# HIGH-VOLTAGE INSTALLATIONS

**Guide for work in electromagnetic fields**

Statnett

# Guide

This guide describes how work in Statnett's high-voltage installations is to be planned and performed to ensure compliance with the Norwegian regulations concerning occupational exposure to electromagnetic fields (EMFs).

Both the employer's and the employee's responsibilities are discussed, together with a review of the content and consequences of the regulations.

It does not deal with Statnett's internal organisation in relation to the operationalisation of the regulations.

The target group for this guide is all personnel who work with or plan work on or near Statnett's high-voltage installations. The document is also suitable for contractors working in or near Statnett's high-voltage installations, acting as background information and a supplement to their own instructions and procedures.

Background documents, measurements and other information are available to Statnett employees in the SharePoint area on EMF information.

This guide is largely a translation of the Danish enterprise Energinet's brochure "Høyspændingsanlæg. Vejledning om arbejde i elektriske og magnetiske felter." A big thank you to Energinet for their goodwill in allowing Statnett to produce a version based on their original document.

# Contents

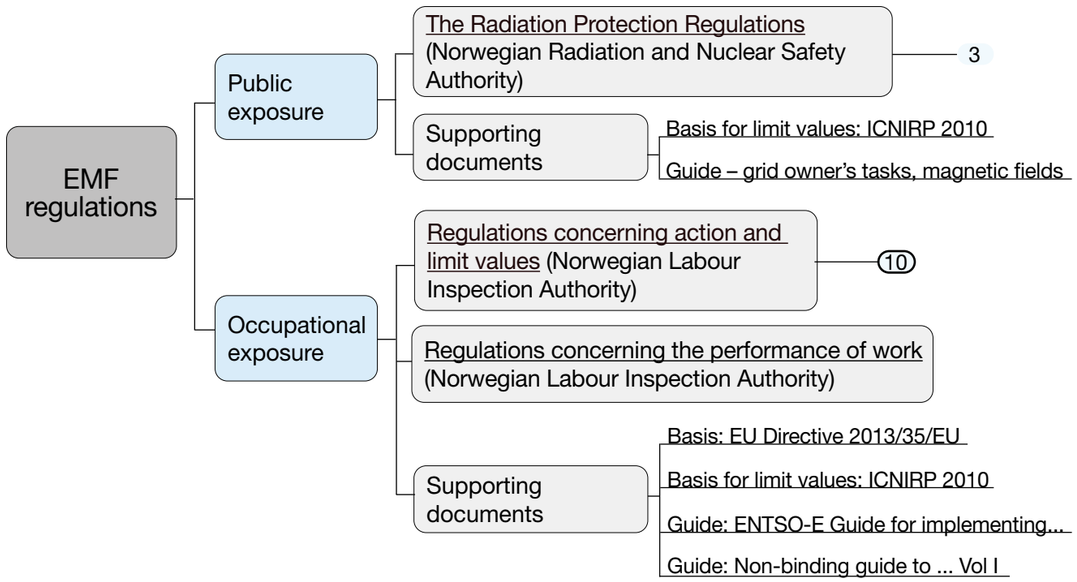
# Background

This guide is based on the Norwegian "Regulations concerning action and limit values" and "Regulations concerning the performance of work".

The "Regulations concerning action and limit values" stipulate action levels that indicate when action must be taken, as well as exposure limit values (ELVs) for health effects from exposure to electromagnetic fields in Norwegian workplaces. The "Regulations concerning the performance of work" describe the employer's responsibility in relation to matters such as risk assessment, surveying, training and providing information, as well as requirements for actions in the event of occupational exposure to EMFs.

The purpose of the regulations is to prevent and protect against sensory and health effects from occupational exposure to electromagnetic fields. This guide discusses the sizes of the electromagnetic fields present around Statnett's high-voltage installations.

***Figure 1:*** *Overview of regulations and supporting documents. See link to original figure for more detailed information (EMF information for Statnett employees in the Sharepoint area)*




The guide contains information on electromagnetic fields when working on Statnett's high-voltage installations, as well as instructions for planning and performing work tasks on or near live high-voltage installations (132–420 kV).

In the vast majority of work situations, the exposure limit values are not exceeded, but in some cases an assessment of the exposure must be made and special measures may need to be implemented. This mainly applies only to electric fields. Magnetic fields will not normally be a problem in Statnett's high-voltage installations.





