GUIDE FOR IMPLEMENTING DIRECTIVE 2013/35/EU ON ELECTROMAGNETIC FIELDS

Implementation of the Directive 2013/35/EU on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (electromagnetic fields)

Asset Implementation 4/13/2016

This document is intended to help the European Transmission System Operators (TSOs)/ ENTSO-E members implement the Directive. The objective is to explain how to assess exposure and to evaluate compliance, and to indicate the most critical situations for transmission activities and formulate possible measures to be taken.

CONTENTS

1 EXECUTIVE SUMMARY

The European Union Directive 2013/35/EU of 26 June 2013 on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (electromagnetic fields [EMF]) has to be transposed by EU Member States by 1 July 2016.

This document is intended to help the European Transmission System Operators (TSOs)/ENTSO-E members implement the Directive. The objective is to explain how to assess exposure and to evaluate compliance, and to indicate the most critical situations for transmission activities and formulate possible measures to be taken.

The Directive requires various administrative arrangements relating to worker information and training, maintaining formal exposure and risk assessments, health surveillance, etc. This report explains how a TSO can implement these with minimum extra work.

TSO exposure situations involve close approach to high voltages and currents, and therefore involve the potential for high exposures to EMFs. This report considers the various TSO exposure situations and either concludes that they are compliant or suggests various methods a TSO could use to bring them into compliance. In most cases, assessment can be by means of relatively straightforward calculations or measurements, but this report also suggests methods appropriate to certain specific, more complicated, exposure situations. In addition to the exposure limits applying to staff in general, extra provisions apply to "workers at particular risk", in particular pregnant staff and staff with active implanted medical devices, e.g., pacemakers, defibrillators etc. TSOs need to implement appropriate measures in respect of these staff, if they do not already do so, and this report suggests what measures are appropriate.

A simple summary table is provided at the end of the report, listing all exposure situations considered, and stating, for each one, whether they are compliant and what actions if any are needed.

2 INTRODUCTION

2.1 OBJECTIVE OF THE REPORT

The European Union Directive 2013/35/EU of 26 June 2013 on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (electromagnetic fields (EMF)) (EU, 2013) has to be transposed by the member states by 1 July 2016. It replaces and repeals Directive 2004/40/EC of 29 April 2004 which never actually took effect.

This document is intended to help the European Transmission System Operators (TSOs)/ENTSO-E members implement the Directive. The objective is to explain how to assess exposure and to evaluate compliance, and to indicate the most critical situations for transmission activities and formulate possible measures to be taken. Some of the material is also relevant to distribution networks, but this Report does not systematically cover distribution operations.

This guide deals specifically with assessment of risks for workers concerning EMF. However, it is vital when assessing these risks and when proposing different measures that other risks do not increase and that the total risk level remains the same or decreases.

The Directive covers frequencies from static (i.e. 0 Hz) to 300 GHz. Within this range, TSOs are most concerned with the power frequency (50 Hz in Europe), harmonics of the power frequency, and static fields (because of HVDC). TSOs also have equipment that operate at radiofrequencies (communications devices), but such equipment is general to any industry and not specific to TSOs, so is not covered in this report. Likewise, TSOs may use welding techniques that involve high exposures, but these are general to any industry and are not covered here.

This Report presents the structure and scientific rationale of the Directive in section 3. It then explains the obligations placed on employers in section 4, then considers the various work activities likely to be undertaken by TSOs and what actions might be necessary under the Directive for each one in section 5.

2.2 BACKGROUND OF THE DIRECTIVE

Directive 2004/40/EC, sometimes also referred to as the "EMF Directive", was published on 24 May 2004 and had to be transposed into national law by 30 April 2008. However, this directive caused quite some commotion, in particular in the medical world, by seriously calling into question the application of certain medical imaging-based procedures, prompting the Commission to ask the European Parliament to repeal the directive. The updating of the scientific basis covering the low frequency range (new ICNIRP guidelines were published in 2010) (ICNIRP, 2010) (ICNIRP, 2009) resulted in the withdrawal of the 2004 Directive and its replacing with Directive 2013/35/EU (hereafter "the Directive") (EU, 2013).

The Directive is mainly focused on prevention and is based on the same principles as the Framework Directive 89/391/EEC on "the introduction of measures to encourage improvements in the safety and health of workers at work", namely the responsibility of employers for their workers' health and safety, for risk analysis, for risk limitation measures, for information and training and so on (EU, 1989).

3 DIRECTIVE 2013/35/EU

3.1 SCOPE

In terms of the frequency range, the Directive concerns electromagnetic fields from 0 to 300 GHz and applies to all occupational sectors. It defines exposure limit values (ELVs) and action levels (ALs) equivalent to, respectively, the Basic Restrictions and Reference Levels of the ICNIRP guidelines (ICNIRP, 2010) (ICNIRP, 2009).

Potential long-term effects are excluded from the scope as there is insufficient scientific evidence in this regard.

Unlike the 2004 directive, but consistently with the updated scientific basis, the new Directive introduces two distinct thresholds for both the exposure limit value and the action level.

The first (lower) level has to do with sensory effects. At low frequencies, these relate to transient problems with sensory perceptions and to minor temporary changes (for the duration of the exposure only) in brain functions. The most sensitive such effect, for magnetic fields, is magnetophosphenes (the appearance of light flashes in the vision). The safety margins included in the limits in the Directive are such that these phenomena should never be experienced during normal TSO work activities. These effects are produced by exposure of the central nervous system (CNS), in other words exposure of the head (brain, retina).

The second (higher) level has to do with health effects. At low frequencies these relate to adverse effects mainly attributable to stimulation of nerve and muscle tissue. The thresholds for these effects are even higher than for sensory effects, and again, they should never be experienced during normal TSO work activities. This mainly affects the peripheral nervous system (PNS), in other words the whole body.

Besides these direct effects, some indirect effects are also covered. "Indirect effects" mean effects caused by the presence of an object in an electromagnetic field, which may be cause of a safety or health risk, such as interference with medical devices/implants, electric shocks and contact currents.

Workers with medical implants, along with pregnant workers, are considered as persons at particular risk and require appropriate precautions and protective measures. This is considered more in detail in section 4.6

The Directive applies solely to occupational exposure. For the protection of the general public, the Council Recommendation 1999/519/EC represents the framework at European level (EU, 1999). According to the Directive, workplaces accessible to general public which meet the reference levels specified in the Recommendation do not require further exposure assessment. Also, workers at particular risk will normally be adequately protected by compliance with the reference levels specified in the Council Recommendation.

