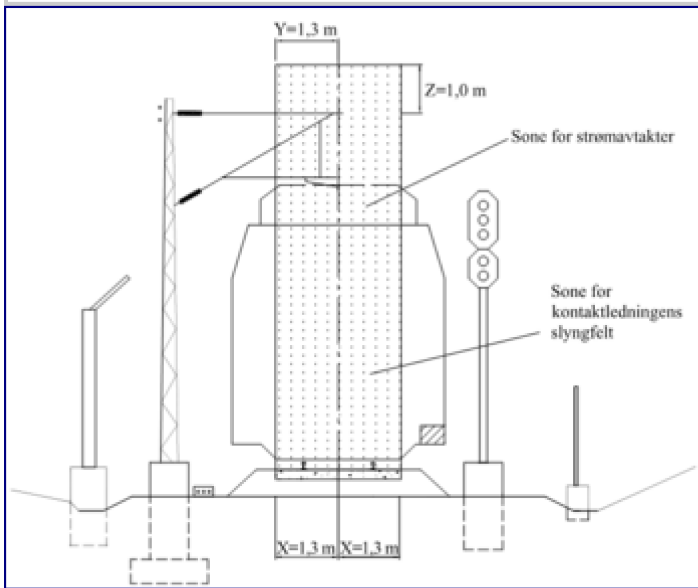
Figur 1: Combined overhead contact line and current collector zone for conventional contact line system. At top: Combined overhead contact line and current collector zone in accordance with NEK EN 50122-1. At bottom: Combined overhead contact line and current collector zone in accordance with requirement a) 4 above.

## 2.3.2 Combined overhead contact line and current collector zone for current conductor rail system

The combined overhead contact line and current collector zone for current rail conductor is defined in Figur 2. The distances X, Y and Z as shown in Figur 2 shall have the following values:  $X=1,3$  m,  $Y=1,3$  m and  $Z=1,0$  m.

1. At ground level the combined overhead contact line and current collector zone applies from and including the top of rails (SOK) and extends down to the ground.

The contact line can be constructed as a current bar with direct the current collector or as a current bar with a contact wire attached.



Figur 2: Combined overhead contact line and current collector zone for current conductor rail system.

## 2.4 Dimensioning of short-circuit current and disconnection delays for the contact line system

Requirements for dimensioning of short-circuit current are specified in [Chapter 4](#).

Requirements for associated disconnection delays are specified in [Chapter 4](#).

Specification of relevant areas used in the detailed requirement are given in [Chapter 4](#).

## 2.5 Interface to other facilities

### 2.5.1 Energy companies

a) The earthing systems of energy companies and the traction return system shall not be connected together.

1. To avoid interconnection of the two earthing systems via electrical paths between earth electrodes, it should be documented that the distance between the electrodes of the different earth systems are adequate. See clause about [Chapter 4](#).}}

### 2.5.2 Track circuits

a) The earthing shall be installed to facilitate the functions of the earthing system (protective

earthing) and at the same time it shall not disturb the function of the track circuits, including detection of trains and possible detection of broken rail etc., see [Signal/Prosjektering](#).

### 2.5.2.1 Track circuits with a.c. (95/105 Hz)

a) Objects with lower leakage resistance to earth than approx. 100  $\Omega$  shall not be bonded directly to the running rails on sections with double insulated track circuits with a.c. (95/105 Hz).

1. If lower leakage resistance than 100  $\Omega$  is likely, the objects can be bonded to the running rails with filter impedances if the distance between such connections are long enough not to disturb the function of the track circuits, see [\[560\]](#) and [\[551, vedlegg a\]](#).

### 2.5.2.2 Jointless track circuits

a) For planning of earthing systems the rules for the selected track circuit shall be observed.

1. For FTGS and TI21 refer to respectively annex [d](#) and [e](#) in [\[560\], Chapter 7](#).

b) If no rules exist, they shall be worked out and agreed with the supplier prior to planning.

1. The rules should deal with:

- where and the amount of connections to the running rail
- which of the running rails that shall be bonded if the right and left rail have different functions
- the use of and the requirements to filter impedances between earthing system and running rails
- the use of continuous parallel earthing conductor and possible construction of sectioning

Possible precautions related to earth electrodes.

## 2.5.3 Axle counters

Earthing of axle counters shall be performed in the same way as for other objects within the combined overhead contact line and current collector zone, see clause 3 about [Performance requirements for different exposed conductive objects within the combined overhead contact line and current collector zone](#). See particular [Figur 8](#), [Figur 9](#), [Figur 10](#) and [Figur 11](#).

When the section is without any track circuit, the clause 2.10 about [Facilities without track circuits](#) is also relevant.

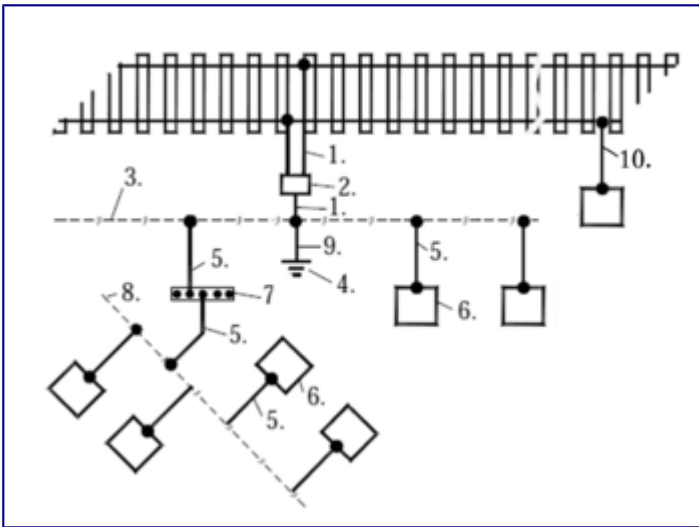
## 2.6 Earthing terminology

a) The terminology for earthing within the combined overhead contact line and current collector zone for electrified railways is depicted by the sketch in [Figur 3](#). To avoid misinterpretations these terms should be used for planning and building of earthing systems.

b) The whole circuit from extended conductive part to the running rail should be denoted “bond(s) to the traction circuit return” (“utjævningsforbindelse til banestrømmens returkrets”) and includes earth conductors, bonds and filter impedances or only direct connections to the running rails.

The term “connection to the running rails” (“jording til skinnegangen”) is not always the most intuitive description.

The construction depends on the actual track circuit in the section and whether the facility has a parallel earth conductor or not.



Figur 3: Earthing terminology

1. Main bond connection
2. Filter impedance
3. parallel earthing conductor (sectioned or continuous)
4. Impulse electrode/earth electrode
5. Bond
6. Extended (conductive) part (within the combined overhead contact line or current collector zone, or in a distance less than 2,5 m from any extended conductive part within the combined overhead contact line or current collector zone)
7. Earthing bar
8. Local earthing conductor
9. Main earthing conductor
10. Bond

## 2.7 Requirements to earthing conductors and bonds

a) Earthing conductors and bonds shall be continuous, functional and without breakage.

Requirements to maximum resistance between the contact line mast and running rail, and requirements to inspections of the value (ohms) is given in [Kontaktledning/Vedlikehold](#).

b) All earth conductors and bonds shall be marked with associated terminating points and shall be distinguishable and permanently marked.

1. As a minimum the numbering of all earthing sections, the different objects/parts connected to the bonds and where the bonds are connected (markings close to the objects/parts) should be marked.

c) All bonds should be as short as possible.

d) See Figur 3: main bond connection (1), parallel earthing conductor (3), bonds (5), local earthing conductors (8) and main earthing conductor (9) shall be dimensioned with the stated cross-sections area for the conductors (copper) according to Tabell 1.

e) Bonds and earthing conductors shall be connected and arranged in such a way that serial connections of connected parts are avoided. Figur 4 depicts examples to interconnections of facility parts without serial connections.

Exception:

Extended conductive parts mounted on steel masts, yoak etc. may be earthed through their

mounting points if these are adequate for a good connection.

- f) Earth conductors and bonds with interconnections shall be protected against mechanical damage and routed to avoid danger of flash-over and damage to other cables and equipment.
- g) Multi-threaded copper conductor with a yellow/green insulation (insulation level of minimum  $U_0 / U = 450 / 600 \text{ V}$ , see also [Chapter 7](#) and [EN 50264-1]). In tunnels the insulation shall be free of halogens.
- h) Parallel earthing conductor (3) and main bond connection (1) shall be installed accessibly.
- I) All interconnections shall be done with (corrosion-)proof and permanent termination.
- j) For earth conductors and bonds the connections and joints shall be accessible for inspection. If the joints are likely not to be accessible, the joints shall be done with termite welding (Cadwell or similar).
- k) If it should happen to be a discontinuity in protective conductors, these shall be treated with care – as for broken running rails – with respect to traction return current and impermissible touch voltages.
- l) Earth conductors and bonds within the combined overhead contact line and current collector zone may contain traction return current in normal operation, and maintenance work/reconstructions shall be performed according to established rules.
- m) Other requirements to installation of cables are given in [Chapter 5](#).

Tabell 1: Requirements for dimensioning of earthing conductors and bonds as shown in [Figur 3](#), which can be become live by the contact line voltage, refer to requirements in 2.3 c) 1.

	<b>Oslo S (and switching station)</b>		<b>Oslo area</b>		<b>The Ofot line</b>		<b>Rest of the country</b>	
	cross-section area [mm <sup>2</sup> ]	max. length [m]	cross-section area [mm <sup>2</sup> ]	max. length [m]	cross-section area [mm <sup>2</sup> ]	max. length [m]	cross-section area [mm <sup>2</sup> ]	max. length [m]
Bonds (10)	95	—	70	—	70	—	50	—
Main bond connection (1)	95	—	2)	—	2)	—	2)	—
Sectioned, parallel earthing conductor (3)	95	100 <sup>1)</sup>	95 70	125 <sup>1)</sup> 90 <sup>1)</sup>	95 70	155 <sup>1)</sup> 115 <sup>1)</sup>	95 70 50	250 <sup>1)</sup> 180 <sup>1)</sup> 130 <sup>1)</sup>
Continuous parallel earthing conductor (3), between to adjacent bonds to the traction return circuit	95	200	95	250	95 70	310 230	95 70 50	500 360 260

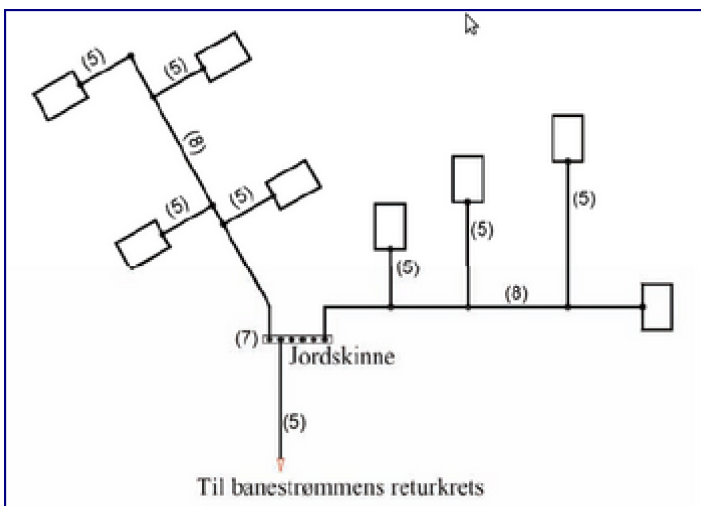


(may also be the same as main bond connection in Figur 3)

Bonds (5)	95	10	70	10	70	10	50	10
Local earthing conductor (8)	95	50	70	50	70	50	50	50
Main earthing conductor (9)	95	—	70	—	70	—	50	—

1) The length applies from and including the main bond connection to and including the outermost object on the earthing section. It may be doubled provided that the main bond connection is located in the middle of the earthing section.

2) Use the same cross-section area as for parallel earthing conductor.



Figur 4: Examples of bond connections (star structure, see also explanations to Figur 3)

## 2.8 Criteria for the use of direct connections to the track

a) On sections with track circuits and without parallel earthing conductor the bonds from extended conductive parts within the combined overhead contact line and current collector zone can be connected to the track if:

1. No connections are made that implies a short-circuit between the rails.
2. No parallel longitudinal path for the track circuit current is established and no other impact on the function of the track circuit is imposed, see also [Signal](#).
3. For tracks with track circuits utilizing one insulated rail the rail denoted “jordet skinne” (“earthed rail”) shall be connected.
4. For double insulated track circuits both rails can alternatively be used as “jordet skinne”, however, a well balance in voltages between the two rails should be optimized by an even distribution of connections to the two rails.

b) The requirements in a) shall be documented. See clause about [Within the combined overhead](#)

[contact line and current collector zone: Earthing plan for all disciplines.](#)

c) If the requirements in a) can not be fulfilled, a parallel earthing conductor shall be used, see clause about [Anlegg med langsgående jordleder.](#)

## 2.9 Methods for connection to the track return circuit

This clause depicts different solutions for the connection of main bond connection to the track, either directly from an exposed conductive part or from a parallel earthing conductor.

a) All connections to the rail shall be made with approved screwed connection.

(The Cembre method)

### 2.9.1 Main bond connection directly to the track

a) Exposed conductive parts or parallel earthing conductor shall only be connected directly to the track if no there are no conflict with interface criteria in the clauses about [Interface to other facilities](#) and [Criteria for the use of direct connections to the track.](#)

### 2.9.2 Main bond connection connected to the track by filter impedance

a) Bond connections and earthing conductors that can have a permanent electrical connection but not directly connected to the track, shall have connection via a filter impedance that is approved by Jernbaneverket.

1. The connection by the filter impedance shall:
  - \* have high impedance for the track circuit current (16,7 Hz).
  - \* sustain the short-circuit currents and the automatic training routines that are likely for the track circuit supply, see [\[546\]](#).
2. The connection by the filter impedance shall either:
  - \* be connected an earth electrode in addition to the track, or:
  - \* have a low impedance for atmospheric over-voltages.