# Electromagnetic fields: Consequences and measures

## Magnetic fields

Magnetic fields are solely dependent on the current in the field source (power line, transformer, reactor etc.). Exposure to magnetic fields from Statnett's installations will normally be relatively low, and in the vast majority of cases well below the exposure limit value (ELV) for sensory effects. However, there may be some locations, such as below air-core coils and near SVC buildings, where the magnetic fields exceed the ELV for sensory effects.

Personnel may not remain in locations where there is a risk that the exposure limit value for health effects will be exceeded.

## Electric fields

Electric fields are solely dependent on the system voltage of the field source (e.g. 132, 300 or 420 kV). When working at ground level, the exposure will normally be below the exposure limit value for sensory effects.

When working at height near 220 kV, 300 kV or 420 kV installations, the exposure from the electric field may exceed the ELV for sensory effects. Such work is permitted if the limitation of spark discharges and contact currents is addressed, and provided that the effect does not exceed the ELV for health effects. The employer must inform the employee accordingly. Depending on the geometry, electric fields may be significantly amplified or reduced by other electrically conductive and earthed objects in the vicinity of the work location, such as power line towers, foundations, earth wires etc.

## Contact currents and spark discharges

Potential differences can occur between a person and electrically conductive equipment when both are within an electric field. In the event of contact, a current will flow through the person to the object being touched. If the person touches a large object such as a trailer, truck or lift, the contact current may exceed the low action level of 1 mA. Contact currents are most easily avoided by grounding isolated objects like trucks, cranes and lifts, as well as grounding or bonding a person before touching grounded structures like towers, foundations and substation structures. Spark discharges can occur when objects are touched, and should be avoided because they can be painful and may cause consequential accidents.

## Shielding electric fields

When working near high-voltage installations, it may be necessary to establish a barrier or shield – for example, using a Faraday cage to remove or reduce exposure to the electric fields. If the shield is conductive, it must be well earthed.

## Examples of shielding

- Metal screen or barrier with, for example, earthed reinforcement mesh or equivalent
- Work from the inside of machines, such as trucks, excavators etc.
- Work under racks for breakers, support insulators etc.
- Crane and lift arms – these have a shielding effect
- Temporarily installed racks that are higher than the work area
- Conductive workwear

# Sensory and health effects

Spending time in a strong electric and/or magnetic field can affect the body directly and indirectly. Table 1 provides an overview of possible effects related to different types of fields and frequency ranges.

Direct effects occur if an external electric or magnetic field induces a smaller electric field inside the body. If the field is strong, the sensory apparatus can be stimulated so as to induce a sensory effect.

When exposed to even stronger fields, the whole body's muscular and nervous system can be stimulated, which can lead to health effects. On exposure to a low-frequency field, the effect is usually temporary and disappears on moving out of the field.

Indirect effects occur if an object in the electromagnetic field represents a safety risk for the person. For example, spark discharges or contact currents may occur between a person and an object if one of the parts is not adequately earthed. Medical implants inside the body, such as pacemakers, insulin pumps or other active or passive implants, can be disturbed by strong electromagnetic fields.

From the Norwegian Labour Inspection Authority's website, on electromagnetic fields:

"Strong electromagnetic fields in the workplace can cause short-term effects or indirect effects. They have not been documented to have long-term effects, even for pregnant women."

***Table 1:*** *Overview of technical installations and associated fields.*
*"Direct effect" in the "Effect" column refers to exposure to very strong electromagnetic fields.*
*Exposure from Statnett's installations is normally too weak for such effects.*

| Field and frequency range: | Effect: | Examples of activities and installations: |
|---|---|---|
| Static electric and magnetic fields 0–1 Hz | **Indirect effect:**<br>• Attraction of magnetic material. Risk of attracting objects that may hit people. Only relevant in the case of very strong magnetic fields.<br>• Electric shock or burns due to contact current.<br>• Possible effect on active implanted medical devices of magnetic fields above 0.5 mT.<br><br>**Direct effect:**<br>• Dizziness, nausea, metallic taste in the mouth. | HVDC and SVC systems |
| Low frequency range for magnetic and electric fields 1 Hz – 100 kHz | **Indirect effect:**<br>• Disruption of active or passive implantable or body-worn medical devices.<br>• Sparks that can ignite flammable liquids or gases.<br>• Electric shock or contact current.<br><br>**Direct effect:**<br>• Flickering before the eyes.<br>• Stimulation of both the central and peripheral nervous systems, such as a tingling sensation or muscular contractions. | • High-voltage power lines and stations.<br>• Production, transmission and distribution of electricity.<br>• Synchronous compensator systems.<br>• Air-insulated coils. |