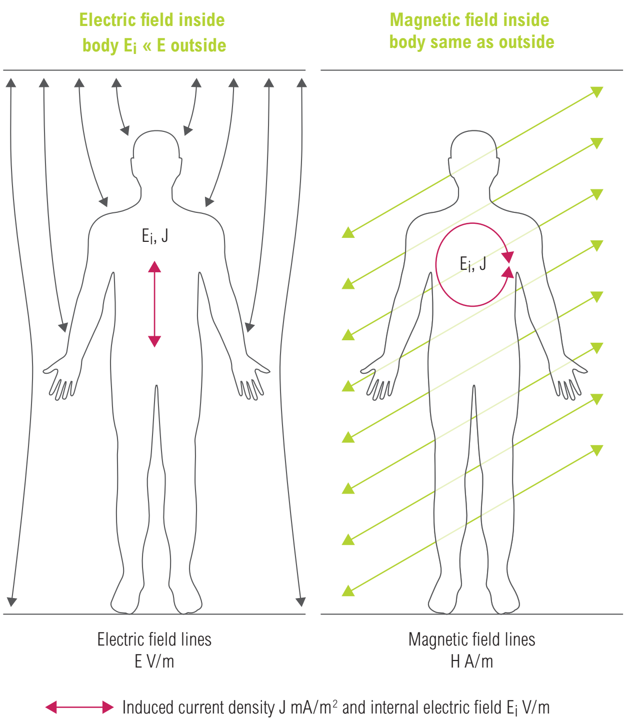
All the requirements in the Directive are deemed minimum requirements that guarantee a sufficiently high level of protection in relation to the considered effects. Member States are given the licence to adopt these requirements at national level or promulgate stricter requirements for the protection of workers.

3.2 EFFECTS OF EXPOSURE TO ELECTRIC AND MAGNETIC FIELDS

3.2.1 DIRECT EFFECTS

The only direct interaction between low-frequency electric and magnetic fields and living tissues takes place through **induced electric quantities (currents and voltages)**. A current that is induced in living tissue is characterised by its density (J, expressed in ampere per square metre A/m²), which corresponds to the current that passes through a unit surface perpendicular to the direction of the current. However, to establish the exposure limit values, the **internal electric field (mV/m)** is used instead of current density as it is considered as the relevant biophysical parameter to characterise the excitation of nerves (ICNIRP, 2010).

The currents and electric fields induced in the body are at their maximum in the case of homogeneous external fields running, for electric fields, parallel to the body, and, for magnetic fields, perpendicular to the body. In other words, all the models that are used to establish the limit values are based on the use of homogeneous fields which are regarded as the most critical exposure situation.



The figures illustrate the induction mechanism for an individual who is exposed to a vertical electric field and to a horizontal magnetic field, such as may occur at ground level under a high-voltage line. In the first case (E-field) a current passes through the body and is then taken away by the ground, in the second case (H-field) the current forms a closed loop in the individual's body.

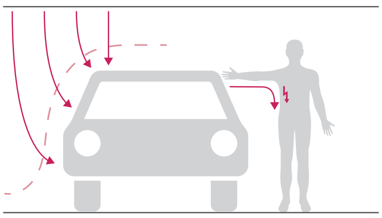
3.2.2 INDIRECT EFFECTS

Indirect effects occur where the presence of an object within an electromagnetic field may cause a safety or health hazard. Examples of indirect effects are interference with worn medical devices (see section 4.6 and Annex A), electric shocks, or burns from contact currents.

Microshocks
When a person and a close conducting object or structure are both exposed to a high electric field, they may be at different potentials depending on their respective sizes, positions in space, and grounding conditions. This can cause spark discharges (also known as microshocks) at the instant when contact is made by a person to a conducting object, if the person and the object are at different potentials. This commonly arises when one out of the person and the object is grounded and the other is not. The peak value of the current during a microshock can be several orders higher than the subsequent continuous contact current, but the duration is very short and the total energy low, comparable to the energy in a static shock when touching a metal object after walking across a synthetic carpet.

This indirect effect of electric fields does not generally have any lasting effect on the body. However, spark discharges can be painful, which in turn creates the risk of a startle reaction (particularly hazardous when working at height). Only exceptionally, if a spark discharge occurs multiple times to the same point of the skin, would damage, e. g. small burns to the skin, occur.

Contact currents
Once the contact is established, the spark discharge is replaced by a continuous contact current. The Directive limits contact currents to 1 mA. This could be exceeded on touching a large ungrounded object such as a vehicle or fence, and steps should be taken to ground all such objects in areas of high electric field.



The typical working situations where contact currents occur are (i) an insulated person (e. g. a worker wearing security shoes) exposed to an electric field and touching a grounded object and (ii) an insulated object (e. g. a vehicle) touched by a grounded person (see figure).

Furthermore, any contact with any lengthy structure that is under the magnetic influence of a live high-voltage line may also result in an electric shock and a contact current. This magnetic induction effect is a well-known safety issue for maintenance tasks of HV lines and it is normally covered by existing safety/security rules. Actions to prevent contact currents and spark discharges are presented in section 4.7.

3.3 EXPOSURE LIMIT VALUES AND ACTION LEVELS

If the occupational exposure conditions comply with the provisions on the limitation of exposure of the general public (1999/519/EU), they will also comply with the action levels set in this Directive and therefore it is not necessary to carry out an assessment.

As mentioned in section 3.1 a distinction is made between sensory (CNS) and health (PNS) effects, and accordingly two levels of exposure limit values (ELVs) are introduced. The first (lower) level applies to the head (CNS) and the second (higher) level applies to whole body (PNS), at power frequency respectively 100 and 800 mV/m. Since the ELVs are internal body quantities (mV/m) which cannot be measured straightforwardly or simply calculated, the Directive introduces action levels (ALs) in term of external field quantities which can be measured or calculated much more easily.

The basic idea is that employers must ensure that they limit any risk to their workers. This is achieved by limiting exposures below the relevant exposure limits, but there is no requirement to reduce exposures further below the exposure limits. For general workers it is sufficient to ensure that the field or contact current levels remain below the ALs (except for workers at particular risk). If the ALs are exceeded, employers must either demonstrate that the ELVs have not been exceeded or take appropriate action to limit the exposures.

	LAL	HAL
Electric field	10 kV/m	20 kV/m
Magnetic field	1,000 µT	6,000 µT (18,000 µT for limbs)
Contact current	1 mA	

Table 1: Overview of action levels at 50 Hz (RMS)

In general, when the ALs are not exceeded, the exposure is deemed to comply with the ELVs and further assessment is not needed. However, the article 3 of the Directive states that, when justified by the practice or process, exposure may exceed the ALs provided that the relevant ELVs are not exceeded. More specifically regarding electric or magnetic field exposure:

For electric fields the Low and High ALs may be exceeded if:

i. spark discharges are limited or measures for limiting spark discharges have been taken;
ii. the contact currents are not excessive;
iii. the workers have been properly informed;
iv. the health effects ELVs are not exceeded [1].

For magnetic fields the Low AL may be exceeded:

a) if the ELV for sensory effects are not exceeded,
b) or if:

i. the sensory effects ELVs are exceeded only temporarily;
ii. appropriate action is taken in the case of transient symptoms;
iii. the workers have been properly informed.

For magnetic fields the High AL may be exceeded if:

i. the above conditions are met
ii. the health effects ELVs are not exceeded

1) In ICNIRP Guidelines from 2010 (ICNIRP, 2010) different spans of conversion factors are given between external electric fields and induced internal electric fields for sensory effects (CNS) and health effects (PNS). The worst case conversion factor for CNS which gives the lowest external electric field yields ~38 kV/m. Hence at the power frequency the level of sensory effects can never be subjected to comparison with Low or High AL. In reasonable cases the level of the external electric field that corresponds to sensory effects is higher than the corresponding field for health effects, therefore are the sensory effects omitted in the text concerning electric fields.