Atmospheric over-voltages seeks the shortest path to earth, hence a dedicated impulsive electrode / earth electrode is preferable.

3. With regards to the positioning at the track the filter impedance:
  - \* shall be adequately mechanically protected.
  - \* shall be adequately protected against climatic stress.
  - \* shall have a well visible colour /alert stick.

b) If new filter impedance is introduced on existing track circuits, the need for re-calibration of the track circuit shall be evaluated. The calibration shall be performed in accordance with the annexes in [\[551\]](#).

### 2.9.3 Use of voltage-limiting devices – “open earthing”

a) The solution depicted in this clause shall be approved by Jernbaneverket.

b) If a permanent connection to the track is not possible, for instance in cases like:

- an exposed conductive part extends far away from the track, and can not be sectioned.
- it is difficult to keep the earthing system of the energy supplier separate from the track return circuit due to fixed installation (e.g. lighting with external energy supply installed in masts

with foundation on concrete)

- a parallel line with d.c. traction exist in the vicinity of Jernbaneverket's line with a.c, and a protection device shall be installed to limit the voltage and hence avoid impermissible touch voltages.

c) Such a voltage limiting device according to b) shall satisfy the following functional requirements:

- Voltage hazards: As soon as a voltage exceeds the allowed touch voltage the protection device shall make a conductive connection.
- Response time: The response time on the protection device shall be coordinated with the actual faulty situations that are likely to happen.
- Safety of function: The protection device shall re-establish normal function (serve as an insulation) once the faulty condition ceases
- Simple indication: It shall be easily visible on the protection device whether it is conductive or insulating.
- Message contact: For critical places/functions an alert/alarm is needed to informed responsible staff at the moment the protection device is tripping
- insulation level: The protection device shall sustained the contact line voltage according to the procedures for disconnection.
- Earthing: atmospheric over-voltages always takes the shortest path to earth. If the protection device shall operate by the transients from lightning, an impulse electrode/earth electrode shall be installed.
- Visibility: The protection device shall have a well visible colour /alert stick and distinguishable marking.
- Location: The protection device shall be installed in accessible work position, minimum 1 m above the ground.

## 2.10 Facilities without track circuits

a) Facilities without track circuits may have continuous parallel earthing conductor, see clause about [Continuous parallel earthing conductor](#).

The parallel earthing conductor may be installed along the track or in the contact line masts.

## 2.11 Facilities with parallel earthing conductor

a) In the facilities with parallel earthing conductor all extended conductive parts within the combined overhead conductor line and current collector zone shall have bonds to the parallel earthing conductor.

b) For single track lines with stations where there are more than one track with dedicated parallel earthing conductor, these parallel earthing conductors shall be bonded with cross-bonds.

1. The cross-bonds should be installed at the same location where the parallel earthing conductors are connected to earth electrodes.

c) Places with transition from parallel earthing conductor to facilities with direct bonds to the track return circuit shall be documented and marked.

### 2.11.1 Connections to the track return circuit

a) Parallel earthing conductor shall be connected to the track with well marked signs at well visible locations.

- b) The connection from parallel earthing conductor to the track (main bond connection) shall have the same cross-area section as the main conductor.
- c) The connection to the rail shall be in accordance to the clause about [Methods for connection to the track return circuit](#).
- d) If it is necessary to maintain the interface between track circuits and earthing facilities, the connection between the earthing conductor and the track shall be done via an approved impedance filter. Refer to clauses about [Methods for connection to the track return circuit](#) and [Track circuits](#). See also figures Figur [5](#) and Figur [6](#).

Exceptions:

1. Facilities without track circuits can be constructed without filter impedances.
2. For single insulated track circuits there shall not be any filter impedance.

### **2.11.2 Electrodes connected to parallel earthing conductor**

- a) Parallel earthing conductor shall have a dedicated earth electrode, see clause about [Earth electrodes](#).
- b) The electrode should be connected to the parallel earthing conductor at the same location as the parallel earthing conductor is connected to the track.

### **2.11.3 Connection points**

- a) Connections between earthing conductors and bonds shall be done by permanent and approved methods.
- B) Connection points shall be accessible for inspections.
- c) Connections to earth electrodes or other parts of the facility that have to be separated during maintenance routines, shall have screw construction.
- d) The connection points shall be marked in the documentation, see clause about [Within the combined overhead contact line and current collector zone: Earthing plan for all disciplines](#).

### **2.11.4 Sectioned parallel earthing conductor**

Continuous parallel earthing conductor is normally preferred as the alternative (parallel) current paths – both to the track and to earth. Facilities with sectioned parallel earthing conductor is more vulnerable as there is only one path for the current to the track and to earth. The great variations in climate during the year gives impacts the resistance to earth, rather for sectioned parallel earthing conductor than for continuous parallel earthing conductor. Continuous parallel earthing conductors should be assessed.

- b) The use of sectioned parallel earthing conductor shall be coordinated to facilitate the interface between track circuits and earthing. See Figur [5](#) for examples of the principle construction.
- b) The sections of earthing conductor shall not extend the lengths given in Tabell [1](#).
1. The lengths depicted assumes that the connection to the track is made in the middle of the section of earthing.
  2. The section lengths shall be coordinated with the track circuits. Tabell [1](#) and dimensions for the insulation plans for track circuits dictates the allowable lengths of the sections.
  3. One or more earth electrodes may be connected to a sectioned parallel earthing conductor, but there shall only be one connection to the track.

The lengths depicted is independent of the cross-section area of the earthing conductor and the amount of short-circuit current. The disconnection delay is 0,3 seconds. To assess the disconnection delay and cross-section area refer to the clause about [Dimensioning of short-circuit current and disconnection delays for the contact line system](#) and the annex 6.c.

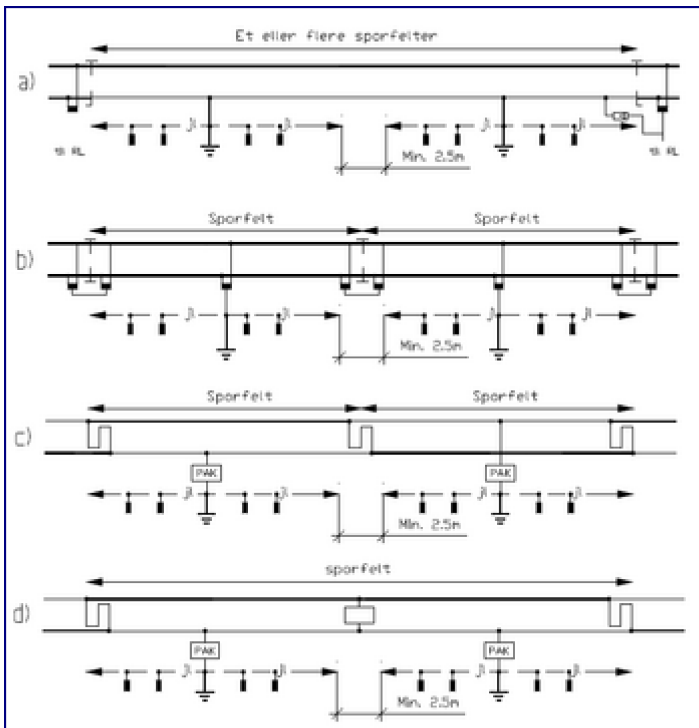
c) The ends of the earthing sections shall be insulated for minimum 750 V and marked.

Purpose:

- maintain the separation between the two earthing conductor sections.
- Easily identification of the separation between the two earthing conductor sections in the facility.
- Avoid moisture and degradation of the earthing conductor sections.

d) There shall be minimum 2,5 m separation between to exposed conductive objects:

- if they are connected to different earthing conductor sections
- if one of the objects is connected to the track and the other object is connected to an earthing conductor section.



Figur 5: Examples of principle use of sectioned parallel earthing conductor (connection to the track depends on the type of track circuit). a) conventional single insulated track circuit, b) conventional double insulated track circuit, c) jointless end-fed track circuit, e.g. FTGS, d) jointless centre-fed track circuit, e.g. FTGS.

symbols of earth indicates recommended position of possible earth electrodes. (PAK: serial impedance)

### 2.11.5 Continuous parallel earthing conductor

a) Continuous parallel earthing conductor:

1. should be used in stations with single insulated track circuits, if it is not in conflict with the track circuits.
2. may be used on sections without track circuits.

3. may be used on sections with axle counters.
4. shall not short-circuit the whole or parts of the secondary windings of a booster transformer. Read about parallel earthing conductor in [Equipment in the vicinity of booster transformer with neutral section](#).

Use of continuous parallel earthing conductor on sections with track circuits shall be approved by Jernbaneverket in every case.

Continuous parallel earthing conductor is a prerequisite for installation of low voltage energy with TN-S, see requirements in [Chapter 8](#).

- b) The distance between the connections to the track and the distance between earth electrodes should not be greater than for sectioned parallel earthing conductor, see relevant clause [Sectioned parallel earthing conductor](#).
- c) The connection points to the track shall be coordinated with the track circuits. See Figur 6 for examples of principal constructions.
- d) For conventional double insulated track circuits, see Figur 6, b): As a main rule the existing filter impedance in conjunction with the joints may serve for connections to the parallel earthing conductor.
  1. If the intermediate distance is too long and the requirements for lengths in Tabell 1 are exceeded, new connections with filter impedance shall be established between the joints associated with the earth conductor connections, assuming that the function of the track circuits are maintained, see clause about [Track circuits](#).
- e) For jointless track circuits, see Figur 6 c) and d): If the parallel earthing conductor may not be connected directly to the rail. A filter shall be inserted, see clause about [Methods for connection to the track return circuit](#).

Note! The principles in Figur 6 c) and d) is depicted for the case with FTGS track circuits, but the recommendations are valid also for other types of jointless track circuits.

- f) For facilities without track circuits the use of parallel earthing conductor shall be as the principles in Figur 6 e):
  1. the distance between connection points between the parallel earthing conductor and the track shall follow the same principles as depicted in Tabell 1.
  2. Earth electrode may be installed at the connection points as depicted in clause 1.

The distance between cross-bonds rail-to-rail shall not exceed 500 m within “Oslo-området” (Oslo area), and otherwise 750 outside Oslo-området. (For the definition of Oslo-området, see [Dimensioning of short-circuit current and disconnection delays for the contact line system](#).) These places should be the same as the connection points in clause 1.

1. If a return feeder is present in the section the location for connection between the parallel earthing conductor and the track should be co-located with the access to the return feeder.
2. A cross-bond rail-to-rail shall always be present at the access point to the return feeder.

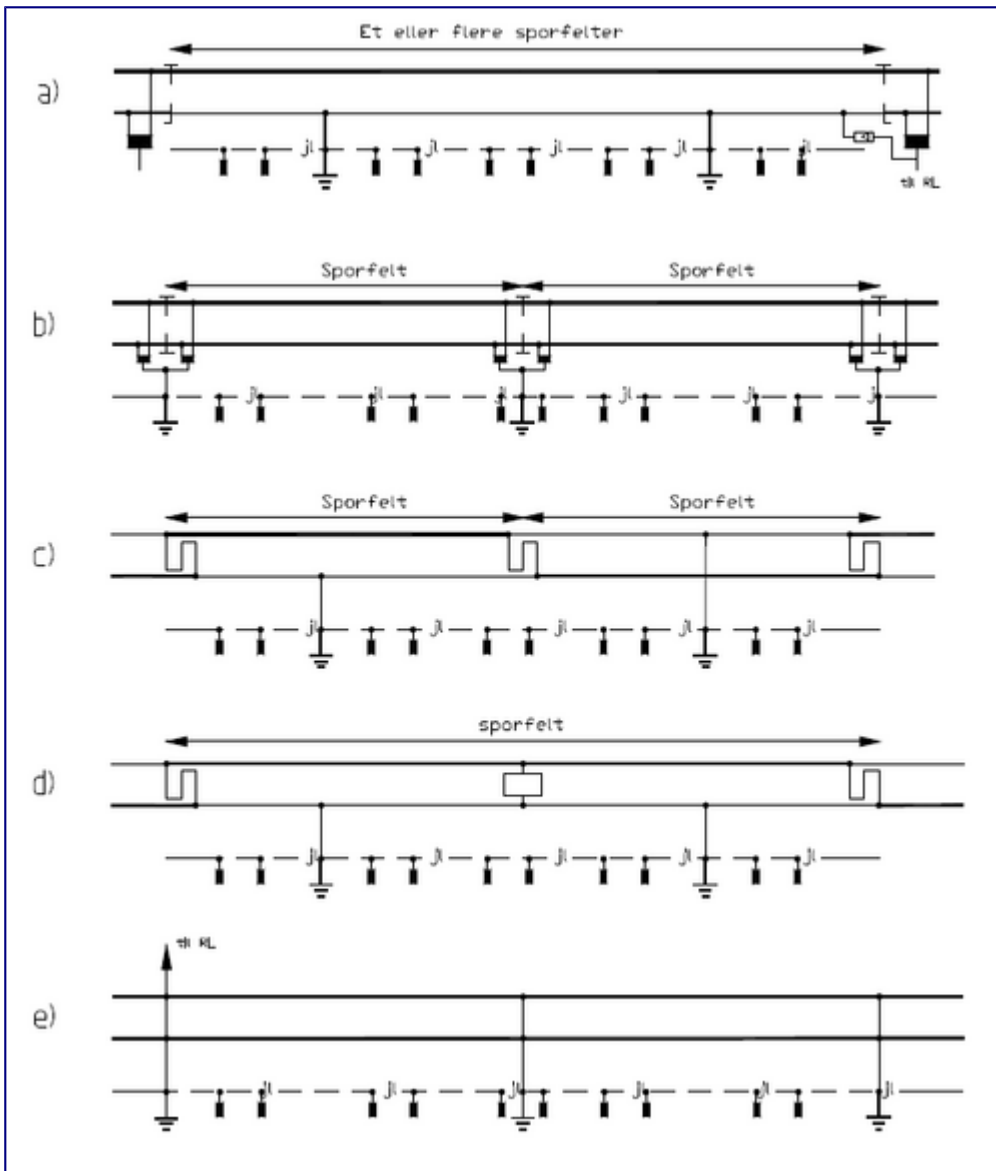
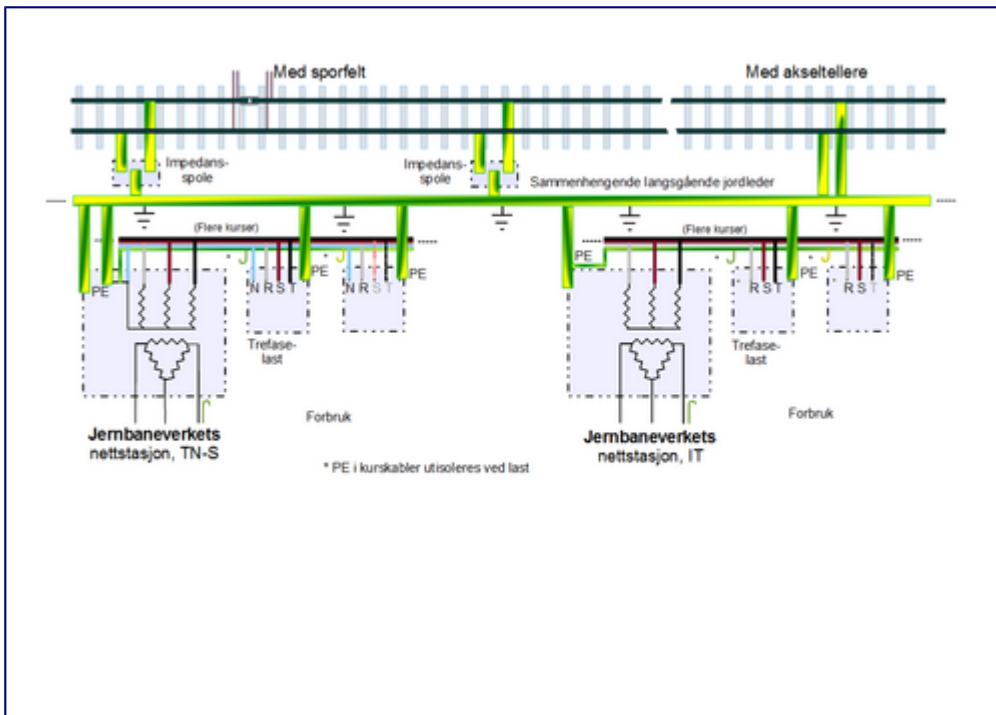