# Exposure limit values and action levels

The regulations distinguish between exposure limit values (ELVs) and action levels (ALs). ELVs are electric fields (E) inside the human body caused by an external field. The exposure limit values indicate the levels (rms) at which sensory or health effects may occur. Because fields inside the body cannot be calculated easily, the regulations instead state action levels. These are external field sizes that can relatively easily be measured or calculated. The action levels are derived from the ELVs and have a safety margin in relation to them:

- If the lower action level is complied with, compliance with the exposure limit value for sensory effects is ensured
- If the higher action level is complied with, compliance with the exposure limit value for health effects is ensured

The low AL may be exceeded if the requirements for information and training, as well as the maximum permitted contact current, are met. The high AL should not normally be exceeded, but may be exceeded if the ELV for health effects (E = 0.8 V/m) is complied with.

Detailed field calculations of the human body show that an external field of E = 24 kV/m will give an internal field that complies with the ELV for health effects (E = 0.8 V/m). For hands and forearms, external fields up to E = 50 kV/m may be permitted. The highest electric fields that Statnett employees can work in without protective measures are therefore:

- Maximum permitted external electric field (head and body): E = 24 kV/m
- Maximum permitted external electric field (hands and forearms): E = 50 kV/m

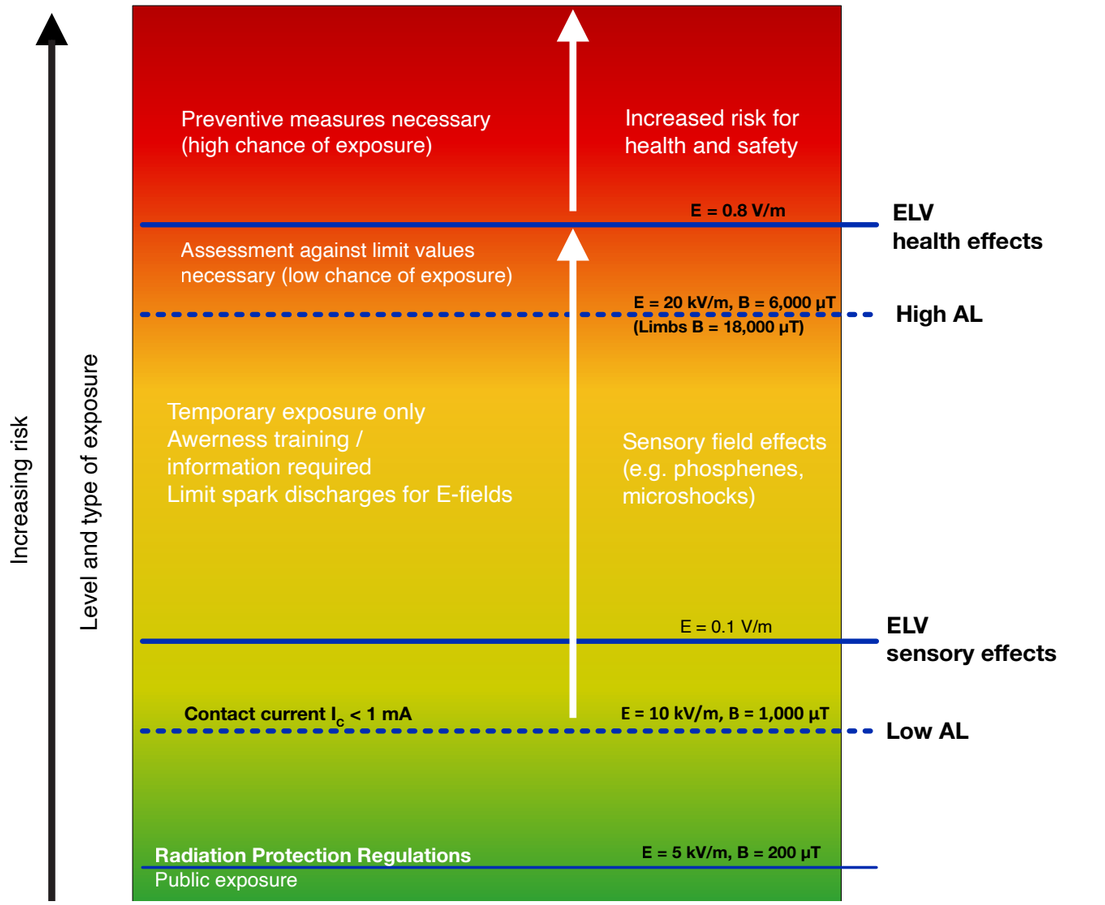



*Illustration of the principle of the relationship between AL and ELV in the regulations. (For the electric field, the relationship is somewhat more complicated than the figure shows for "ELV sensory effects".)*