3.4 EXPOSURE LIMIT EQUIVALENT FIELD

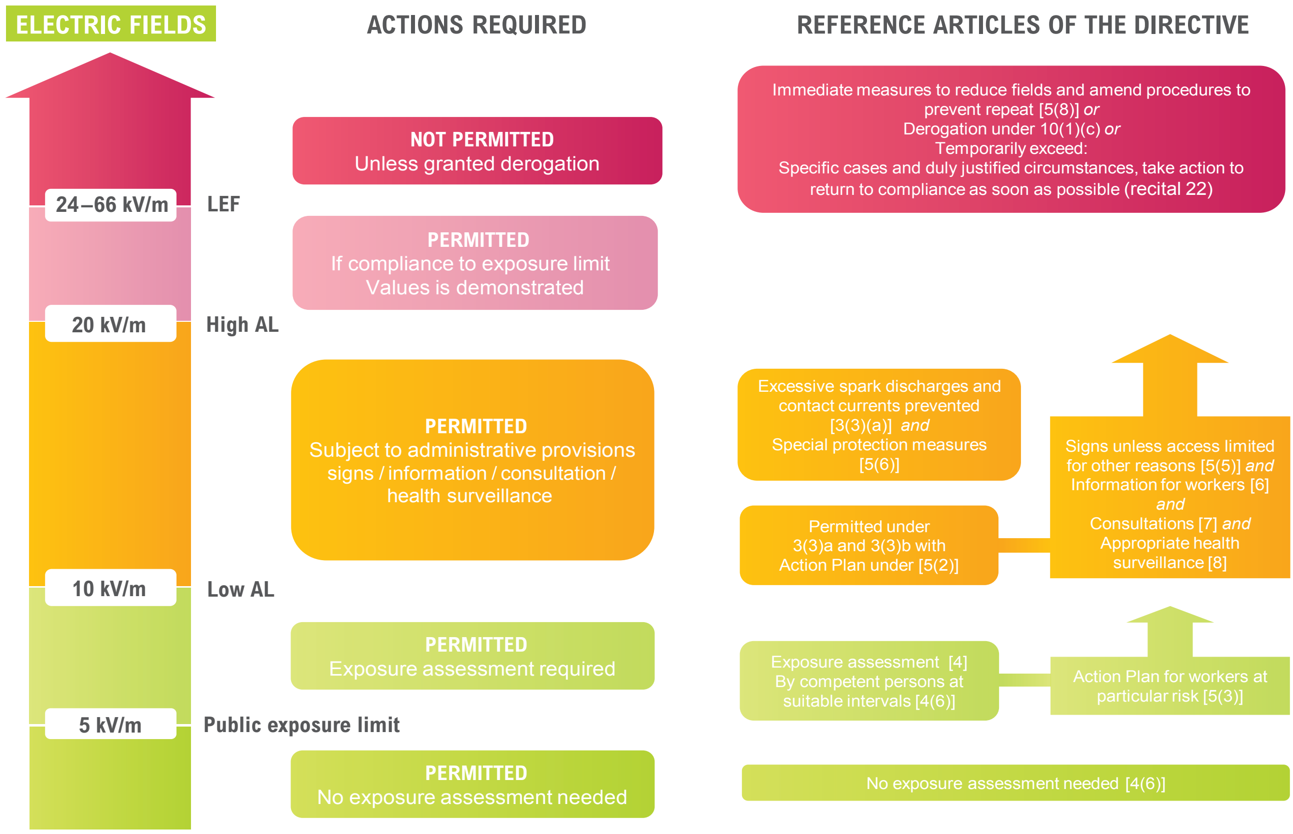
When ALs are exceeded, it is necessary to assess compliance against the ELV. The assessment of the electric field induced inside the body requires the use of dosimetric studies, i. e. sophisticated models of human bodies and electromagnetic computation software. The result of such studies is to establish an equivalence relation between the external field and the induced electric field (or induced current) inside the body. This relation depends on the model, on the orientation and the coupling of the external field to the body.

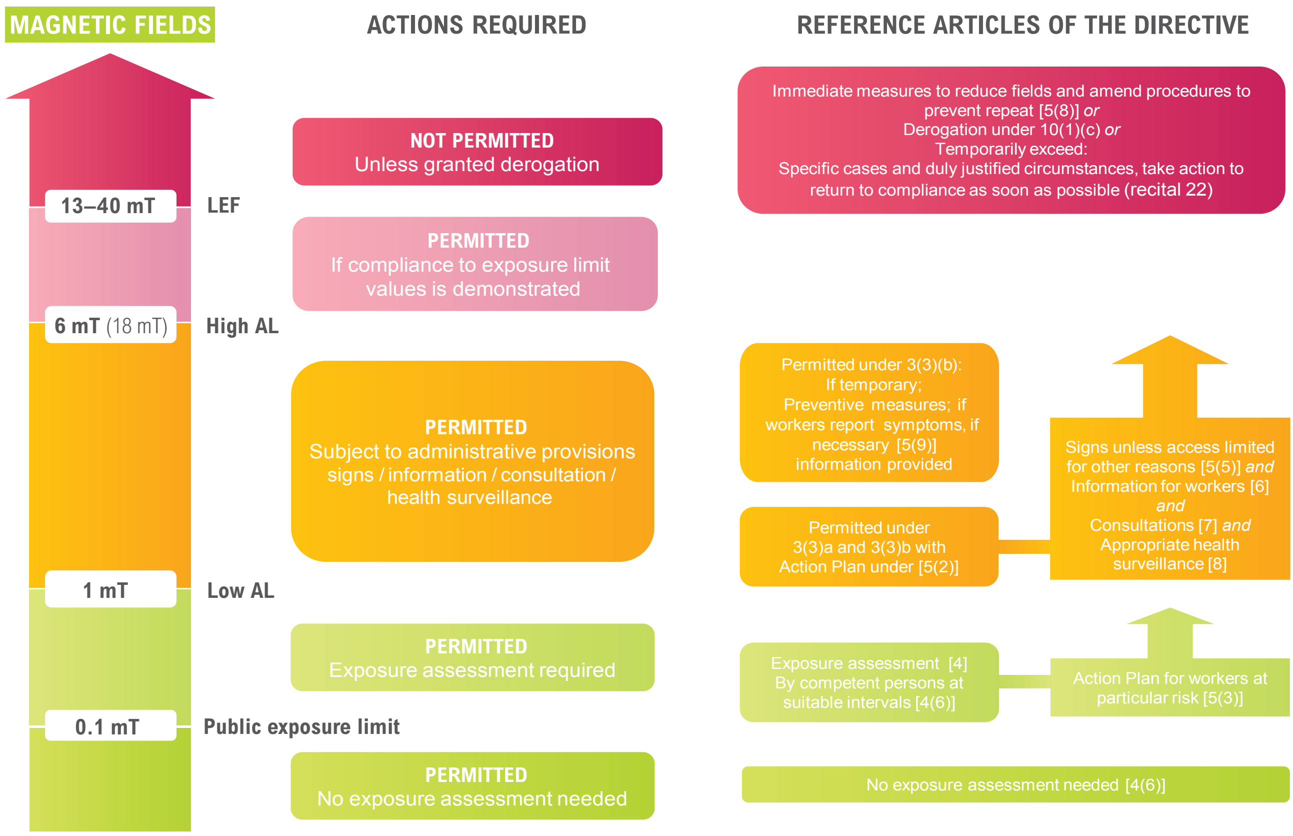
The Exposure-Limit-Equivalent-Field (LEF), as defined in a draft CENELEC standard [2] (CENELEC, 201X), is the lowest homogeneous (i. e. uniform) external field value, derived on the basis of scientific literature, which induces internal electric field values equivalent to the ELVs. Different LEFs can be defined for electric and magnetic fields and regarding the ELVs for sensory or health effects. When this Standard is published, which is expected in 2016, TSOs are recommended to adopt the values of the LEFs given in it, although alternative scientifically based values are equally acceptable. One possible alternative way of deriving the LEFs would be to use the dosimetric values stated by ICNIRP (ICNIRP, 2010), which would result in a LEF for the health ELV of 24–66 kV/m and 13–40 mT. The corresponding LEF for sensory effects based on ICNIRP would be 1–3 mT. The fact that ICNIRP give only a range, not a single value, makes practical use of values derived from ICNIRP difficult, and TSOs are likely to prefer the single values in the CENELEC standard when these become available.