Figure 6: Examples of principles for the use of continuous parallel earthing conductor (connection to the track depends on the type of track circuit). a) conventional single insulated track circuit, b) conventional double insulated track circuit, c) jointless end-fed track circuit, e.g. FTGS, d) jointless centre-fed track circuit, e.g. FTGS.

symbols of earth indicates recommended position of possible earth electrodes. (PAK: serial impedance)

### 2.11.6 Bonds between continuous parallel earthing conductor and the energy supply with 50 Hz

Figure 7 depicts possible configurations of bonds as the whole section is featured with a continuous parallel earthing conductor.



Figur 7: Bonds between continuous parallel earthing conductor and the energy supply with 50 Hz

### 2.11.7 Possible construction of continuous parallel earthing conductor

- a) Where a new line is constructed the continuous parallel earthing conductor may be established on the toe of ballast.
  1. A dedicated parallel earthing conductor is established for each track.
  2. 95 mm<sup>2</sup> uninsulated copper conductor is laid on geotextile beneath the track.
  3. At each contact line mast or mast portal a branch of insulated copper conductor is established. The joint is made as a termite welding. The branch shall be protected with a plastic sleeve that emanates outside the cable free profile close to the mast.
- b) For refurbishment of the facilities a continuous parallel earthing conductor may be hang up in the masts.
- c) In tunnels the continuous parallel earthing conductor may be clamped to or hanged at the tunnel wall.
- d) At platform the continuous parallel earthing conductor may be installed under the edge of the platform or in a tube.
- e) Other installation methods are possible.

An installation technique that prevents vandalism (theft) should be preferred.

## 2.12 Benches, ticket vending machines, validators, kiosk machines, monitors, speakers, and other electronics on platform

For the station area a documentation of the earthing facilities that identifies all objects connected to the track return circuit shall be present. In particular at electrified tracks all ticket vending machines, validators, kiosk machines, monitors, speakers, and other electronics that are installed in



the same area where other objects are bonded to the track return circuit – on platform or within the combined overhead contact line and current collector zone – shall be bonded to the track return circuit. See requirements for exposed conductive parts in the clause [Performance requirements for different exposed conductive objects within the combined overhead contact line and current collector zone](#).

Systems that are constructed of more metallic objects in a common or integrated on common bearing structures (examples are ticket vending machines, validators, kiosk machines, monitors etc.), shall be approved by Jernbaneverket regarding electrical equipotential bonding between the internal units and the external closure/bearing structures.

When benches and other permanent objects with large exposed conductive surface are located on the platform at electrified tracks, they shall be bonded to the track return circuit, see also [Combined overhead contact line and current collector zone](#). Waiting sheds and larger metallic objects that are screwed together, shall have electrical interconnections between the modules – which presuppose exposed metallic materials in the interconnecting points. See requirements for different exposed conductive parts within the combined overhead contact line and current collector zone [Performance requirements for different exposed conductive objects within the combined overhead contact line and current collector zone](#).

## 3 Performance requirements for different exposed conductive objects within the combined overhead contact line and current collector zone

### 3.1 Main rules for the earthing of cables

a) The shield or the PE conductor extending to installations and facility parts within the combined overhead contact line and current collector zone shall as a main rule be earthed in one end only to avoid interference from the track return current (16,7 Hz) and to avoid parallel paths for the track return circuit (running rails).

1. For high voltage cables necessary marking and protection shall be provided, see [FEF, §4-4].
2. For high voltage cables “open earthing” may be provided for the shield with a voltage limiting device or the shield may be insulated (unterminated), see [Isolasjonskoordinering og overspenningsbeskyttelse](#).
3. High voltage cables installed in concrete ducts should have an electrical insulating sheath.
4. If high voltage cables with semi-conductive sheath is left unterminated, the semi-conductive sheath shall be removed and any shield shall be insulated.

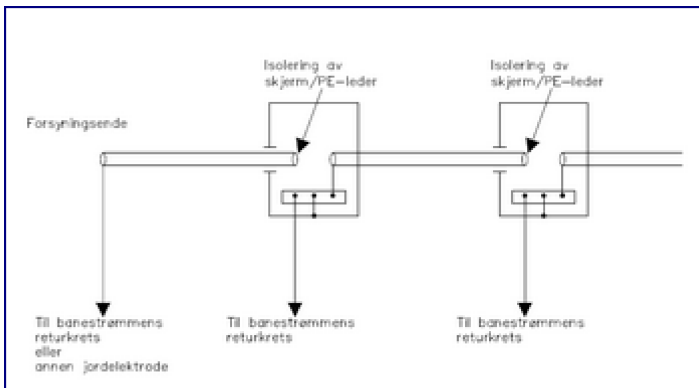
b) Cables in low voltage facilities shall be earthed at the source end and be insulated (unterminated) in the drain end, see Figur [8](#) and Figur [11](#).

1. Shield / PE conductor shall always be connected at the main earthing bar at the entrance in electrotechnical buildings, see [Earthing network in buildings](#).
2. Cables may have PE conductors terminated in both ends, but onwards the termination shall be insulated from exposed conductive parts in the facilities, see [Alternative earthing of cables for facilities with isolation of continuous PE conductors in cables](#).
3. Insulation/termination of shield/PE conductor shall be performed on a separate insulated bar with a minimum protection of IP2X. The insulation level shall minimum correspond to the insulation level for the cable.

Requirements to the insulation level of the outer sheath to high voltage cables corresponds to the insulation level for return cables.

4. The terminated isolated shield / PE conductor shall be accessible for inspections (e.g. for measurements etc.).

The terminated isolated / PE conductor shall be treated as a live conductor.



Figur 8: Earthing and insulation of cables to and between exposed conductive parts within the combined overhead contact line and current collector zone

### 3.1.1 Insulation of earthing conductor og PE conductor for the track return circuit

- a) Cables where the shield / PE conductor is not locally connected to the track return circuit, but guided in tube or by other protection to a more far point for connection to the track return circuit, shall be insulated to avoid electrical contact between the shield and the protection
- b) At crossings between cables and earthing lines of the contact line system or parts in metallic contact with the track, a layer of insulating material shall be provided.

### 3.2 Alternative earthing of cables for equipment in closures insulated for 15 kV

For facilities requiring a polite detection of earth failure in all cables it may be necessary with other principles for earthing than those specified in 3.1. This applies for safety system (track circuits) where safe and polite detection of train and control of signals and switch points. With insulated closures the interpretation is a closure that protects the containing equipment against flash-over from high voltages (15 kV of the contact line system), drop of the contact line or arbitrary contact with high voltage lines.

- a) The use of insulated closure located within the combined overhead contact line and current collector zone facilitates earthing of cables according to Figur 9.
  1. Shield / PE conductor for the incoming and outgoing cables shall be terminated and connected to the earthing bar within the cabinet / closure. Observe that the shield / PE conductor only shall be continued in the end that is most close to the electrotechnical building.
  2. All conductive parts in the cabinet / closure shall be connected to the earthing bar.
  3. The earthing bar in the insulated closure shall be insulated from the environment (other conductive parts and local earth).
  4. The distance to other objects / facility parts shall be a minimum of 2, 5 m.
- b) Cabinets / closures to be used shall be approved by Jernbaneverket.

c) The principles in clause a) may also be used where parallel cable (main cables) is passed by within a cabinet / closure located outside the combined overhead contact line and current collector zone and for cable drop connecting objects within the combined overhead contact line and current collector zone, see Figur 11.

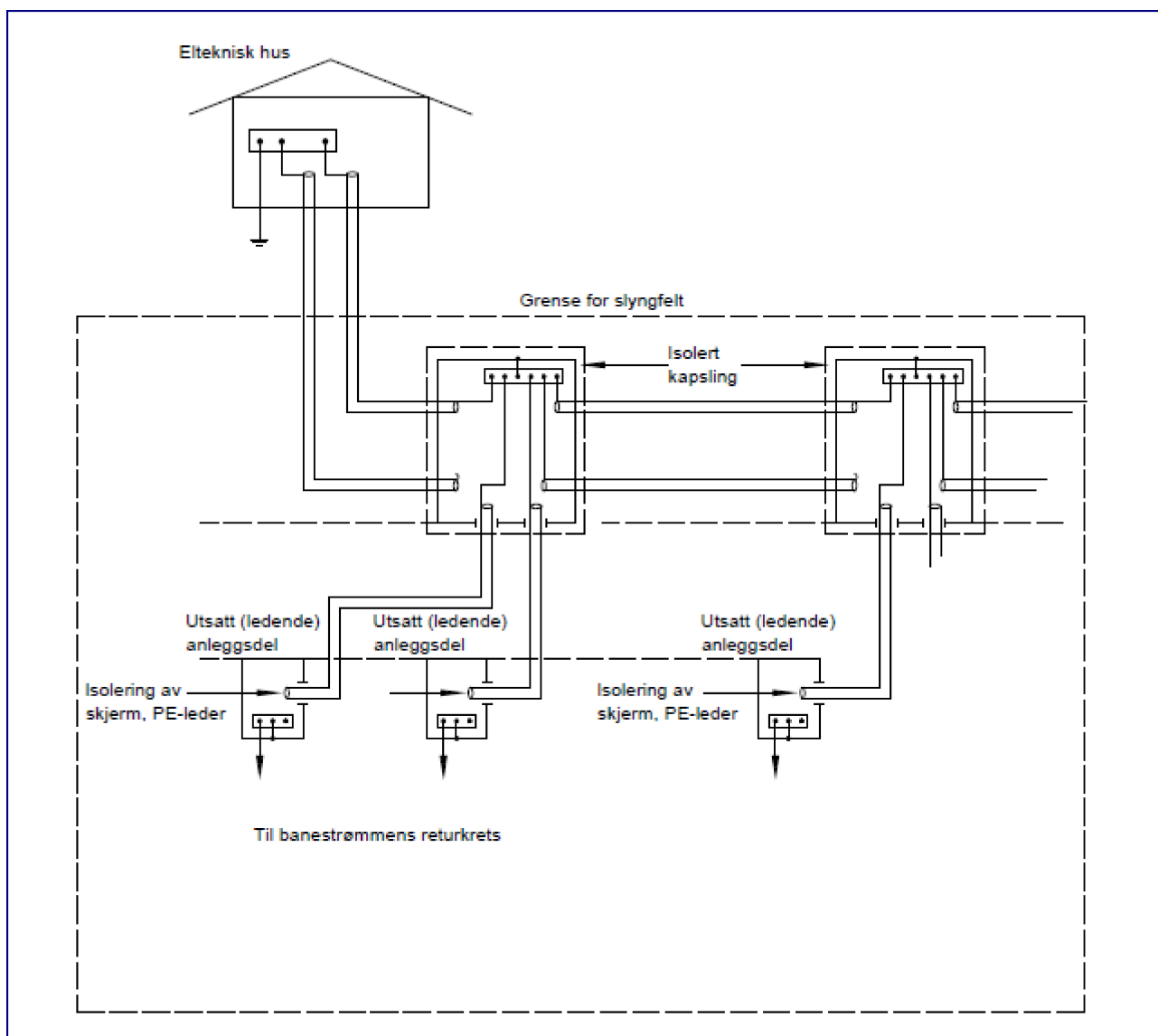
1. Cabinets located outside the combined overhead contact line and current collector zone may be insulated or conductive.
2. The distance to other objects / parts of the facilities within the combined overhead contact line and current collector zone shall be a minimum of 2,5 m.

d) Protection shall be provided against impermissible touch voltages and access voltages between conductive parts within the cabinet for persons maintaining the facilities.

This is particular critical for long cables, typical signal cables.