# Information and training requirements

The employer is obliged to inform employees about risks in connection with exposure to electromagnetic fields. This includes:

- Possible health hazards caused by electromagnetic fields
- Information about transient symptoms and sensations related to effects on the nervous system

Furthermore, the employer must ensure that employees receive training on:

- Working procedures and methods that reduce the risk of exposure
- The correct use of appropriate protective equipment

The low action level (E = 10 kV/m) may be exceeded provided that the requirements for information and training are fulfilled, and that preventive measures have been introduced for spark discharges and contact currents. Contact current (IC) must be limited to less than IC = 1 mA.


# Elimination and limitation of risk

Below are examples of elimination and limitation of the risk of exposure to electromagnetic fields.

- Alternative working methods that result in less exposure to electromagnetic fields.
- Choosing work equipment that creates less intense electromagnetic fields, to the extent that the task allows.
- Technical devices that reduce electromagnetic fields, such as (where applicable) the use of earthing, disconnection, shielding or similar mechanisms that minimise exposure.
- Devices and procedures for the prevention of spark discharges and contact currents by means of technical aids and employee training.
- Suitable plans for the maintenance of work equipment, work locations and workplaces.
- Design and adaptation of work locations and workplaces.
- Limiting exposure time and intensity.
- Access to appropriate personal protective equipment.
- Measures for employees in a high-risk group (workers at particular risk).
- Procedures for reporting unpleasant effects of EMF exposure through the company's nonconformance system.
- Offering medical examinations.





# Workers at particular risk

Employees who are pregnant or have active implanted medical devices, including pacemakers, implanted defibrillators, hearing implants, implanted insulin pumps etc. may be particularly vulnerable to exposure. It is the responsibility of each employee to notify their employer if this applies to them.

The employer is responsible for ensuring that the exposure risk is mapped for the activities the employee is to perform. In this connection, prohibition or restricted access may be introduced for all or parts of Statnett's high-voltage installations.

The employee must also be informed of the risk associated with exposure to electromagnetic fields.

Pregnant women employed by Statnett must not work in field strengths that exceed the public exposure limit values. (See the section "Exposure limit values and action levels".) If necessary, Statnett offers employees alternative work during pregnancy in order to fulfil this provision.

In the case of employees with an active implant, a risk assessment must be performed of the effect of electromagnetic fields on the implant. This assessment must be performed in consultation with a doctor or hospital. If no medical assessment is available, the exposure limit values for public exposure must not be exceeded.

In practice, this means that there will be locations within the station area or in the immediate vicinity of live installations where pregnant women and people with active implants should not be present.

People who are to visit or work in Statnett's installations will be informed of Statnett's procedures for workers at particular risk. This will be done both in job interviews and during safety reviews before they are given access to Statnett's high-voltage installations.


***Table 2:*** *Summary of treatment of particularly vulnerable employees*

| **Health electronics:** | **Type:** | **Limitation:** |
|---|---|---|
| Active medical implants | Pacemakers, defibrillators, hearing implants, implanted insulin pumps etc. | A risk assessment of the effect of EMFs on the implant is performed. The assessment is performed in consultation with medical personnel and for field strengths relevant to the activities the employee is to perform. If no medical assessment is available, the exposure limit values for public exposure must not be exceeded. Risk assessment and medical certificate are documented. |
| Pregnant women | | The exposure limit values for public exposure to electromagnetic fields must not be exceeded. |

# Exposure to multiple types of fields with different frequencies

HVDC and SVC systems contain magnetic fields of multiple frequencies. Typical frequencies in the vicinity of the AC parts in these systems are in the range of 50–1,200 Hz. Although the magnetic fields from these systems contain multiple frequencies, the low action levels for magnetic fields are not exceeded.

The electric fields in the vicinity of HVDC and SVC systems are affected to a very small extent by higher frequency components (overharmonics, switching frequencies etc.). Therefore, frequencies above 50 Hz are not taken into account in the action levels for electric fields.

## Construction projects

In construction projects, the technical solutions must be adapted wherever possible with consideration to exposure to electromagnetic fields, by selection/placement of components, and/or by using barriers or signage.