2) Pr EN 50647, dealing with occupational exposures in electrical companies

3.5 OVERVIEW OF THE LIMITS

The following diagrams indicate the Action levels and Exposure-Limit-Equivalent-Fields explained in the previous sections. The diagrams also summarise the actions required at these different levels. These actions are discussed in more detail in section 4.





3.6 LIMITS FOR STATIC FIELDS

	ELVs	ALs
Normal working conditions, sensory effects	2 T	
Localised limb exposure, sensory effects	8 T	
Controlled exposure, health effects	8 T	
Workers with active implanted medical devices		500 µT
Attraction and projectile risk in the fringe field of highfield strength sources (> 100 mT)		3 mT

Table 2: Overview of exposure and action levels for static fields

The preceding discussion relates to exposures at power frequencies. The Directive also gives limits for static fields (note that for static fields, unlike alternating fields, the ELVs are expressed in terms of the external field):

These limits cover both the direct effect of the magnetic field on the body, and also effects caused by motion of the body through a static field.

No limits are given for static electric fields.

4 EMPLOYERS' OBLIGATIONS UNDER THE DIRECTIVE

4.1 ASSESSMENT OF RISKS AND DETERMINATION OF EXPOSURE

Employers are required to "assess and, if necessary, measure or calculate" the levels of electromagnetic fields to which workers are exposed. If they determine that the action levels have been exceeded, they will either evaluate if provisions to reduce exposure under action levels can be taken (ref. 4.2), or, alternatively, they will assess and, if necessary, calculate, the actual exposure levels to check whether the limit values themselves have been exceeded, as described in 3.3 above. The assessment must be carried out by competent services or person. If no action is required, this too should be documented.

When measurements are used either a broadband or a 50-Hz-only measurement should be taken; harmonics should be ignored. Measurements protocols should be according to IEC measurement standards (IEC, 2009) (IEC, 2013) (IEC, 2014). Measurements (for activities at ground level) should be performed 1 m above ground; if other heights are used, the actual height should be recorded. Measurements of electric fields should keep to a minimum distance from metallic structures of 20 cm to avoid proximity effects.

In some circumstances, e. g. for work on towers or above ground in substations, electric field measurements are problematic because the electric field is highly non-uniform. An alternative technique in these situations is to measure contact currents as a proxy for electric field. It is described in Annex B, and its application to work on towers is described in Annex C.

Section 5 of this Guide lists those exposure scenarios that a TSO is likely to need to assess, and indicates what the findings of the assessment are likely to be.

4.2 PROVISIONS AIMED AT AVOIDING OR REDUCING RISKS

When assessment shows that the limit values have been exceeded, employers must take any appropriate measures to reduce the exposure below the permitted levels (e.g. other alternative working methods, measures to reduce the emissions of electromagnetic fields, use of the appropriate personal protection equipment, etc.).

Locations where there is a risk of exceeding the action levels must be appropriately signposted, and access to them must be limited where technically possible; however this is not required if access is already restricted for other reasons, which is always the case at substations and towers, so no signposting should be necessary for TSOs.

Employers must also tailor the measures to the requirements for workers at particular risk. Section 5 of this Guide indicates, for each exposure scenario, what actions, if any, are likely to be necessary.

4.3 WORKER INFORMATION AND TRAINING

Employers must ensure that workers (and their representatives) receive any necessary information and training relating to the outcome of the risk assessment (e.g. plans, limit values, action levels, assessment results, action taken, safe working methods, health surveillance, etc.). Convenient practice is to combine it with the existing safety training. It is important, in any case, that any training should put EMF risks into perspective with other risks in the workplace.

Where staff exceeds the Sensory Effects ELV, there is the theoretical possibility of them experiencing transient symptoms of sensory effects. The effects that would be expected to be the first to be noticed are "phosphenes", a flickering sensation round the periphery of the vision, followed, at even higher fields, by giddiness or nausea. TSOs need to inform workers of these possibilities, and to have a system for workers to report these symptoms if they occur. Note, however, that because of the safety margins included in the exposure limits, these symptoms are very unlikely in practice.

Where there are risks of spark discharges or contact currents, information and training will need to specifically identify these risks. It will be necessary to explain the measures implemented to reduce the risks, particularly where these require action by workers.

Workers should be informed of their responsibility to inform their employer if they have an implanted medical device or if they are pregnant (these are discussed in more detail in 4.6)

Information and training of workers, as well as health surveillance, must be weighted and tailored according to their specific tasks and duties. Measures identified to reduce exposures under specific tasks must be clearly explained.

In case of presence of visitors and external workers in workplaces which don't meet limits for general public, basic information must be provided by an appropriate method (e.g. distributing sheets or verbally).

The provision of information and training should be documented. Contractors and subcontractors should be required to operate equivalent systems for their own staff.

4.4 CONSULTATION AND PARTICIPATION OF WORKERS

Provision must be made for the consultation and participation of workers or of their representatives.

4.5 HEALTH SURVEILLANCE

Long-term or routine surveillance is not required by the Directive.

An appropriate health examination is required when workers report health effects or when the health ELV is exceeded. The Directive also provides for a health examination if the sensory effects ELV is exceeded and transient sensory symptoms are reported. These symptoms are permitted by the Directive, but are unlikely to occur in practice at exposure levels occurring within TSOs.

When a health examination is required, there are no specific signs of over-exposure to look for, so the examination can be general in nature.

In addition to normal national requirements, the Directive requires that the results of health surveillance shall be preserved in a suitable form that allows them to be consulted at a later date, subject to compliance with confidentiality requirements; that individual workers shall, at their request, have access to their own personal health records; that such examinations or surveillance shall be made available during hours chosen by the worker, and that any costs arising shall not be borne by the worker.