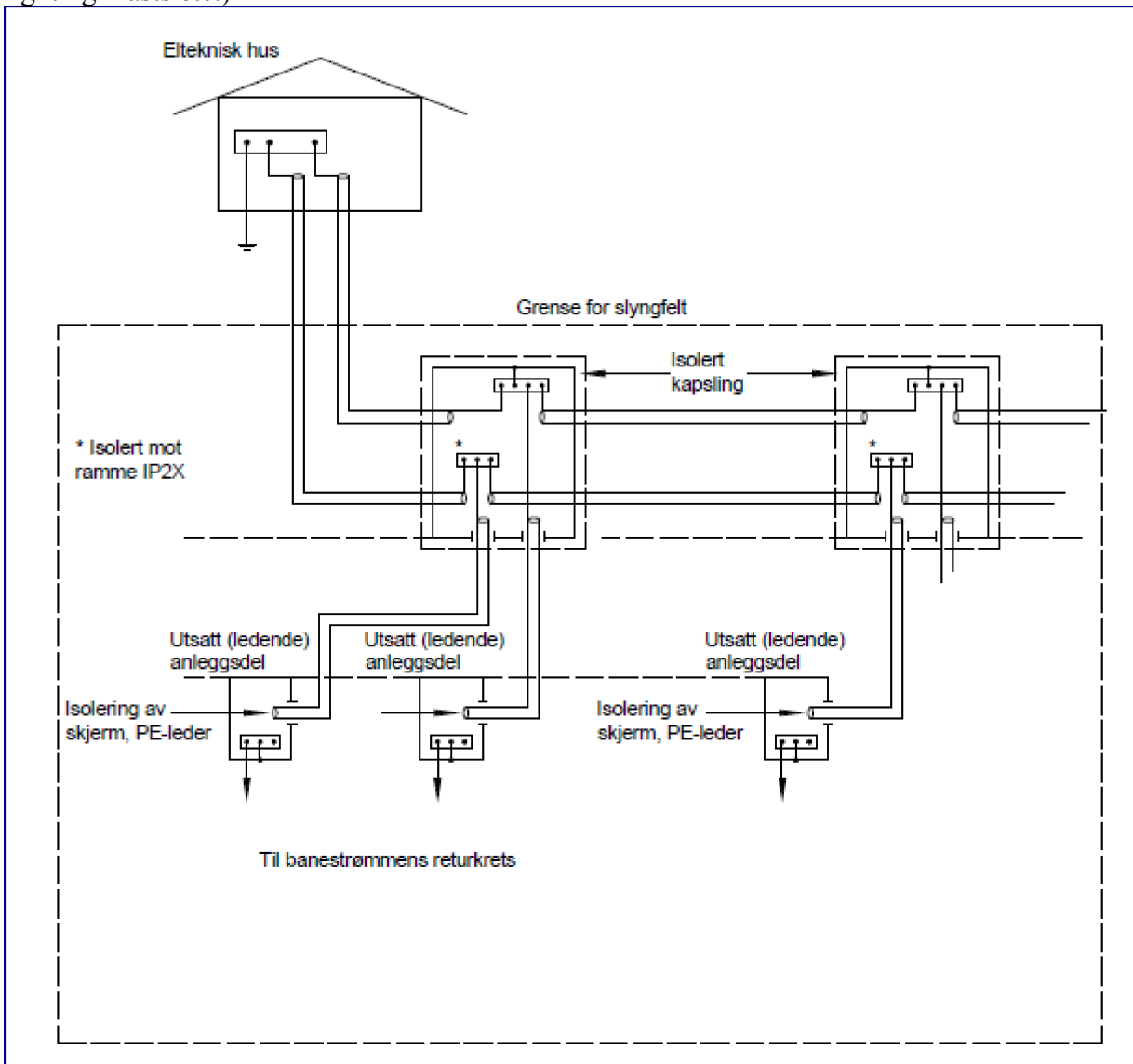
e) Where continuous cable connections between station exist the earth connection shall be interrupted between the stations, see Figur 12.

1. The separation shall be documented in the earthing plan of the facilities, see [Documentation of earthing construction](#).

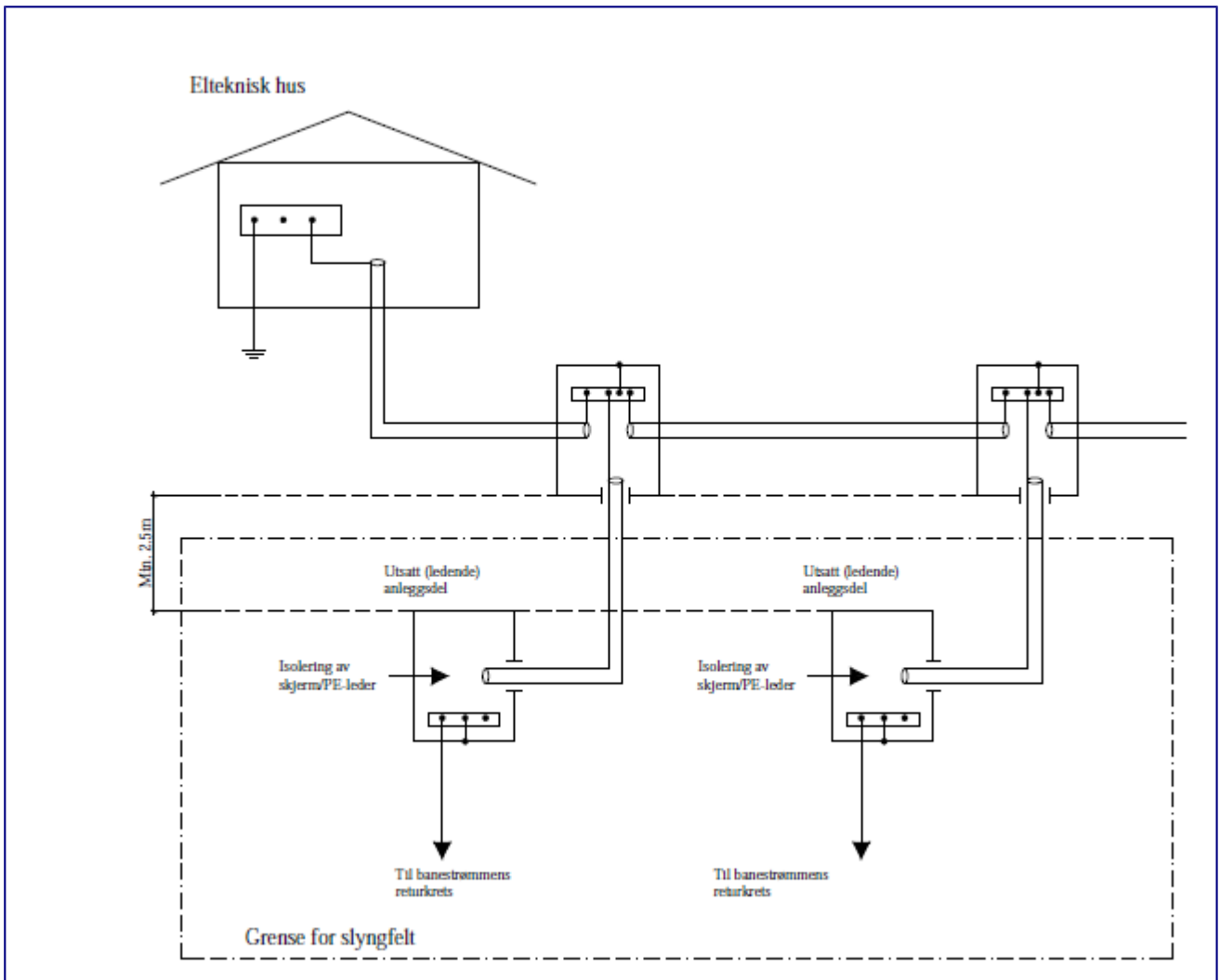


Figur 9: Earthing of cables at the entrance to insulated closures within the combined overhead contact line and current collector zone and exposed conductive parts (signal mast, switch motor,

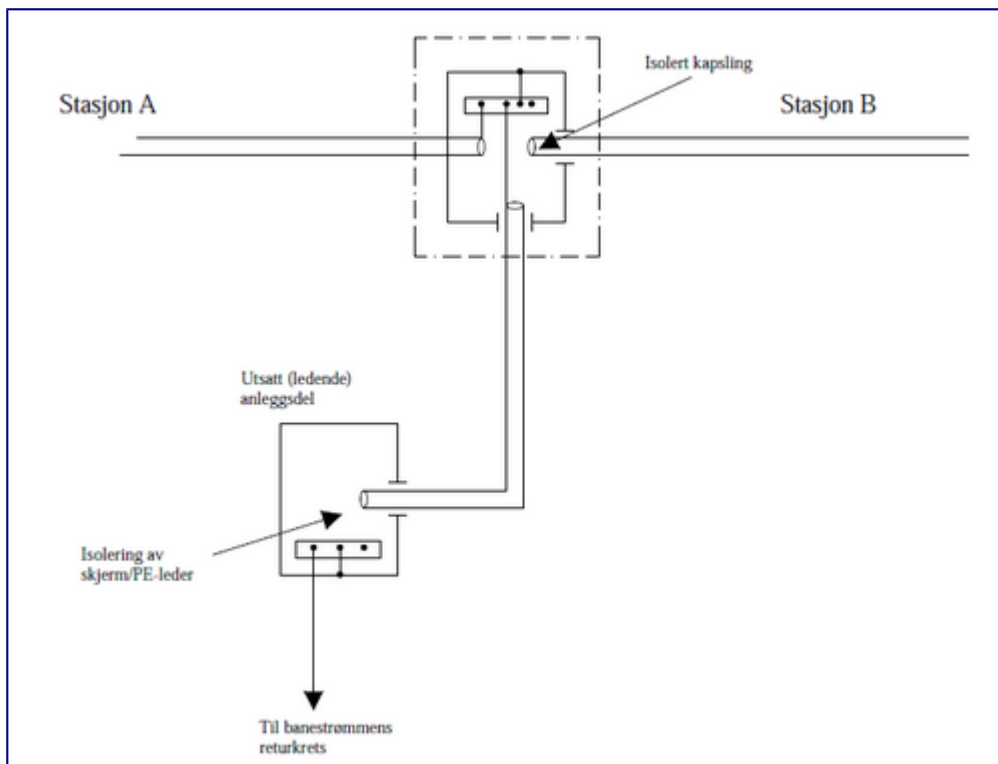
lighting masts etc.)



Figur 10: Alternative earthing of cables at the entrance to insulated closures within the combined overhead contact line and current collector zone and exposed conductive parts (signal mast, switch motor, lighting masts etc.).



Figur 11: Earthing and isolation of cables at and between equipment outside the combined overhead contact line and current collector zone and to exposed conductive parts (signal mast, switch motor, lighting masts etc.) within the combined overhead contact line and current collector zone.



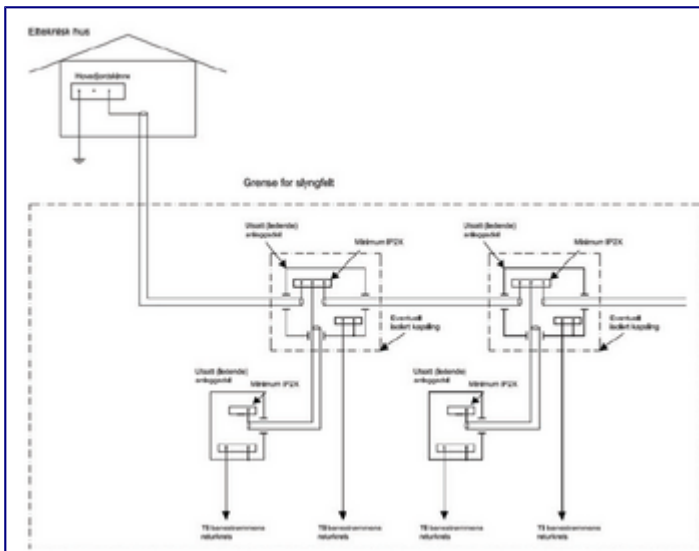
Figur 12: Isolation / interruption of shield / PE conductor between stations.

### 3.3 Alternative earthing of cables for facilities with isolation of continuous PE conductors in cables

For certain installations/systems safe detection of earth faults of connected cables implies that all shields/PE conductors are terminated on the main earthing bar.

- a) At the entrance of cabinets/closures within the combined overhead contact line and current collector zone the shield/PE conductor for ongoing cables requiring internal connection to the facility's main earthing bar shall be terminated on a dedicated bar with a minimum protection of IP2X in all cabinets/objects.
  1. The insulation level shall in minimum be as the insulation level for the cable.
  2. For cabinets/objects with only incoming cable the shield/PE conductor shall be terminated with isolation according to [Main rules for the earthing of cables](#).
  3. Shield/PE conductor in the outgoing cable shall be terminated in the same way as for the incoming cable with electrical continuity.
- b) The terminated isolated shield/PE conductor shall be accessible for inspections (for measurements etc.).
- c) Isolated bar shall be marked in a consistent and secure manner.
- d) The terminated isolated shield/PE conductor shall be treated like a live conductor.
- e) Other exposed conductive part in/on cabinets/closures shall have a connection to the track return circuit.
- f) Cabinet/closure may have insulated or conductive closure.

Figur 13 depicts the principle for earthing for terminated isolated earthing connection of ongoing cables.



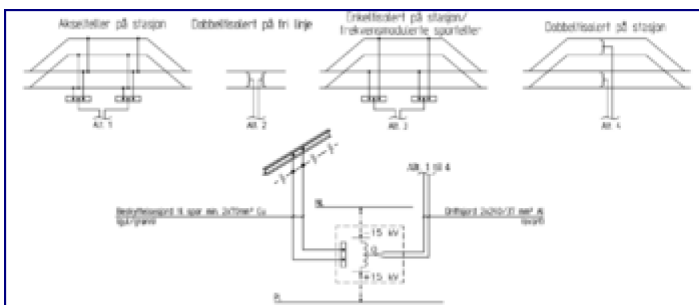
Figur 13: Earthing of cables and equipment in facilities with ongoing terminated isolated shield

### 3.4 Auxiliary transformer and auto-transformer (AT)

a) Auxiliary transformer shall be connected to the track return circuit with dual bonds with a cross-section area according to Tabell 1. For connection diagram refer to [Chapter 8](#) with [Annexes](#).