HSE plans for construction projects must include the following:

- An assessment of the personnel's risk of exposure to electromagnetic fields.
- A plan to reduce the exposure risk where relevant.





# Health problems in connection with work near high-voltage installations

If any personnel experience any of the symptoms described in Table 1 during work in the vicinity of Statnett's high-voltage installations, the work must be terminated and then the incident reported in accordance with the relevant procedures. See also page 9, which deals with workers at particular risk.

## Measurement and calculation of fields

Electric and magnetic fields must be assessed in connection with the planning of the work. If the fields exceed the given ELVs or there is any doubt as to whether they have been exceeded, measures must be taken to reduce the levels and/or further investigations must be made as to whether the ELVs have actually been exceeded.

Measurement of magnetic fields is relatively uncomplicated, while measurement of electric fields requires a higher level of expertise. One of the reasons for this is that the electric field is disturbed by the people and equipment making the measurements. Measurements must be made in accordance with NEK EN 50647 (50413).

This standard stipulates that the relative humidity must be below 70 per cent. Since the instruments are battery-powered, in practice the measurements will be limited to the warmer months due to reduced battery capacity in winter. Within Statnett, there are people from DAX who are qualified to perform EMF measurements.

Calculations can be an alternative to measurements. If a large number of field sources are contributing to the field, extensive 3D modelling is required to determine the field accurately. Therefore, like measurements, calculations can be time-consuming and must be planned well in advance.

# Handling various work situations

## Work at ground level

**Substation:**
The lower action level for electromagnetic fields is not normally exceeded for traffic, lawn mowing and ground-floor inspections in station installations. Near earthed structures, however, the electric field is amplified and the ELV for sensory effects may be exceeded. Activities such as ground work and erecting fences must therefore be organised so as to minimise risk and exposure and to ensure compliance with the high AL.

**Cables:**
Performing ground work near live cables requires organisation similar to that required for ground work in stations.

## Work at height

When working at height, the electric field strength increases because you are closer to the source. In this case also, the ELV for sensory effects may be exceeded in some work situations. Therefore, adaptation is required to minimise risk and exposure.

## Assessment of work tasks in different exposure situations

Table 3 on the next page is for guidance, and can be used to plan and perform work in various situations where there is exposure to electromagnetic fields. The table includes an assessment of whether the requirements of the regulations are complied with in the work situation in question, and whether measures are necessary.

The table also refers to descriptions of how exceeding the exposure limit values is to be handled or has already been handled at Statnett's high-voltage installations.

**The employer must assess the risk of exposure associated with the tasks the employee is to perform.**

Guide for work in electromagnetic fields – IFS no. 3273394

**Table 3:** *Assessment of requirements and measures in different work situations*

| Place of exposure | Assessment | | Measures needed? | | | Comments |
|---|---|---|---|---|---|---|
| | Electric fields | Magnetic fields | Personnel in general | Workers at particular risk [1]) | Contact currents and spark discharges (9) | |
| Busbars, transformers etc. (at ground level) | New substations OK; substations older than 1990 must be assessed | Requirements complied with | None | Workers at particular risk must not be given access | Yes | |
| Air-core coils (at ground level) | Requirements complied with | May exceed the low action level directly beneath the coil ❶ | Limited access, depends on magnetic field | Workers at particular risk must not be given access | No | Depends on the load current in the air-core coil |
| Work above ground level or near uninsulated conductor in station area | Requires further assessment ❸ | Requirements complied with | Depends on assessment | Workers at particular risk must not be given access | Yes | |
| Work outside high-voltage areas | Requirements complied with | Requirements complied with | None | No | No | |
| Insulated conductor (cable) | Requirements complied with | Requirements complied with based on known load currents ❷ | None | Workers at particular risk must not be given access | No | |
| Climbing towers on the opposite side to a live conductor | Requirements complied with | Requirements complied with | None | Workers at particular risk must not be given access | No | Not particularly relevant for Statnett |
| Working on towers near live conductors | May exceed the high action level ❹ | Requirements complied with | Yes (measures against electric fields) | Workers at particular risk must not be given access | Yes | |
| Work next to antenna towers for radio link stations | Addressed by separate note ❺ | Addressed by separate note | Addressed by separate note | Workers at particular risk must not be given access | No | |
| Live working using the bare-hand method | Addressed by separate procedure ❻ | Addressed by separate procedure | Addressed by separate procedure | Workers at particular risk cannot perform live work | Addressed by separate procedure | |
| Live working in towers and substations using the insulation-rod method | Requires further assessment ❼ | Requirements complied with | Depends on assessment | Workers at particular risk cannot perform live work | Yes | No requirements beyond existing regulations |
| Cable tunnels | Requirements complied with | Requires further assessment | None | Workers at particular risk must not be given access | No | |
| Short-duration events (faults, transient connections etc.) | Requirements complied with | Fault situations can produce fields above the action level for short time periods, e.g. for live working using the bare-hand method | Must be assessed | No additional requirements beyond existing regulations | No | |
| HVDC and other static fields | Requirements complied with | Requirements complied with | None | Workers at particular risk must not be given access | No | |
| Guided tours for employees | Requirements complied with | Requirements complied with | None | Workers at particular risk must not be given access | No | |
| Guided tours for private individuals, educational institutions etc. | Requires assessment ❽ | Requires assessment | None | Workers at particular risk must not be given access | No | Guided tours must meet the requirements for public exposure |