4.6 ACTIONS REQUIRED FOR WORKERS AT PARTICULAR RISK

The Directive recognizes a category of "workers at particular risk". These workers may not be adequately protected by the ALs and ELVs that protect staff in general, and TSOs should perform separate assessments where appropriate.

The Directive considers two categories of workers at particular risk: workers with active implanted medical devices (AIMDs), and pregnant workers. Further information on the issues affecting these workers is given in Annex A.

In both cases, the public exposure limits are normally considered to provide adequate protection. So no further assessment is needed for these staff in areas that comply with the public exposure limits, e.g. offices.

For pregnant workers, a simple and sufficient approach is to allow or to require them to be subject to the public limits instead of the occupational limits for the duration of their pregnancy.

For staff with active implanted medical devices, TSOs should take adequate steps to ensure that staff with these devices does not enter areas where there are fields high enough potentially to cause interference. This can be achieved through various combinations of identifying the workers affected and marking the areas, as described in Annex A.

4.7 ACTIONS REQUIRED TO CONTROL CONTACT CURRENTS AND SPARK DISCHARGE

The Directive does not give any quantitative limit regarding transient spark discharges or microshocks, but as they can be painful, it is required to take adequate protective measures to prevent their occurring. For continuous contact currents it gives an Action level of 1 mA. The Directive requires steps to control these indirect effects of electric fields when the LAL (10 kV/m) is exceeded. This is, in practice, comparable to the field level at which workers would often start reporting spark discharges, and therefore at which a TSO would already be taking appropriate measures, separately from the Directive.

Typical steps that a TSO can take to control these indirect effects include:

- Ensuring that workers are well grounded, and thus at the same potential as towers, substation structures, etc, all of which are usually also well grounded. Measures to ground workers include:
  - wearing conducting boots and socks (this is advisable on towers but not in substations as step-potential may raise during faults)
  - use of conducting harnesses for work above ground with suitable grounding straps or clips.
  - If workers cannot be at the same potential as the object they are about to touch, making contact in a way that minimizes pain:
  - by making firm and rapid contact;
  - by making contact with the forearm (or some other less sensitive part of the body) rather than the fingers;
  - by making contact with a metal tool that is itself grasped firmly with the whole area of the hand.
- If neither of those is possible, by screening of the field.
- Ensuring that workers are informed of the origins and consequences of spark discharges, which can increase their acceptance of them by removing the element of the unknown.

5 EXPOSURE SITUATIONS

Here are described the typical exposure situation for a worker in a TSO, distinguished for workplaces and equipment, possible critical point and necessary actions. In addition to the specific actions identified for each exposure situation, all these exposure situations trigger the need for worker information as described in 4.3. Where measurements are required, they should follow the provisions of section 4.1.

5.1 SUBSTATIONS

5.1.1 WORK AT GROUND LEVEL IN HIGH-VOLTAGE AREAS

i. Busbars

Magnetic fields are almost certain to be below the Low AL (and most often below the reference level for the public: 100 μT) except where air-cored reactors are present or where close approach to insulated conductors is possible, both of which are considered separately below.

» **Assessment:** the fields are likely to be so far below the Action level that no further assessment is needed.
» **Action:** No further action should be necessary.

Electric fields in substations below 380/400 kV will be lower than the HAL (20 kV/m) and no further action is necessary. In 400 kV substations electric fields can be as high as 20 kV/m (or even higher at higher voltages). If fields exceed the HAL, assessment shall be done with ELVs, deriving an Exposure Limit Equivalent Field (LEF).

» **Assessment:** measurements should be performed to confirm that the fields are below the HAL or LEF. The highest fields will be found where two adjacent busbars are of the same phase.
» **Action:** Avoidance of excessive microshocks and contact currents is necessary, but existing rules and practices should already address these issues (as detailed above in 4.7). No further action should be necessary.

Electric fields will almost certainly exceed the public levels relevant for workers at particular risk, requiring a separate assessment.

ii. Individual items of equipment (transformers, circuit breakers, current transformers etc)

Both Magnetic and Electric fields: Except where air-cored reactors or air-cored transformers are involved, there is no individual item of equipment in substations that produces any higher fields than the busbars connecting it.

» **Assessment:** no further specific assessment of individual items of equipment is needed beyond the general assessment of the substation.
» **Action:** no action needed.

The controls put in place for workers at particular risk or substations in general will cover transformers, circuit breakers etc.

iii. Air-cored reactors

Magnetic fields: Equipment with large air-cored reactors (Static Var Compensators, Series Capacitor installations, filter coils for HVDC Convertors etc) produce high magnetic fields, which can be capable of exceeding the HAL and the Limit Equivalent Field as well.

» **Assessment:** Fields can be calculated if the geometry and rating of the coils is known. Manufacturers are able to supply these calculations for new installations and requiring this should become standard practice when the Directive will be in force. Calculation results can be presented as contour lines of either the Low and High AL and any other relevant threshold, such as the LEF.
Fields can also be measured, either at the point of highest field or at the closest accessible point. In both cases, the

highest field will normally correspond to the maximum load; at maximum load the waveform is likely to be a reasonably pure 50 Hz sinewave and the harmonics can be ignored, while at lower loads, harmonics cannot be ignored.
Scaling to maximum load measurements taken with harmonics is not trivial and requires expert knowledge.

» **Action:** The layout of such coils varies. Sometimes the coils are mounted above ground on insulators at a height designed only to provide flashover clearance above ground. Approach to these coils will already be restricted for voltage safety reasons. It is likely that the barrier already erected for this purpose will be sufficient to keep staff out of the area where high magnetic fields are found, in which case no further action will be needed.
An alternative design has the ground potential end of the insulators mounted on grounded posts of a height that allows walking up to and underneath the coils. In this case, a barrier may need to be erected purely for the purposes of restricting magnetic fields. If a barrier is needed, it should be clearly distinguished from barriers used for high-voltage safety clearances, so that staff do not confuse. The existing designation of a "hazard zone" may be suitable.

Electric fields: Such coils do not produce any higher electric fields than busbars in substations in general.

» **Assessment:** no further assessment needed.
» **Action:** no further action needed.

Magnetic fields are highly likely to exceed the public levels relevant for workers at particular risk, at distances well beyond the contour calculated for the Action Level or Limit Equivalent Field, requiring a separate assessment.

5.1.2 WORK ABOVE GROUND LEVEL IN HIGH-VOLTAGE AREAS

Magnetic fields: Except for live working at bare hand or for insulated conductors, which are considered separately, high-voltage safety clearance distances will ensure that busbars cannot be approached closely enough to exceed the low AL.

» **Assessment:** the justification comes from calculations as set out for example in the CENELEC Standard.
» **Action:** no action needed.

Electric fields: When working above ground level in substations (e.g. close to switchgear equipment), electric fields significantly higher than HAL can be measured, but these fields are highly non homogeneous and the highest values are linked to the peak effect which can be observed close to metallic structures. Therefore, these high values are deemed to overestimate the actual exposure of workers.