The figures in annex 8.a are schematic only. Detailed information about cross-section area etc. is not contained.

b) Auto-transformer shall have connection with dual bonds to the track return circuit with a cross-sections area as depicted in Figur 14. Parallel earthing conductor is possible. This figure depicts the principle for earthing and bonding of the auto-transformer for different types of track circuits.

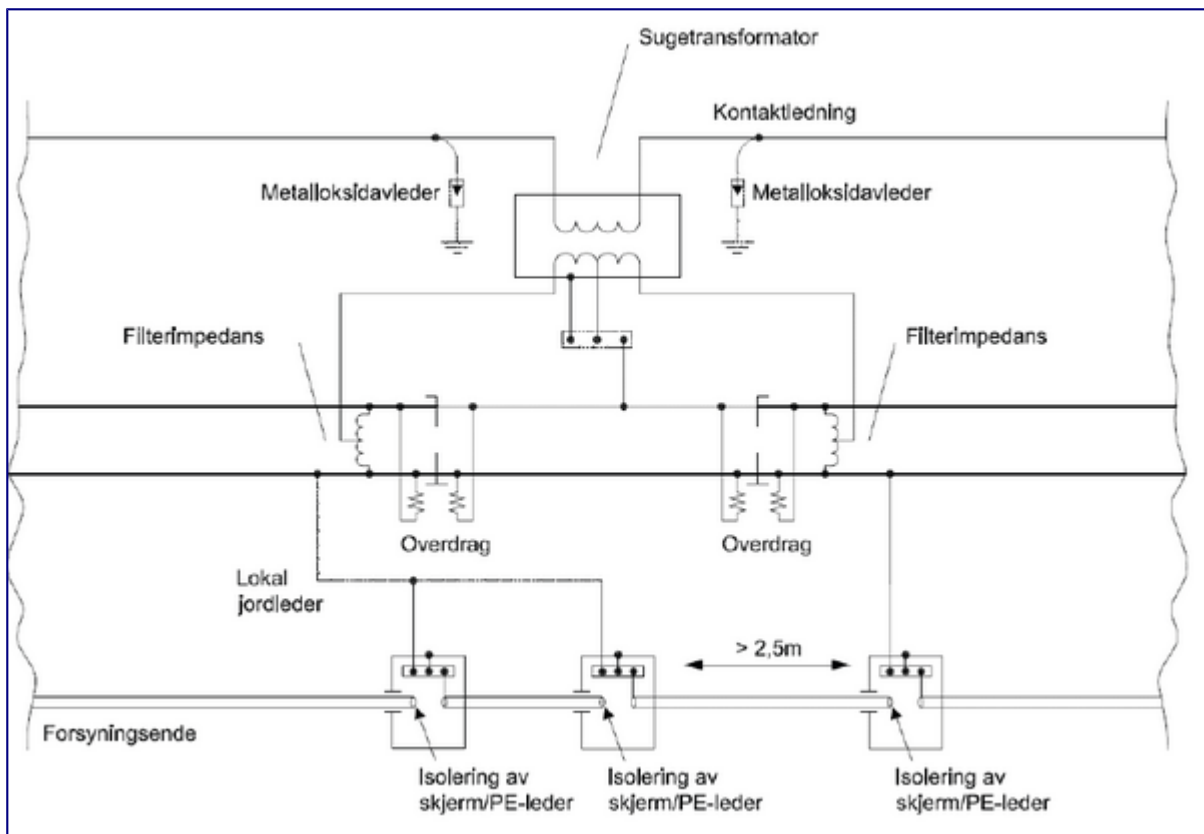


Figur 14: Earthing and bonding of auto-transformer for different types of track circuits

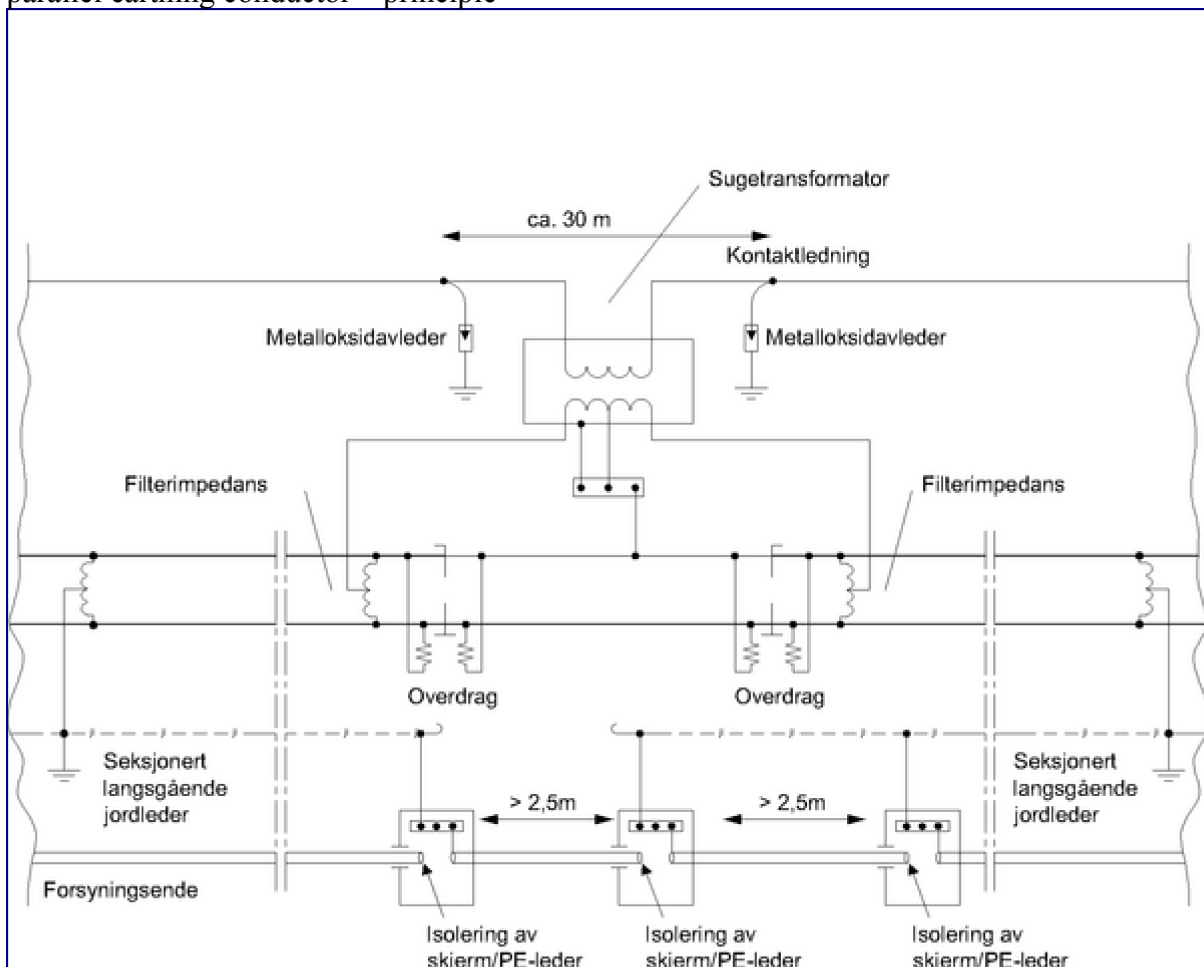
### 3.5 Equipment in the vicinity of booster transformer with neutral section

a) Apparatus and equipment in the vicinity of a booster transformer neutral section shall have a bond to the track return circuit such that the apparatus and equipment within each isolated track section or earthing section are connected to the track at the same point.

1. It shall not be possible at the same time to touch apparatus and equipment of different track sections or earthing sections (minimum distance 2,5 m).
2. Bonds shall not be connected to the reference rail, see [Figur 15](#) and [Figur 16](#).
3. Connection of over-voltage protection as shown in [Figur 15](#), [Figur 16](#) and [Figur 17](#), shall be installed in accordance with [Isolasjonskoordinering og overspenningsbeskyttelse](#).

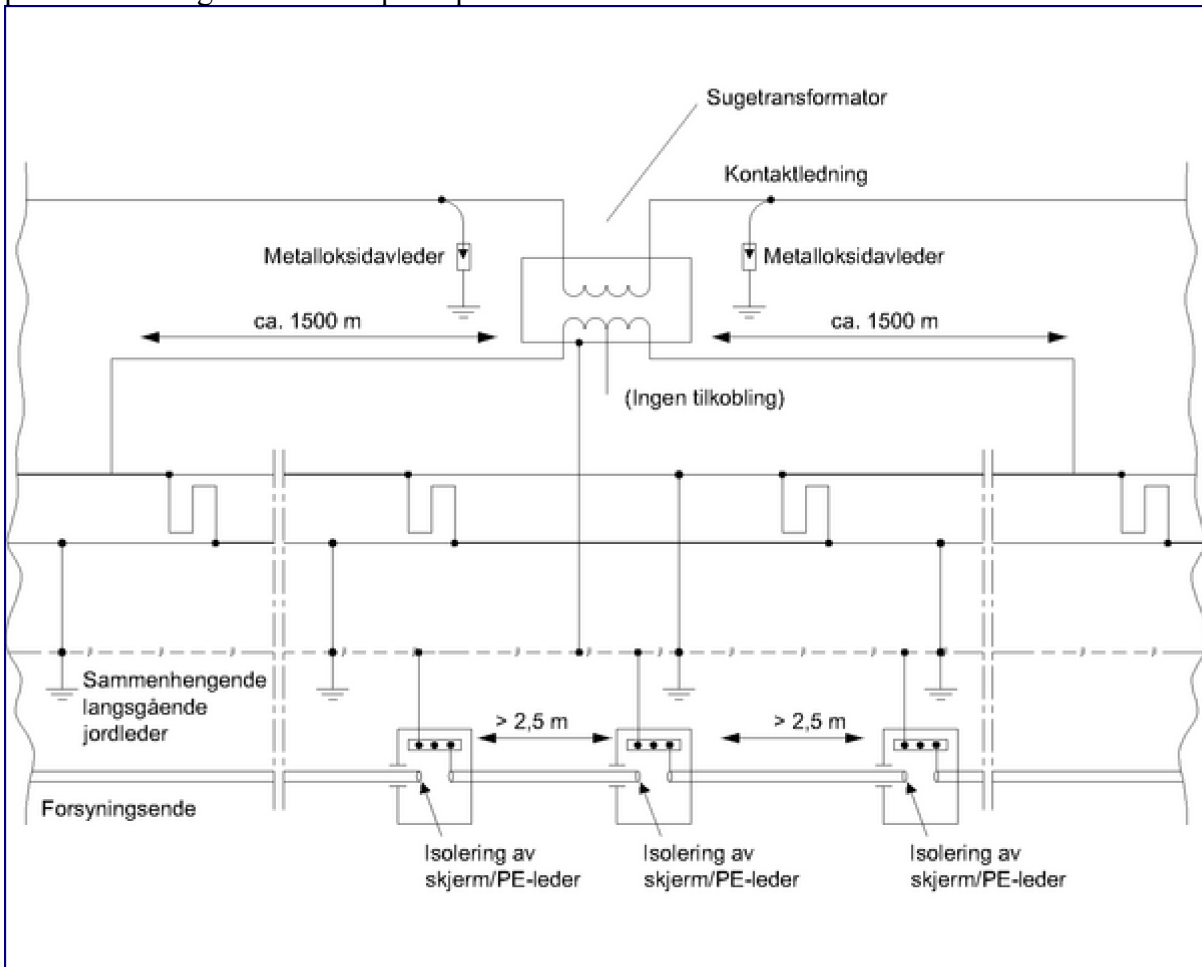


Figur 15: Earthing of facility parts in the vicinity of a booster transformer – installations **without** a parallel earthing conductor – principle





Figur 16: Earthing of facility parts in the vicinity of a booster transformer – installations **with** a parallel earthing conductor – principle



Figur 17: Earthing of facility parts in the vicinity of a booster transformer – installations **with a continuous** parallel earthing conductor – principle

### 3.6 Continuous conductive objects

a) Continuous conductive objects within the combined overhead contact line and current collector zone, e.g. fences, noise barriers, railings etc., shall be connected to the track return circuit.

b) If the continuous conductive objects have a large length they shall be sectioned with insulating barriers, see Figur 18.

1. There shall be two insulating barriers to prevent a person to simultaneously touch beyond both the two barriers.
2. The insulation level shall be minimum 1000 V. The section between the barriers shall not have contact with earth.
3. At doors or gates in fences the fences on both sides of the opening shall be bonded together with a bond with as large cross-section area as for the bond to the track return circuit.

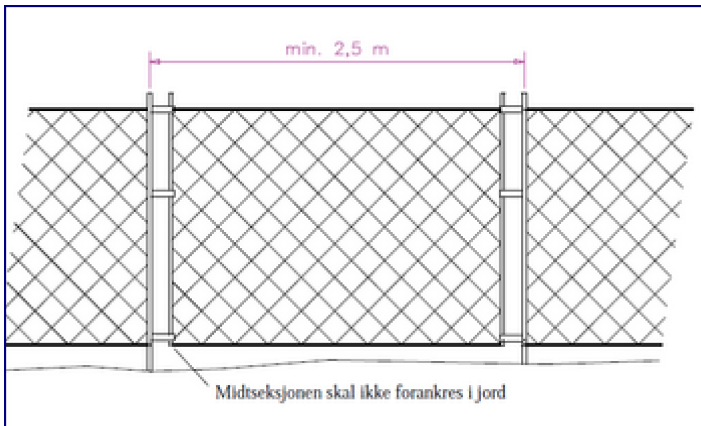
c) In sections without parallel earthing conductor or with continuous parallel earthing conductor the continuous conductive objects shall be sectioned for every 300 m.