= Requirements complied with = Requirements not complied with or require assessment

❶-❾ = Explanation of the points follows on the following pages

1) Other answers possible if medical assessment is available

## ❶ Magnetic fields from air-core coils

When moving around near air-core coils installed as part of incoming overhead lines, at cables or filters, the low action level (B = 1,000 µT) is not normally exceeded. You will therefore not experience sensory disturbances while you are in the area around the coils. Magnetic fields from coils of the type shown in the photo may, in certain load situations, exceed the low action level. It is still possible to cut the grass with a strimmer without exceeding the exposure limit values, but remaining directly under the coil should be avoided. Other air-core coils in HVDC filters, SVC systems and reactor coils are secured in buildings or behind barriers, fences or chains, where access during operation will not normally be possible.

## ❷ Magnetic fields from insulated cables

When moving around in the vicinity of insulated conductors, preferably with cable end sleeves or in cable vaults, the low action level (B = 1,000 µT) may, in some load situations, be exceeded in the immediate vicinity of the cables, especially for 132 kV and 150 kV cables.

Personnel should not touch live cables. However, the currents in cables and lines are so small that no sensory disturbances are caused by the magnetic fields.

**Table 4:** *Magnetic field strengths at different distances from a cable with 1 m between the phases*

| Distance from cable | Magnetic field [µT] at 500 A | Magnetic field [µT] at 1,000 A |
|---|---|---|
| 10 cm | 990 | 1,980 |
| 20 cm | 495 | 990 |
| 30 cm | 318 | 636 |
| 40 cm | 247 | 495 |

## ❸ Work at height

For work tasks performed from a lift or ladder in the vicinity of a live high-voltage installation, such as assembly, repair and/or maintenance tasks related to breaker poles, gas-filling etc., one or more of the following measures may be required to reduce the field before the work starts:

- disconnecting the installation or part(s) of the system closest to the work location
- adapting the work location with a view to increasing the distance to live installations. This may be achieved through the placement of lifts and ladders; setting up barriers around live installations, either in the form of shielding (Faraday cages) on the lift or by electrical shielding, e.g. with wooden barriers fitted with earthed reinforcement mesh insulation plate; or by wearing rubber gloves when performing tasks such as gas-filling breakers, to avoid contact currents
- limiting exposure time, and wearing suitable personal protective equipment such as conductive workwear





As previously mentioned, the lower action level may be exceeded as long as the requirements for information and training, as well as the maximum permitted contact current, are met.

When filling with gas or oil from a ladder, the exposure limit values for sensory effect are not exceeded, even if the hands or parts of the body come close to zones with higher field values when the work is performed.