» **Assessment:** When making electric fields measurements it is therefore recommended to keep a minimum distance to the metallic structure (20 cm recommended) and to average the measurements over the workers body. Alternatively, measurements of the total contact current between the worker and the grounded structure can be used as a proxy for electric fields measurements as detailed in Annex B.
» **Action:** Many situations will be found to be compliant, but if these assessments show that the ELVs are exceeded, action to reduce the exposure should be taken, by screening the field or by providing conducting suits for workers.

Fields are highly likely to exceed the public levels relevant for workers at particular risk, requiring a separate assessment.

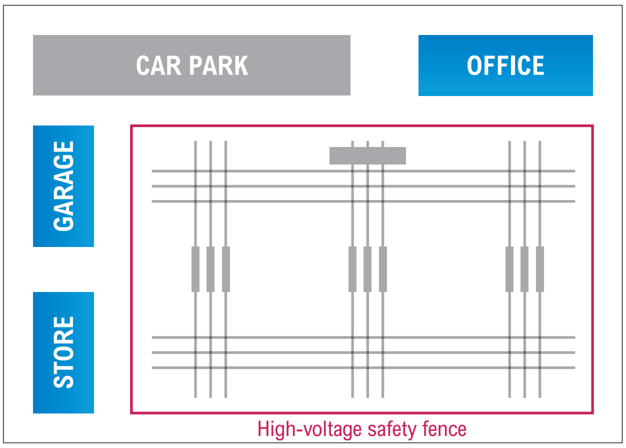
5.1.3 WORK OUTSIDE HIGH-VOLTAGE AREAS

High-voltage substations sometimes have an outer perimeter fence, enclosing car parks, offices, stores, etc. Within this is a separate high-voltage area enclosed by a separate fence with access controls. All high-voltage equipment is within this inner area, and any busbars or lines passing over the outer area are at higher clearance.

This subsection addresses exposures outside the high voltage area but still within substation perimeter.

» Exposures outside the high-voltage area are very unlikely to exceed the Action Levels.

» It is possible for the fields to exceed the public levels relevant for workers at particular risk, requiring a separate assessment. This could happen, for magnetic fields, if an air-cored reactor is located close to the perimeter of the high-voltage area, if underground cables cross an accessible area and, for electric fields, if there are unusually low-clearance conductors or busbars immediately outside the high-voltage area. Site-specific assessments may be needed.



5.2 INSULATED CONDUCTORS

Cable	Current rating	Radius of the cable	Magnetic field at contact	Magnetic field at contact + 1 cm	Magnetic field at contact + 4 cm
90 kV	1,000 A	4,2 cm	4.8 mT	3.8 mT	2.4 mT
220 kV	1,500 A	6,0 cm	5.0 mT	4.3 mT	3.0 mT
400 kV	1,800 A	7,5 cm	4.8 mT	4.2 mT	3.1 mT

Table 3: The magnetic fields generated by typical cables at current rating

Magnetic fields: Insulated cables, for example where an underground circuit enters a substation and leaves the ground, or where transformer tails enter the ground, can carry typically up to 1.8 kA and are typically of outer radius 7.5 cm and can therefore be approached so closely. This potentially gives rise to magnetic fields on their surface of several mT. However, the field falls with distance quite rapidly, approximately with factor of 1/d.

» **Assessment:** Measurements can be performed, but are difficult to interpret, because of the issue of the size of the measuring probe in relation to the distance over which the field falls off. Calculations are preferable. Only the 50 Hz component should be considered; harmonics should be ignored. For the LAL and sensory ELV, it should be assumed that the thickness of the skull and helmet ensure the brain is a minimum of 4 cm from the surface of the cable; for the HAL and health ELV, it should be assumed that the thickness of clothing means the skin is a minimum of 1 cm from the surface of the cable. The field calculated (current rating) after taking account of these separations for typical largest cables in use at various voltages are shown in this table 3.
The field is always below the HAL and hence the health ELV. The calculated values of field exceed the LAL, but this is a worst case calculation, because it takes no account of the cancelling effect of the other currents making up the circuit nor of the variation of field across the tissue in question.
» **Action:** no action needed.

Electric fields: Such cables always have a conducting outer layer that screens the electric field.

» **Assessment:** no further assessment needed.
» **Action:** no further action needed.

Magnetic fields very close to such conductors are highly likely to exceed the public levels relevant for workers at particular risk, requiring a separate assessment.

5.3 TOWERS

5.3.1 CLIMBING OPPOSITE SIDE TO LIVE CONDUCTORS

» Both electric and magnetic fields: it is unlikely that any exposures exceeding the Action Levels will be experienced when climbing a tower either on the opposite side to the live conductors or inside the body of the tower.

» For workers at particular risk, requiring a separate assessment

5.3.2 CLIMBING PAST LIVE CONDUCTORS

Magnetic fields: If climbing on the body of the tower past live conductors is permitted at all, high-voltage safety clearance distances will ensure that conductor cannot be approached closely enough to exceed the High/Low Action Levels.

» **Assessment:** No further assessment needed. Calculations can be used to confirm if necessary.
Action: no action needed.

Electric fields: Electric fields can be high, and clearly above the High Action level and Limit Equivalent Field. Measurements in the vicinity of tower steelwork are unreliable, but fields of 30 kV/m or even higher have been measured on 400 kV towers. However, the field is aligned, broadly speaking, horizontally through a linesman's vertical body (see figure in annex C), an orientation where the coupling is less strong then the reference one (person standing at ground level and exposed to a vertical field). So the field measurements in excess of the Action levels does not necessarily indicate exceeding of the exposure limits values.

» **Assessment:** alternative assessment methods are available, and are detailed in Annex C.
» **Action:** It is likely that, using one of the above alternative methods, this activity will be demonstrated to be compliant, and therefore no further action is needed.

The electric field in this exposure situation is highly likely to exceed the public levels relevant for workers at particular risk, and the magnetic field may do so as well, requiring for both a separate assessment.

5.4 LIVE-LINE WORK ON TOWERS AND IN SUBSTATIONS

All maintenance performed on electrical equipment executed while the equipment is energised is designated as live-line work. At present, two basic techniques of live-line work are used by TSOs for work on overhead lines or in substations: the "distance technique" (or "hot stick" working) and the "contact technique" (or "bare hand" working or "hot glove" working).

The "hot stick" technique requires that the workers directly involved be kept at ground potential and operate from the tower on live parts by using special insulating tools.

The "contact technique", which is the more common technique used for 220 and 380 kV lines, requires that the operators, who wear suitable protective conductive overalls, reach the same potential as the live parts on which they must operate and utilize hand-held metal tools. The conductive overalls provide a screen from electric fields (but not from magnetic fields).

HOT GLOVE OR BARE HAND

Magnetic fields: Live-line works, like close approach to insulated conductors in substations considered above, involve close approach to high currents, and hence to high magnetic fields that fall rapidly with distance. It should also be considered that live-line working situations imply close proximity (in fact, contact) to one conductor and safety distance to the other phases; exposure from the other phases can therefore be neglected.