Where parallel sectioned earthing conductor is used, these earthing sections shall be coordinated with the sectioning of the continuous conductive object.

d) Where it is not possible to prevent the insulated barriers to make contact with earth – see requirement b) 2 above – the earthing may be performed according to [Large conductive constructions](#).

Such a case may for instance be relevant for objects fixed in concrete constructions, Earthing in accordance with [Large conductive constructions](#) implies that the objects are treated in the same way as the concrete constructions (see “BK” objects in 6.16).

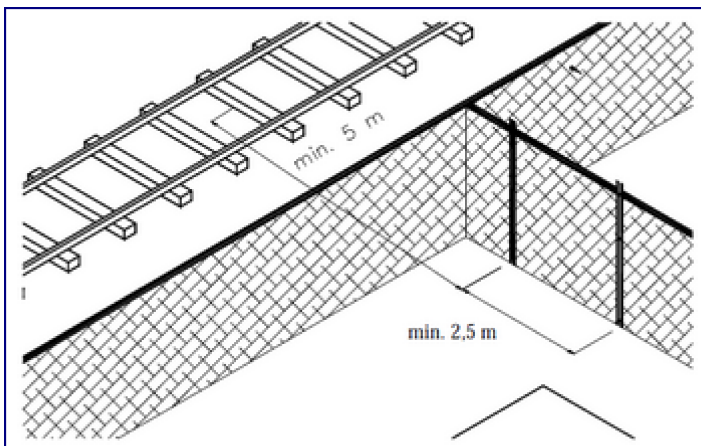
1. Documentation shall show compliance with track circuits and compliance with safe touch voltages.
2. With such a solution the continuous conductive objects shall be sectioned close to where the relevant area ends (e.g. at the end of the concrete construction).



Figur 18: Sectioning of fence

### 3.7 Conductive object leading away from the railway track

- a) If a continuous conductive object leads away from the railway track and is connected to conductive objects parallel to the railway track, the objects shall be sectioned and be isolated.
  1. This sectioning shall be made such that all of the object leading away from the railway track is separated minimum 5 m away from the middle of the track, see [Figur 19](#).



Figur 19: Example of sectioning of fence originating from fence parallel to the track. See [Figur 18](#) for more details

### 3.8 Tunnels and culverts

Compliance with EMC in tunnels request for return conductor and parallel sectioned earthing conductor, see [Chapter 4](#) and [Chapter 5](#).

- a) Parallel earthing conductor shall be contained in cable duct or fixed to the tunnel wall.
- b) All exposed conductive parts in the tunnel shall be bonded to the parallel earthing conductor.

1. The length of the earthing conductors and attachment to the track shall be done as depicted in [Facilities with parallel earthing conductor](#).
- c) A possible reinforcement of concrete constructions in tunnels shall be bonded at every 50 m (approx.). The attachment to the reinforcement shall be done with a permanent mechanical and electrical connection, and shall be accessible for inspection.
1. The reinforcement shall be connected and sectioned in accordance with section length of earthing conductor.
- d) Earth electrodes for each earthing section should fulfil the requirements as depicted in [Earth electrodes](#).
1. If the requirements for resistance against earth can not be fulfilled, it shall be documented that there is no danger for impermissible touch voltages between exposed conductive parts that is simultaneously accessible.
- e) Metallic hand rail in tunnels shall be bonded to the track and be sectioned (refer to clause c) in [Continuous conductive objects](#)).

Earthing may be avoided if all metallic surfaces are substituted by polymers or composites.  
Hand rail may also be combined with emergency lighting.

### **3.9 Telecommunication cables with metallic elements**

- a) For earthing of telecommunication cables (shield/armoured, twisted pair cable with reduction factor) in parallel with the contact line system the requirements shall be in accordance with [Tele/Prosjektering og bygging](#).
- b) If any doubt whether the distance between the earth electrode for the telecommunication cable and the earth electrode for the track return circuit is adequate the position of these earth electrodes shall be coordinated in accordance with [Coordination of the position of the electrodes](#).
- c) At the entrance to the tunnel the telecommunication cable shall have connection to earth with a resistance as low as possible, see [Non-electric railways](#). d) Cabinets and closures for equipment within the tunnel that is connected to the telecommunication cable shall be made with insulated closures, refer to the clause [Alternative earthing of cables for equipment in closures insulated for 15 kV](#), to protect equipment against the contact line voltages and any exposed conductive parts in the neighbourhood.

### **3.10 Large conductive constructions**

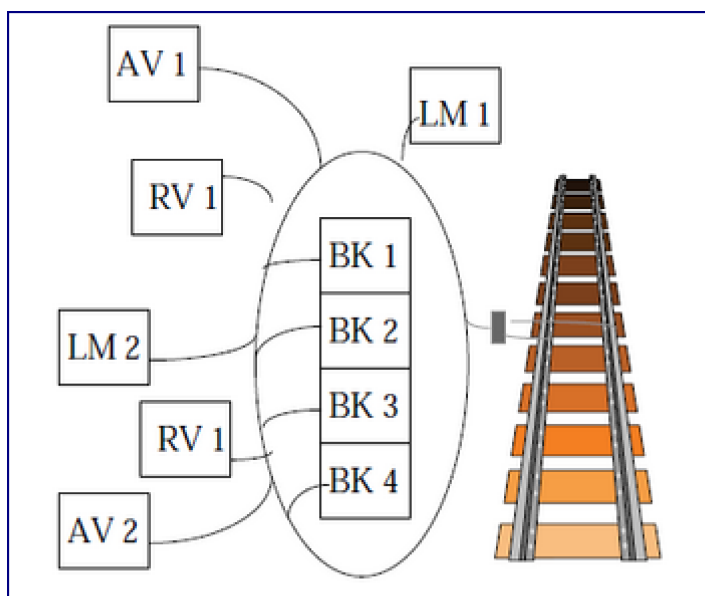
- a) All larger conductive constructions (crossing bridges, culverts or other constructions of concrete) within or partly within the combined overhead contact line and current collector zone shall be bonded to the track return circuit.
1. The reinforcement shall be electrical continuous for the whole construction by welded or by winded iron wire.
  2. Earthing bolts shall be attached for the termination of external copper conductor/parallel earthing conductor and serving for proper electrical connection to the reinforcement. The iron bolts shall be welded to the reinforcement by at least two connections in horizontal and two connections in vertical direction. If the reinforcement consists of two layers, both should be attached.
  3. A continuous copper conductor should be installed round the construction. Any present parallel earthing conductor may be used.
  4. All conductive objects connected to the construction, including reinforcement, is connected

to the copper conductor, see Figur 20.

b) Large conductive constructions that is partly within the combined overhead contact line and current collector zone and also extend far bay on the track area shall be avoided.

1. If such constructions is necessary, an insulating barrier should be included in the construction to avoid leakage of track return current and to prevent touch voltages far off the track. The sectioning shall be performed by two barriers with no possibility to reach over both barriers (more than 2,5 m distance), see clause [Continuous conductive objects](#).

c) The copper conductor is connected to the track return circuit by a parallel earthing conductor – if necessary via an impedances filter – to the rails and dependent of the track circuits used. The connection to the track return circuit should be doubled.



Figur 20: Example of interconnection of conductive objects for a large construction, AV = road barriers, RV = railing, LM = lighting mast, BK = concrete construction  
See also exceptions in [Combined overhead contact line and current collector zone](#).

## 3.11 Bridges

### 3.11.1 Railway bridges (along the track)

a) For all bridges parallel earthing conductor shall be used.

Exception:

Bridges without exposed (conductive) parts attached to the bridge construction.

b) Bridge construction shall be connected to the parallel earthing conductor at approx. every 50 m. The reinforcement shall be interconnected by a copper conductor that is bonded to parallel earthing conductor. The bonding to the track return circuit shall be doubled.

### 3.11.2 Bridges crossing the track

a) Bridges in concrete or steel shall be treated as large conductive constructions, see clause [Large conductive constructions](#).

### 3.12 Conductive objects crossing more tracks

- a) Conductive parts crossing more tracks, e.g. portals, bridges etc., shall only be bonded to the track return circuit at one side of the railway path.
1. The earthing plan shall unambiguously document which side the object is bonded to track return circuit.

### 3.13 Emergency earthing

- a) The installation of emergency earthing is depicted in [\[540\]](#), [Kontaktledningsbrytere](#).

### 3.14 Over-voltage protection

- a) Requirements for earthing installation for over-voltage protection is given in [Chapter 7](#).

### 3.15 Turning plate

- a) Turning plate with electric operation shall have bonding to the track return circuit via “kongestol og kran” (the mechanical drive).
1. All adjacent tracks shall be equipped with cross-bonds and be interconnected if this is in accordance with any present track circuit.
  2. Both rails on the turning plate shall be connected to the main body of the turning plate.

### 3.16 Crane

- a) Crane with fixed foundation close to the track shall have dual bonds to the track return circuit.
- b) Crane on dedicated rails above tracks shall be earthed with bonds from the dedicated rails to the track return circuit.

### 3.17 Tank facility

- a) Tank facility for flammable liquids and gases or freight that can produce combustive dust should not be located within the combined overhead contact line and current collector zone or close to adjacent track that may carry track return current.
- b) Earthing of tank facility shall be installed in accordance with [EN 50122-1].

In addition see recommendations of UIC Fiche 603E.

- c) Tank facilities shall be approved by the Jernbaneverket.

### 3.18 Antenna masts

- a) Antenna masts may function as a lightning rod and shall have a dedicated impulsive electrode to divert the lightning over-voltages.
- b) In addition a separate bond (Cu, yellow/green) shall be installed between the impulse electrode of the mast and the main earth bar in the electrotechnical building. The shield of the (coaxial) cable from the antenna shall be bonded to the mast in one end and the main earth bar in the other. See [Figur 22](#).
1. The bond between the antenna mast and the main earthing bar shall be installed in the same

- path as the cable from the antenna.
2. Exception 1: If the antenna mast is far away from the electrotechnical building there will be no (little) overlap between the impulsive electrode and the the earthing system of the electrotechnical building, the bond connection should be omitted.
  3. Exception 2: If the antenna mast is located within the combined overhead contact line and current collector zone, the bond to the main earthing bar in the electrotechnical building is substituted with a bond from the impulsive electrode of the mast to the track return circuit (or the parallel earthing conductor).
  4. If one of the exceptions above is in force, a filter shall be installed in the coaxial cable (“DC-block”).

The purpose of the DC-block is to prevent galvanic earthing and at the same time allow the transmission of the information signals.

1. For existing facilities: If the cable from the antenna is contained in another path than the bond connection between the antenna mast and the main earthing bar in the electrotechnical building, a filter shall be installed in the coaxial cable (“DC-block”).

The main purpose is to terminate the outer earth potential in the main earthing bar and not directly on other earthing bars within the electrotechnical building.

c) For high antenna masts on exposed locations (mountain top) with pure earthing conditions (more than 60 Ω) an EMP plate should be installed external on the wall of the electrotechnical building and cables from the antenna mast should all pass this plate. The EMP plate shall have an impulse electrode.

### 3.19 Radio system in tunnels

a) For earthing of conventional antenna facility in tunnels refer to clause b) 3 and 4 in [Antenna masts](#).

Singular antennas are regarded similarly as an antenna mast.

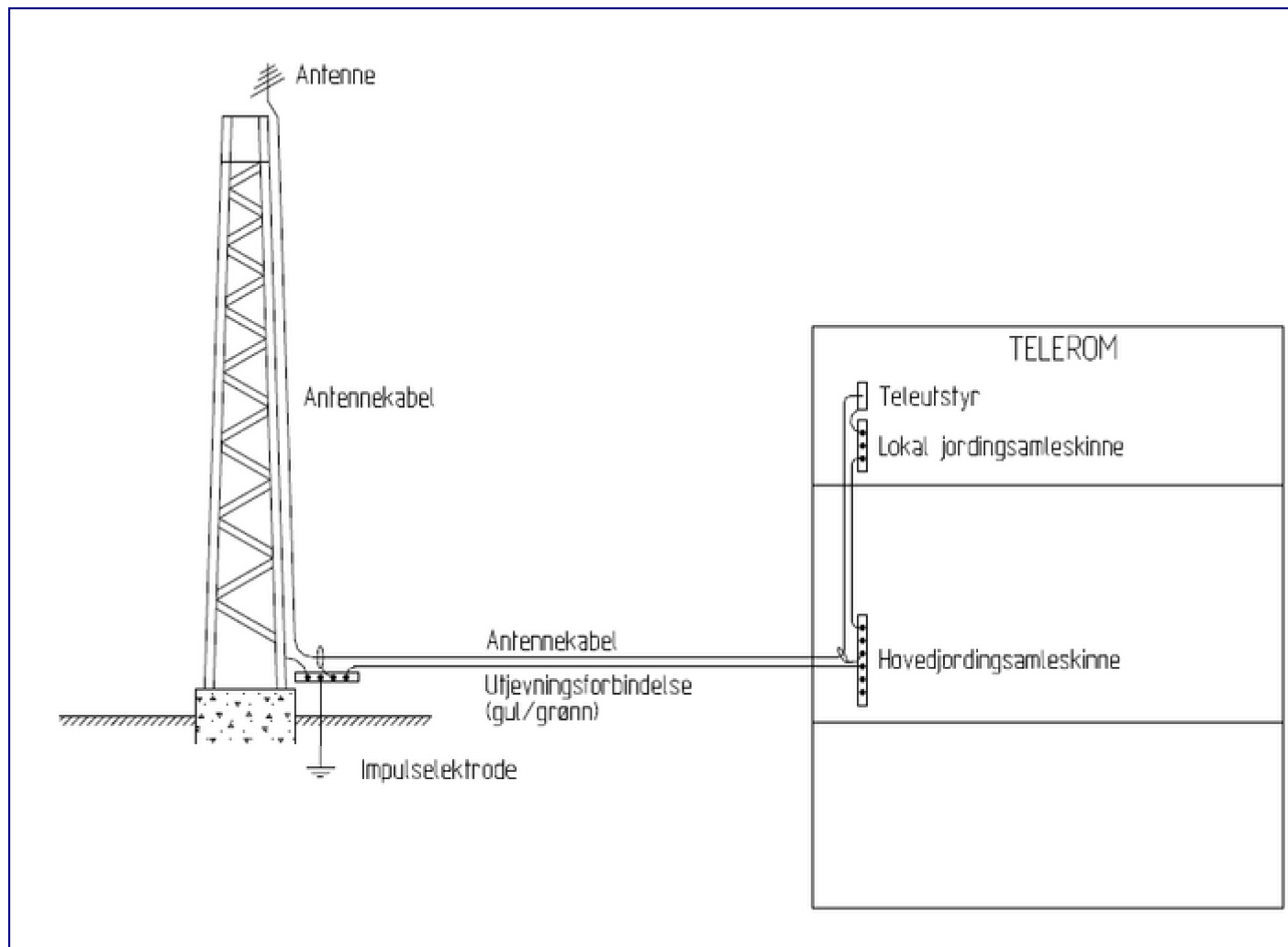
1. If the antenna is installed out of reach in normal operation (with live contact line) and are relevant for the exception in [Combined overhead contact line and current collector zone](#), the requirements in clause b) 4 in [Antenna masts](#) apply for all equipment connected to the antenna – from the DC-block and onwards.

b) Parallel leaky coaxial cable radio applications (GSM etc.) in tunnels shall be earthed (see [Earth electrodes](#) and [Criteria for the use of direct connections to the track](#)) unless the following requirements are fulfilled:

1. The outer sheath of the leaky cable is minimum 2 mm thick.
2. The free end of the leaky cable shall be protected with crimp material that will sustain the voltage of the contact line system (see [Chapter 7](#)).
3. The connection to equipment is supplied with a DC-block (both shield and centre conductor) that will sustain the voltage of the contact line system.
4. If a metallic support is used to fix the leaky cable, there shall be extra insulation between the outer sheath and the support.
5. If a conductive catenary wire – insulated from the leaky cable – is used for support, the catenary wire shall be sectioned, and each section should have a bond to the track return circuit.