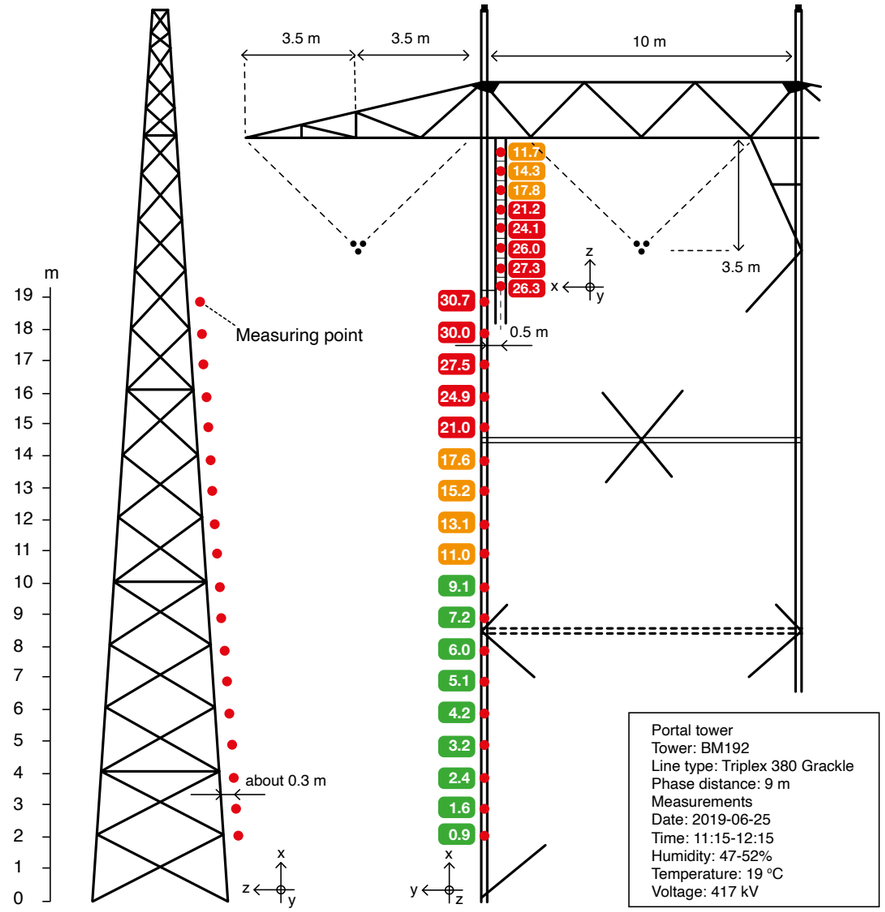
## ❹ Work in or near towers

When climbing towers with live lines, the electric field may exceed both the lower (E = 10 kV/m) and upper (E = 20 kV/m) action levels. The height at which this occurs depends on factors such as the system voltage, type of tower and string configuration.

Above the lower action level, preventive measures must be taken against contact currents and spark discharges. This may be by means of a device that equalises the potential difference between person and tower, such as conductive soles or metal straps between forearm and tower.

If the power line must be live and at the same time the work operation requires personnel to be in the upper part of the tower, conductive workwear is an appropriate measure to reduce the field strength.

An example of measurements of electric fields in a 420 kV portal tower is shown below (measured at a distance of 30 cm from the tower structure).