Considering a single conductor for simplification, this close proximity to the conductor also means that the conductor can most often be modelled by a straight wire. The modelling of such exposure situations is simple, and Ampere's law can legitimately be applied: $B(\mu T) = 0.2\, I/d$

As a consequence, the previous statement on the minimum distance between the brain or the skin and the surface of a conductor also applies here, but the radius of line conductors are in the order of 1–2 cm, smaller than for insulated cables. Considering a worker in contact with a line conductor (radius of 1.5 cm), the minimum distance to the skin is 1 cm and to the brain is 4 cm (see section 5.2). Using Ampere's law, it follows that the Low AL (1000 μT) is reached in the brain with a current flow of 275 A and the LEF for sensory effects as proposed by the draft CENELEC standard with a current of 550 A. The High AL is reached in the skin with a current flow of 750 A. From these basic calculations, simple safety rules can be proposed, which basically consist in translating the AL (or LEF) for magnetic field into AL for current:

- for currents lower than 500 A, no restriction for live-line work: the direct contact is allowed;
- between 500 and 750 A, the contact is allowed but not for the head;
- over 750 A, no contact is allowed (but the live-line work can carry on using a protective equipment around the conductor which prevents any direct contact).

This simple approach can be adapted to other situations (e.g. bundles of conductors, bigger conductors such as busbars).

- **Assessment:** for all the work situations where the simplified assumption of the straight conductor is applicable, the simple assessment method described previously can be applied. For more complex exposure situations the most appropriate assessment method is numerical dosimetry. Several such calculations for geometries specific to live-line work have been published.
- **Action:** basically, applying the Directive will consist in translating the field limits into current and distance rules: whatever the assessment method (simplified calculation or dosimetric study) it finally results in calculating the conditions of current and distance at which the considered limit (AL or LEF or any other applicable limit resulting from specific dosimetric studies) is met. If the risk assessment shows that the limits can be exceeded then further actions will have to be defined for managing the two action parameters: current and distance.
  For example, permanent monitoring of the current can be required if the estimated current during the live-line operation is in the order of the "Action Level" for the current (500 A for a single conductor). Alternatively, if such monitoring is not possible, safety equipment (for example a tube 5 cm thick) can be positioned around the conductor to increase the contact distance so that the exposure limit will not be reached whatever the current.

Electric fields: bare-hand live-line work is only undertaken when wearing a conducting suit or some other method of providing a Faraday cage, and standard designs of such suits also ensure that the electric fields are below the Action Levels, even around the opening for the face.

- **Assessment:** no further assessment needed
- **Action:** no further action needed

HOT STICK TECHNIQUES

Magnetic fields: Hot-stick work ensures that sufficient distance is maintained from the conductors such that the magnetic-field AL is not exceeded.

Electric fields: For hot-stick techniques, it is likely that the exposure of the worker will be similar to that of workers climbing towers past live circuits, considered in section 5.3.2. If hot-stick techniques require closer approach to the live conductors than this, further measures may be necessary, for example, live-line suits.

The magnetic field in this exposure situation is highly likely to exceed the public levels relevant for workers at particular risk, requiring a separate assessment.

5.5 CABLE TUNNELS OR VAULTS

Magnetic fields: Cable tunnels allow close approach to insulated conductors. Confined working space may mean that deliberate close approach to conductors may be necessary, and accidental close approach may be difficult to control.

» **Assessment:** Calculations are possible for straight runs of cables in tunnels but become difficult when there are complex geometries and multiple circuits. Measurements may be preferable but need scaling to maximum load which may not be easy where multiple circuits are involved (depending on the phasing, the worst case may not simply be the maximum load in every circuit). In principle, there may be scenarios where the field from the multiple cables is larger than from any single conductor. However, practical experience shows that in most situations, multiple cables actually increase the degree of cancellation and lead to a lower overall field. It is therefore recommended that cable tunnels or vaults be treated as single conductors, as in 5.2 above.
» **Action:** no action necessary.

Electric fields: All such cables will have conducting outer layers which ensure the electric field is close to zero.

» **Assessment:** no further assessment necessary.
» **Action:** no further action necessary.

The magnetic field in this exposure situation may exceed the public levels relevant for workers at particular risk. Either such staff should be identified and person-specific assessments performed, or entry into such areas should be prevented for all such staff.

5.6 SHORT-DURATION EVENTS (FAULTS, SWITCHING TRANSIENTS ETC)

Magnetic fields: Faults on transmission systems produce high currents, and hence high magnetic fields (well above the High Action Level in scenarios where a person is present in the worst-case location at the time of a fault, although such scenarios are extremely rare given how rare faults are).

Electric fields: Switching transients when re-energising an overhead line circuit can produce voltages three times normal, and hence peak electric fields three times normal, often made up of the 50 Hz plus a higher-frequency component. Lightning strikes can also produce similarly high voltages for extremely short periods.

General approach to short duration events: both faults and switching transients last, except in very rare circumstances, for no more than a few cycles of a 50 Hz waveform. It is considered that these events are of too short a duration to fall within the scope of the Directive. Neither the Directive, nor the ICNIRP Guidelines on which it is based, give a minimum duration, so it is appropriate to refer to ICES, which suggests 200 ms or ten cycles of the 50 Hz waveform. The CENELEC Standard specifies that exposures of duration less than this should be considered not to constitute over-exposure.

5.7 HVDC AND OTHER EXPOSURES TO STATIC FIELDS

The commonest source of high static fields in TSOs is HVDC convertor stations. HVDC cables or lines also produce static fields, but generally at lower levels. Superconducting fault current limiters may be used by some TSOs.

Magnetic fields: Static magnetic fields in the general areas of HVDC convertor stations are likely to be less than 1 mT. The highest static magnetic fields likely to be encountered in accessible areas of HVDC convertor stations is against the surface of an insulated cable. This is analogous the AC case considered in 5.2 and, depending on the rating and diameter of the cable, fields of several mT are possible.

» **Assessment:** Static magnetic fields will not exceed the ELVs.
» **Action:** no action needed.

Electric fields: The Directive does not contain limits for static electric fields. Elsewhere, ICNIRP give a guideline figure of 25 kV/m for static electric fields (ICNIRP, 2009). Electric fields under DC busbars in HVDC convertor stations have been measured as around 20 kV/m, and are thus below even this guideline figure.

» **Action:** no action needed.

For workers with AIMDs, the relevant threshold for static magnetic fields is 0.5 mT. This is the threshold to avoid operation of the reed switch included in most devices, and is constant for all devices, unlike interference from power-frequency fields, where the sensitivity varies from device to device. Fields in HVDC convertor stations are highly likely to exceed this level. This level could also be found at distances of order 10 m from a superconducting fault current limiter. Steps should be taken to prevent staff with these devices entering the relevant areas.