If the leaky cable should be bonded at several places, the shield may be a part of the track return circuit and carry large currents.

c) By planning and building new facilities the radio system shall be located outside the combined overhead contact line and current collector zone, see clause a) 5 in [Combined overhead contact line and current collector zone](#).



Figur 21: Earthing of antenna mast

## 4 Facilities outside the combined contact line and current collector zone

a) Earthing of all facilities outside the combined contact line and current collector zone shall fulfil requirements in [FEL] and [FEF].

Electrical low voltage facilities shall normally be performed in accordance with [NEK 400]. This document is not by itself a legal document, but if the low voltage facility does not fulfil [NEK 400] documentation of conformance of the selected solution shall be provided.

b) Earthing conductors and bonds shall not be connected to the running rails.

c) Electrotechnical building shall be located outside the combined contact line and current collector zone, and the earthing system shall be located outside the domain of earth electrodes of other facilities, see clause [Distance between electrodes belonging to different earthing systems](#).

## 4.1 Earthing network in buildings

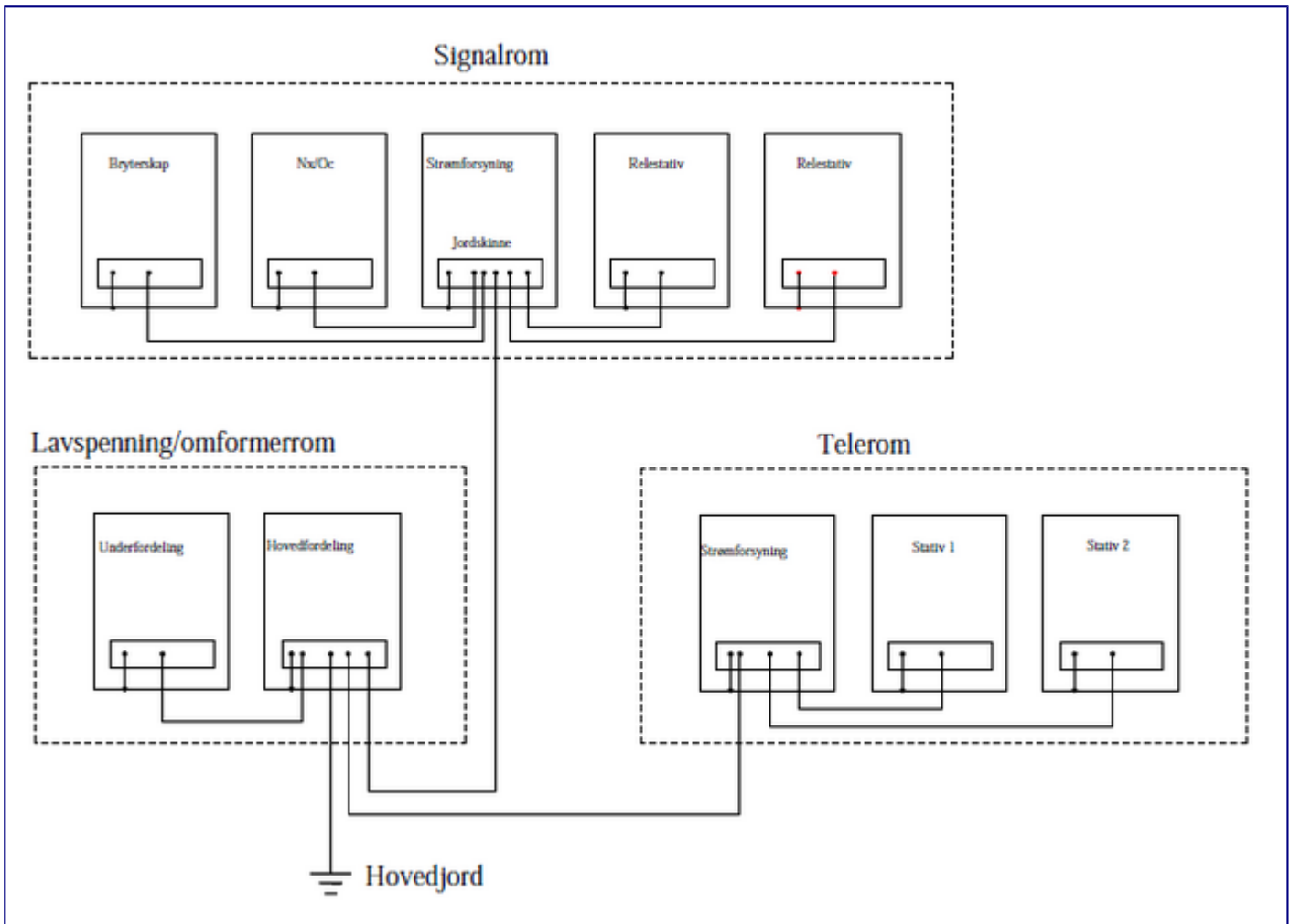
Additional requirements for earthing and bonding internal in telecommunication rooms and for telecommunication installation in [Chapter 9 and clause about Electrotechnical requirements](#).

- a) All buildings shall have a dedicated earth electrode with proper high frequency performance, see clause [Resistance to ideal earth](#) and annex 6.e.
- b) Earthing network in buildings shall have a star configuration, see Figur [23](#).
1. The start configuration shall have its origin in the main earthing bar.
  2. Earthing conductors and bonds shall be short as possible.
  3. All cables should be installed in cable ladders, baskets or ducts.
  4. Metallic cable ladders, baskets or ducts shall have bonds to the earthing system of the building.
  5. Earthing terminals, earthing bars, earthing conductors etc. shall be clearly and permanent marked for inspection.
- c) All cables with metallic elements shall enter the building via one common point of entry and shields shall be connected to the main earthing bar of the building, see also [Chapter 5](#).

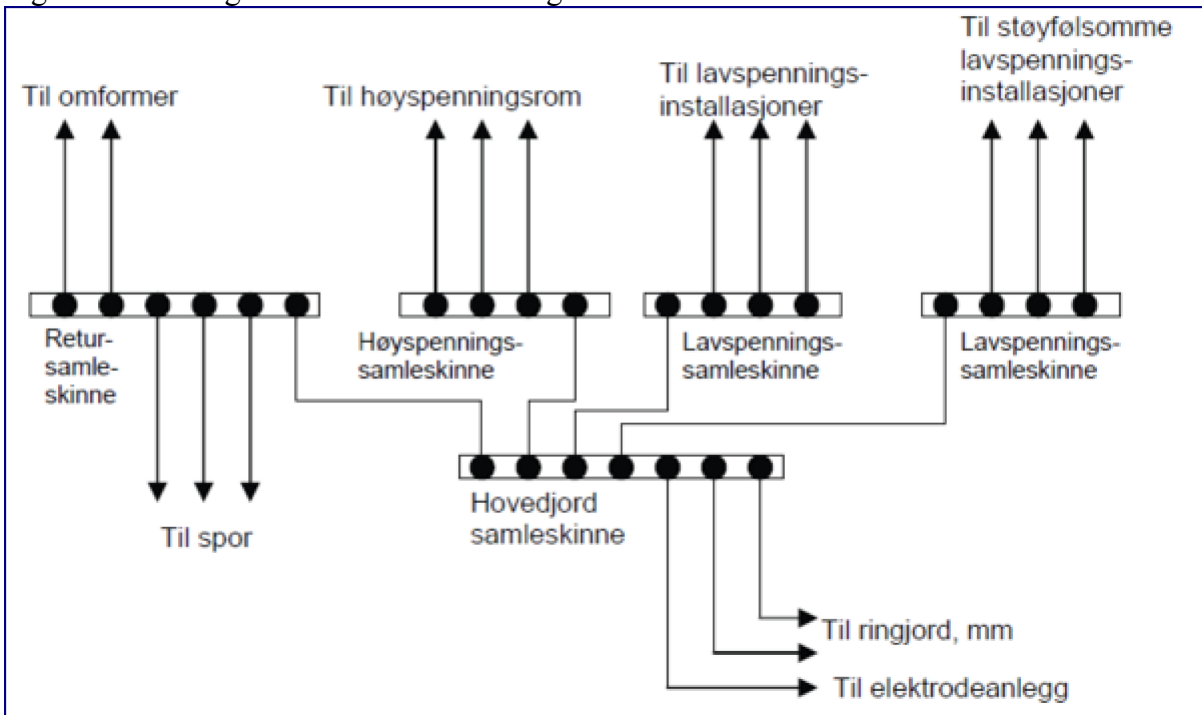
This applies also for cables where the source end is within the combined overhead contact line and current collector zone, see clause 3.1.

- d) Separate installed earthing conductor shall in minimum be  $16 \text{ mm}^2$  where it is exposed without any specific protection against mechanical damage.
1. The cross-section area shall not be less than  $4 \text{ mm}^2$  where the earthing conductor is protected.
  2. Buried earthing conductors shall have a minimum of  $25 \text{ mm}^2$  cross-section area.
- e) In rooms with signal facilities the exposed parts (in cabinets with relays, cable termination), cabinets with protection devices etc. shall be bonded to an earthing bar within the cabinet.
1. These shall in turn be bonded to a central earthing bar, see Figur [23](#).
  2. The earthing bars shall be insulated from the base (the cabinet).
  3. The cabinet shall have a dedicated bond to the earthing bar.
- f) The cabinets shall be electrically separated to facilitate identification of leakages with earthing faults.
- {{lærebookstoff}}It should be possible to disconnect bonds in one frame or cabinet and have the frame or cabinet insulated from the rest of the facility.
- g) Bonds from the earthing bar in rooms for signal and telecommunications to mains distributions shall be minimum  $50 \text{ mm}^2 \text{ Cu}$ .
- h) In addition bonds shall be established to piping for drainage and water and any divert system for lightning.
- i) For large buildings bonds should also connect to the reinforcement in the concrete construction.
- j) For buildings with entrance of the track return circuit of the facility (substations, feeding stations etc.) a dedicated bar shall be provided for the track return current, and it shall have a bond of minimum  $50 \text{ mm}^2 \text{ Cu}$  to the main earthing bar for the building. See Figur [24](#).





Figur 23: Earthing network with star configuration



Figur 24: Earthing concept for buildings where the track return circuit is connected to the facility

## 4.2 Insulation supervision, earth fault alarm

a) Faulty signals from earth fault detectors or insulation supervision shall – if faults are not otherwise detected – be transferred to a maintenance centre, a station or another place with maintenance staff with competence to judge the alarm signals.

## 5 Non-electric railways

a) Earthing of all facilities for non-electric railways shall fulfil the requirements in [FEL] and [FEF].

See also informative text in clause a) in the clause [Facilities outside the combined contact line and current collector zone](#).

b) If a rail is within 2,5 m from a conductive part which have, or are in connection with an electrical power source, a bond shall be established between the conductive part and the rails.

1. The connection to the track shall be performed according to any track circuit present.
2. The connection may be omitted if it is granted that any impermissible touch voltages by hands or feet is eliminated, see [NEK 400-4-41].

c) Installations supplied from an electrotechnical building and located far away, shall have its own earth electrode.

An indication of the words “far away” may be whether the earth electrodes have a common resistance or not.

### 5.1 Earthing network in buildings

a) Earthing network in buildings for non-electrified railways shall be performed as facilities outside the common contact line and current collector zone, see the clause [Earthing network in buildings](#).

Explanation under clause c) in the clause [Facilities outside the combined contact line and current collector zone](#) is omitted.

### 5.2 Insulation supervision / earthing fault detection

a) Insulation supervision / earthing fault detection in buildings for non-electrified railways shall be performed as facilities outside the combined contact line and current collector zone, see clause [Insulation supervision, earth fault alarm](#).

## 6 Earth electrodes

The purpose for the use of earth electrodes in an earthing network is to:

1. divert fault currents to earth to limit impermissible touch voltages by hands or feet to a minimum and within permissible values, refer to [FEL] and [EN 50122-1],
2. divert electromagnetic pulses (lightning pulses) to earth to avoid damage to electrical and electronic equipment,
3. achieve equipotential for the limitation of electromagnetic interference between different electrical systems.