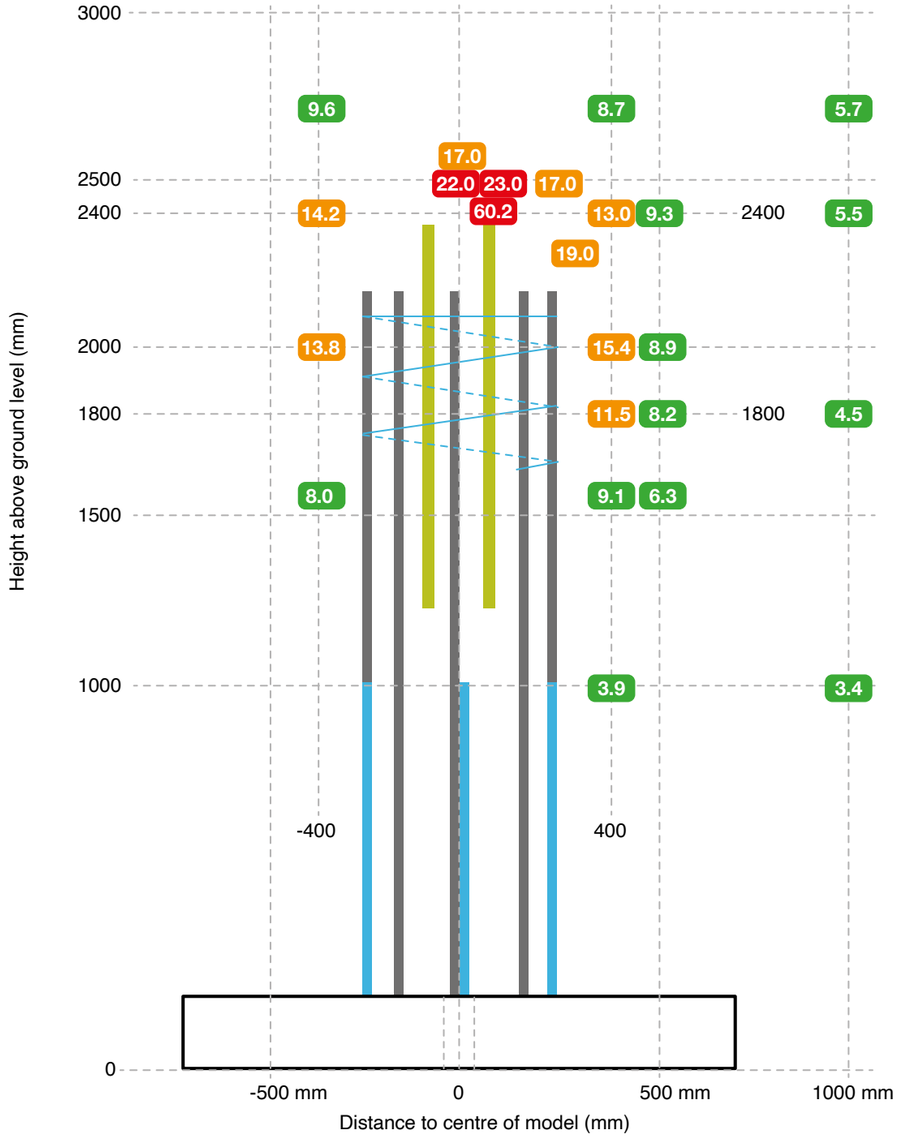



*Measured electric field strength E [kV/m] for a 420 kV portal tower.*

When performing ground work below or near live lines, the electric field may exceed both the lower (E = 10 kV/m) and upper (E = 20 kV/m) action levels.

An example is measurements of electric fields around a foundation just below a 420 kV line in operation. The measurements showed that there was considerable strengthening of the field around the top of the foundation.

Relevant measures may include considering the working position (maintaining a distance to the upper body and head) and various shielding measures, including conductive clothing.




*Measured electric field strength E [kV/m] around a model of a foundation with steel reinforcement and bolts.*





### ❺ Work close to antennas (radio link stations)

Close to antennas in radio link stations, the field strength from the electromagnetic fields may exceed the occupational exposure limit values. Statnett employees must therefore follow the content of the note "Assessment of radiation hazard during the establishment and operation of our radio link systems".

### ❻ Live-working assignments using the bare-hand method or the insulation glove method

For live-working operations using the bare-hand method, within Statnett the EMF regulations are addressed by special live-working procedures (see the document "Exposure to magnetic fields during bare-hand work", last updated December 2018).

### ❼ Live-working tasks using insulated rods (hot sticks)

For live working with insulated rods, the same action and exposure limit values apply to EMFs as for all other work in Statnett's installations.

### ❽ Guided tours of high-voltage substations

For guided tours by private individuals, such as school pupils, family etc., the guideline exposure limit values for public exposure apply. The exposure limit value for the magnetic field is 200 µT, and this may in some cases be exceeded when moving around below the electrical installation. However, this will usually only happen under air-core coils or in the immediate vicinity of cable glands. The exposure limit value for the electric field is 5 kV/m, and this level is often exceeded when moving around near the devices in Statnett's high-voltage installations.

The routes used for guided tours by private individuals must therefore be adapted so that time spent in outdoor installations is minimised.

### ❾ Contact currents and spark discharges

When planning and performing work tasks, contact currents and spark discharges must be taken into account. For example, when filling gas or oil or when working in contact with de-energised busbars or overhead lines in the vicinity of live system components, equalisation and earthing according to Statnett instructions must always be carried out to prevent contact currents and spark discharges. This can be done by means of an electrical equalisation between the metal ladder or lift and the electrically conductive component(s).

Remember that when working on high-voltage installations, you must always check that the system is de-energised and earthing performed according to Statnett instructions. When trucks, excavators, cranes, trailers and other machines are to be used below live cables, an earth connection should be established to them. It may also be necessary to perform equalisation between different metal parts on the vehicle.

**Statnett SF**
Nydalen Allé 33
NO-0484 Oslo, Norway

**T** +47 23 90 30 00
**F** +47 23 90 30 01

**For more information on electromagnetic fields,** please visit Statnett's internal EMF workspace, where you will find background documentation in the form of measurement reports from Statnett installations (substations and power lines), a flow chart for risk assessment, presentations etc.

**Questions and comments** about this guide can be directed to group HSE.

Statnett