## 6.1 The function and design of the electrode

a) The function and design of the electrode shall be in accordance with requirements in [FEF] and [FEL].

FEF § 4-11 and 5-5 depicts earthing systems. It is written that “railways are excluded from §4-11. With “jernbane (railways)” in this connections is interpreted to the earthing system of the railway which is in common with the track return circuit – in other words within the combined contact line and current collector zone. This is contained in FEF §8-6 and otherwise §4-11 applies. Moreover the most of the guidance to §4-11 may be applied.

b) Connections to earth electrodes should be performed with stranded copper conductors and shall have a minimum cross-section area of 25 mm<sup>2</sup>.

1. Copper applied on steel (kobberweld) should not be used.
2. Connection between copper conductors, earthing rods and main earthing conductor shall be made in a solid corrosion-proof way.
3. Screw connections shall be available for inspections.

c) For ground with rock holes may be drilled. An uninsulated earthing conductor with 25 mm<sup>2</sup> or 50 mm<sup>2</sup> is lowered, and a water solution containing cement and petrol coke (1:3) is added around the earthing conductor. The drilled holes should be 6 m or more.

d) Singular electrodes (earthing rod may be knocked down or earthing conductor may be buried etc.) shall be measured prior to interconnection to an earthing system.

## 6.2 Distance between electrodes belonging to different earthing systems

Examples of “different” earthing systems may be electrodes connected to the track return circuit, the shield of telecommunication cables, main earthing bar in electrotechnical house or external facilities.

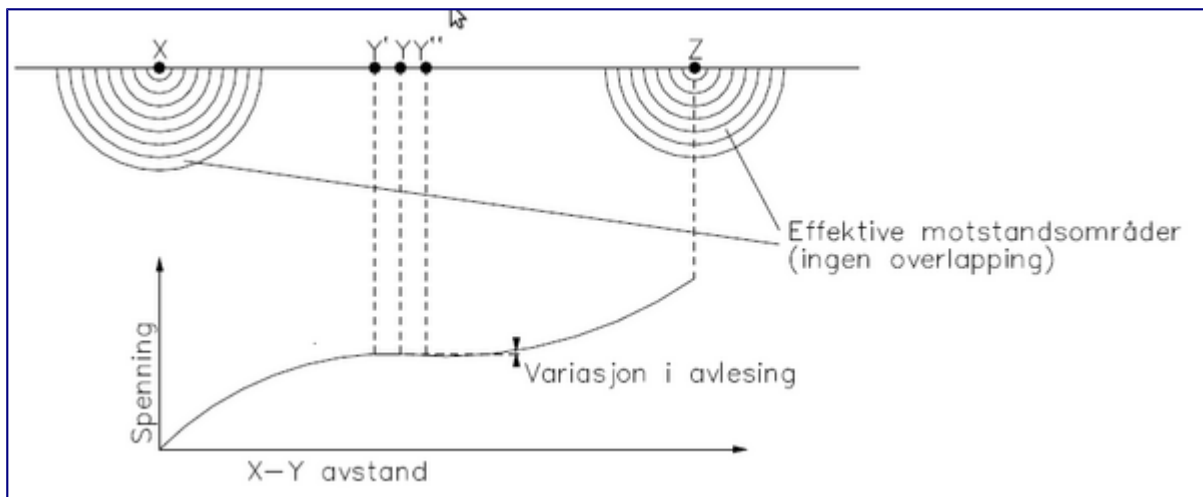
a) The distance between earth electrodes connected to different earthing systems should not have any significant overlapping resistance range, see Figur [25](#).

1. Verifications shall show compliance by measurements or documentation.

Sufficient distance is equivalent with the flat range in the “S” curve depicted in Figur [25](#). Due to the great differences of seasons and inhomogeneity of the soil the ideal distance is not clearly defined. It is important to gain information of the locations to fix the very distance. The method depicted in annex 6.g gives an indication of the extent of the immediate area of the earth electrode.

b) If it is not practical to separate the two earthing systems, they shall rather be connected by a solid bond, and the earthing system shall be dimensioned and constructed to sustain the relevant currents.

1. The bonds shall be documented in the earthing system documentation.



Figur 25: Effective resistance ranges for the electrodes "X" and "Z"

## 6.3 Installations of earthing electrodes to divert atmospheric over-voltages

a) Electrodes connecting over-voltage protection and lightning protection shall be designed as an impulse electrode with one or more earthing rods or similar, see annex 6.e.

1. The connection between the protection devices and the impulse electrode shall be as short as possible.
2. The path of the connection between the protection devices and the impulse electrode shall be with large radii and without any kink.

The impulse electrode may be used in combination with other earthing systems (ring earth conductor, earthing sheets/bands, earthing rods, foundations etc.).

b) The resistance to earth for each structure supporting the contact line is most important for the over-voltage protecting in the facility, and where possible an earthing rod (3-6 m) should be installed close to the foundations:

1. On distances with parallel earthing conductor
2. On distances with single insulated track circuits
3. On distances without track circuits

This will result in a low wave resistance for the lightning current, and a large part of the current will be diverted to earth at the structure(s) where the flash-over occurred. In facilities with parallel earthing conductor the structures may have very low resistance to earth, and hence a solution with parallel earthing conductor will result in lower stress due to over-voltages in the facilities in many ways. See report EB.800043-000 for more information.

Earthing electrodes to divert atmospheric over-voltages is not relevant within tunnels other than at the ends of the tunnel.

## 6.4 Coordination of the position of the electrodes

a) The main rule is to locate the electrodes close to the facility to be connected.

1. Exception 1: If the soil resistivity is far better at some distance (5-25 m), the electrodes should be installed at this place.
2. Exception 2: If it is necessary to increase the distance between electrodes belonging to two different earthing systems, the distance should be increased, see clause [Distance between](#)

[electrodes belonging to different earthing systems.](#)

b) Impulse electrodes or similar shall always be in the very vicinity of the over-voltage protection device to be served, refer to the clause [Installations of earthing electrodes to divert atmospheric over-voltages](#).

To divert high frequency over-voltages (MHz range) the wave impedance of the conductors – and not the distributed resistance ( $\Omega/m$ ) – becomes important for the impedance to earth.

c) Distributed earth connection of long range telecommunication cables with insulated sheath (METE) is established by electrodes in conjunction with the intermediate splices. See [\[560\]](#).

If such a splice is situated too close to any earth electrode connected to the track return circuit, an electrode shall not be installed in the every vicinity of the splice, but farther off.

This is important to avoid overlap in the common resistance to earth between the track return circuit and the shield of the telecommunication cable. Refer to Figur [25](#).

d) Electrodes connected to the track return circuit should be established within a range of 5 m from the middle of the track, but fairly greater distance may apply if it is essential to reach the soil with significantly lower resistivity.

## 6.5 Resistance to ideal earth

The resistance to earth shall not be as large that impermissible touch voltages are created. FEL recommends isolation of live parts, and there is requirements to the maximal touch voltages, FEF § 4-1, in EN 50122-1 and in HD 637 – independent of the type of facility.

The resistance to ideal earth is strongly dependent on the soil itself. Some rock material have very poor conductivity, and the same is true for ice and frozen soil. Earth electrodes must be installed below the frozen zone to give sufficient functionality.

a) For objects in need of an earth electrode and with bond to the parallel earthing conductor, an earthing rod with a length of 6 m should be adequate.

b) Earth electrode for sectioned parallel earthing conductor:  
An earthing rod with a length of 6 m should be adequate.

c) Earth electrode for earthing of telecommunication cables:  
An earthing rod with a length of 6 m should be adequate.

d) Earth electrode for over-voltage protection and possible bond to a booster transformer, AT transformer and shield of high voltage cables:  
an earthing rod with a length of 6 m should be adequate.

e) Earth electrode for auxiliary transformer (see figures in [Felles elektro/Prosjektering og bygging/Lavspent strømforsyning/Vedlegg - Skisser for oppkobling av reservestrømstransformator](#)) shall have a resistance to earth ( $R$ ) that is sufficient low to protect against impermissible touch voltages if the track return circuit should be intercepted.

$$R = U_b * U / S$$

where  $U_b = 60$  V is the maximum allowed touch voltage (see EN 50122-1)

$U$  is the voltage at the primary side of the auxiliary transformer [kV]

f) Earth electrode for lightning protection system:

A more complex earthing system may be needed, i.e. an earthing rod of minimum 6 m in each corner of the building with the addition of a buried ring earth conductor.

g) Earth electrode for protection of electrotechnical building:

A more complex earthing system may be needed to protect technical equipment from damage.

h) Procedures for measurements and control is contained in annexes 6.g and 6.h.

For electrotechnical building where vital and costly facilities resides an assessment shall be performed to the risk of damage if the resistance to earth is in the range of 40  $\Omega$  to 100  $\Omega$ . The resistance to earth should be as low as possible, but this may arise cost. The requirements to the resistance to earth shall be adapted to the calculated risk, and the important criteria are the fixed value of electronics (safety facilities and similar) and the consequences for the traction of trains (availability of spare material, and anticipated repair time). If the value of the resistance to earth becomes greater than 100  $\Omega$  or the assessment results in a too big risk, the earthing system of the electrotechnical building shall be improved by lowering the resistance to earth.

[Vedlegg e – Kråkefotelektroder](#) gives guidance about construction and possible installations of earth electrodes and earthing systems.

## 7 Documentation

### 7.1 General

a) All documentation elaborated shall be in accordance with Jernbaneverkets formats for drawings, symbols and title bar, see [\[501\]](#), [Generelle bestemmelser](#).

b) After construction of an earthing system measurements and documentation of continuity within all earthing conductors, bonds and connection points shall be performed.

### 7.2 Documentation of earthing construction

#### 7.2.1 Within the combined overhead contact line and current collector zone: Earthing plan for all disciplines

a) All earthing facilities constructed within the combined overhead contact line and current collector zone shall be documented of a plan comprising all disciplines where all exposed conductive parts are contained.

b) The plan of the earthing facility should be elaborated when planning earthing systems and shall at any time be updated by the changes in the facility (i.e. changes of: track insulation, track return circuit, earthing system or the amount of objects).

The plan of earthing should be scaled in length with one division for each 100 m of track, and should in minimum contain:

- The rails (with thick and thin line if an earthing rail or a return rail is defined).
- Switch points /side tracks, road crossings, bridges, booster transformers etc. (located by kilometer markings).
- All earthing conductors and bonds.
- All exposed (conductive) parts in the facility within the combined overhead contact line and current collector zone (structures for the contact line, signal post, cabinets, fences etc.).
- Sectioning of long objects parallel to the track (fences etc.).

d) The plan of the earthing should contain a table listing all exposed conductive parts in the facility

within the combined overhead contact line and current collector zone with location (km location) and the relevant discipline involved.

Examples of earthing plan for all disciplines with table listing are contained in annex 6.b.

## 7.2.2 Outside the combined overhead contact line and current collector zone: Local earthing plans

a) Local earthing facility within electrotechnical buildings, in kiosks and cabinets shall be documented with local plans – in addition to other documentation for the facility.

## 7.3 Documentation of earthing systems

a) Construction of new earthing system and maintenance in existing facility shall be documented by:

- The design of the electrode (shape, materials and possible additives).
- Location of the electrode is marked in a map (see clause [Within the combined overhead contact line and current collector zone: Earthing plan for all disciplines](#)) and a sketch with distances and depths.
- Measured resistance to earth with information about soil, measurement method and climatic situation (sketch and form included).
- Measured distances between different earth electrode systems and probable areas of overlap and non-overlap.

# 8 Control

[548]. [jording](#) contains maintenance procedures for earthing systems and electrodes.

a) The earthing facility shall be checked:

1. Prior to utilisation.
2. By major changes in the facility. See also clause [Refurbishment of electrical installations](#).
3. Every 10th year.
4. Otherwise when needed.

For new facilities and by extensions any new element (earthing rod etc.) shall be documented by measurements.

b) The check shall comprise measurements or calculations of potentials and touch voltages.

1. By measurements the annex G in [EN 50122-1] should apply.

c) The check should comprise measurements of the resistance to earth for the electrodes, see clause [Resistance to ideal earth](#).

1. Check should be performed more often during the first years after construction. The check should be done for different climatic conditions (dry/wet, with or without frozen ground). Further measurements of the earthing systems should be considered due to local conditions and expected duration for the facility.

d) the check shall comprise inspection and if necessary measurements of continuity of the earthing conductors and bonds, see also clause [Felles elektro/Prosjektering og bygging/Jording#Requirements to earthing conductors and bonds](#).

e) See also [FEF] §4-11, § 6-7 and §8-6.

In the prologue of [FEF] for §4-11 and § 6-7 it is announced that “railways” is excluded, however, the text in the paragraphs are universal and should be applied. The guidance to the paragraph may also be applied wherever practical. See also annex 4.d.

## 9 Annexes

[Vedlegg a \(.pdf\) Planlegging av jordingsanlegg](#)

[Vedlegg b \(.dwg\) Eksempel på tverrfaglig jordingsplan](#)

[Vedlegg b \(.dwg\) Eksempel på tverrfaglig jordingsplan](#)

[Vedlegg b \(.pdf\) Eksempel på tverrfaglig jordingsplan](#)

[Vedlegg b \(.pdf\) Eksempel på tverrfaglig jordingsplan](#)

[Vedlegg c \(.pdf\) Beregning av tverrsnitt og lengder for langsgående jordleder](#)

Vedlegg d Retningslinjer for jording av store ledende konstruksjoner — **not valid**

[Vedlegg - Kråkefotelektroder](#)

Vedlegg f Kombinasjoner av jordings-, banereturstrøms- og sporfeltkonsepter — **not published**

[Vedlegg - Prosedyre for måling av overgangsmotstand mot jord](#)

[Vedlegg h \(.pdf\) Rapport fra måling av overgangsmotstand mot jord](#)

[Vedlegg h \(.xlt\) Rapport fra måling av overgangsmotstand mot jord](#)