5.8 SUMMARY OF EXPOSURE SITUATIONS

Exposure situation	Assessment		Action required		
	Electric field	Magnetic field	Staff in general	Staff at particular risk	Contact currents and microshocks
Busbars, transformers, etc (at ground level)	Compliant	Compliant	None	yes	yes
Air-cored reactors (at ground level)	Compliant	Requires further assessment	Restrict access, depends on outcome assessment	yes	no
Work above ground level in high-voltage areas	Requires further assessment	Compliant	Screening, depends on outcome assessment	yes	yes
Work outside high-voltage areas	Compliant	Compliant	None	yes	no
Insulated conductors	Compliant	Compliant based on existing ratings	None	yes	no
Climbing opposite side to live conductors	Compliant	Compliant	None	yes	no
Climbing past live conductors	Probably compliant but requires assessment	Compliant	None, depends on outcome assessment	yes	yes
Live-line work on towers and in substations: Hot glove or bare hand work	Compliant, given that staff wears conducting suits	Requires assessment	Restrictions on current in conductor or approach to conductor, depends on outcome assessment	yes	no
Live-line work on towers and in substations: Hot stick work	Requires assessment of closest approach	Compliant	Probably none, but conducting suits may be required depending on outcome of assessment	yes	yes
Cable tunnels or vaults	Compliant	Compliant based on existing ratings	None	yes	no
Short-duration events (faults, switching transients etc)	Compliant	Compliant	None	No additional requirement beyond existing provisions	no
HVDC and other exposures to static fields	Compliant	Compliant	None	yes	no

Table 4: Summary of exposure situations

6 BIBLIOGRAPHY

CENELEC. (201X).

EU. (1989). Directive 89/391/EEC of 12 June 1989 on the introduction of measures to encourage improvements in the safety and health of workers at work.

EU. (1999). Council Recommendation 1999/519/EC 12 July 1999 on the limitation of exposure of the general public to electromagnetic fields (0 Hz to 300 GHz).

EU. (2013). Directive 2013/35/EU of 26 June 2013 on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (electromagnetic fields).

ICNIRP. (2009). INTERNATIONAL COMMISSION ON NON-IONIZING RADIATION PROTECTION Guidelines on limits of exposure to static magnetic fields Health Phys, 2009, vol.96, no. 4, p. 504–514. Health Physics, 96(4), 504–514.

ICNIRP. (2010). INTERNATIONAL COMMISSION ON NON-IONIZING RADIATION PROTECTION Guidelines for limiting exposure to time-varying electric and magnetic fields (1 Hz to 100 kHz). Health Physics, 99(6), 818–836.

IEC. (2009). IEC 62110. Electric and magnetic field levels generated by AC power systems – Measurement procedures with regard to public exposure. IEC 62110.

IEC. (2013). IEC 61786-1. Measurement of DC magnetic, AC magnetic and AC electric fields from 1 Hz to 100 kHz with regard to exposure of human beings. Requirements for measuring instruments. IEC 61786-1.

IEC. (2014). IEC 61786-2. Measurement of DC magnetic, AC magnetic and AC electric fields from 1 Hz to 100 kHz with regard to exposure of human beings. Basic standard for measurements. IEC 61786-2.

ANNEX A: WORKERS AT PARTICULAR RISK

A.1 PREGNANT STAFF

Note that there is no actual scientific evidence that the mother or the unborn baby is any more sensitive to EMFs. However, as the unborn baby clearly does not fall within the definition of a worker, and as it may be speculated that the developing embryo is, in general, more sensitive to a number of external insults, it is considered reasonable and precautionary to limit the exposure of the pregnant woman to the public exposure limits.

TSOs should choose either:

» To require all woman, from the point at which they notify their employer that they are pregnant, to be subject to the public exposure limits; or

» To allow the woman to exercise a choice as to whether she wishes to be subject to the public exposure limits or not (this alternative approach avoids any risk that restricting the woman to the public exposure limits, which could involve restrictions on their work practices, could be considered discrimination).

In either case, to avoid confusion, the TSO should make clear that this provision is made for peace of mind and as a precautionary measure rather than for medical reasons.

Where a member of staff is affected by these provisions, reasonable adjustments to her work should be made, as for any other pregnancy-related provision. A simple, but often unnecessarily restrictive, approach is to restrict her to non-operational sites, e. g. offices, avoiding operational sites, e. g. substations. If this is considered unduly restrictive, site-specific assessments can be made.

In order to avoid proliferation of warning signs and the risk of creating unjustified alarm, TSOs are recommended not to use warning signs or restrictions on access related to pregnancy.

A.2 WORKERS WITH ACTIVE IMPLANTABLE MEDICAL DEVICES

"Active implanted medical devices" (AIMDs) include pacemakers, implanted cardiac defibrillators, cochlear implants, implanted insulin pumps, neurostimulators, etc. Any "active" medical device (i.e. one that has a power supply, electronic circuitry, and/or sensing electrodes) should be assumed to be included in this category.

In the absence of any reported effects, passive devices, e.g. joints, plates, pins, screws, etc, can be assumed not to give rise to any interference effects with ELF EMFs.

Some AIMDs can, in some circumstances, experience interference from EMFs at levels below the Directive exposure limits. Except under exceptional circumstances, it is only exposures above the Reference Levels from the public exposure limits that can produce interference, and the public exposure limits should be used to identify such a possibility [3].

The nature of AIMDs and the medical conditions for which they are fitted means that, if interference is created, there is a risk of an extremely serious outcome, including the theoretical risk of fatality. However, experience shows that such serious outcomes, in practice, simply do not occur. TSOs should exercise reasonable diligence to minimise the risk of interference, but absolute prevention of interference under all possible circumstances is not possible.

Further, all people with AIMDs need to be aware of the risks of interference from a number of sources that could be encountered in any workplace or outside the workplace, and will have been informed of these risks at the time of fitting their device. A TSO should take appropriate steps as an employer to protect its staff from hazards that are specific to its business. However, TSOs cannot assume complete responsibility for the protection of staff with AIMDs from all possible interference hazards, and this should be made clear to staff. TSOs can assume that staff with AIMDs will be alert to the risks.

Staff should always be encouraged to follow all advice given to them by their physician or the device manufacturer.

TSOs can choose to protect staff with AIMDs either through a system of identifying locations, or of identifying staff, or a combination of the two.

3) The Reference Levels set by Directive 1999/519/EC are 100 µT for magnetic field and 5 kV/m for electric field, which are lower than the limits for workers, as set out above.

IDENTIFYING LOCATIONS

TSOs could choose to place warning signs or to restrict access for locations where interference is possible, i.e. locations where the public reference levels are exceeded. This would include all substations, overhead lines, cable vaults and tunnels, etc. It would then be expected that staff with AIMDs do not enter these locations.

This solution may be appropriate in cases when external personnel could occasionally access the site.

If a TSO chooses to place warning signs, it is assuming the responsibility for warning of relevant sites, and therefore should ensure that signs are placed at every relevant location.

IDENTIFYING STAFF

TSOs could alternatively choose to create personnel systems to identify all staff with AIMDs, then to perform individual assessments for those staff to identify any restrictions necessary.

This solution applies exclusively to internal staff.

Staff should be identified through:

» Pre-employment medical screening and

» Return-to-work interviews.

Where a member of staff has an AIMD, an assessment of their work environment should be made by relevant EMF specialists, then an assessment of the implications for their role should be made by Occupational Health, taking appropriate account of the member of staff's own attitude to the risk.

Particular AIMDs as fitted to particular individuals often have a higher immunity to interference than the worst case assumed by Standards of the public reference levels. The immunity of particular devices can be assessed on a case-by-case basis, thus avoiding unnecessary restrictions to working practices. It will often be helpful to seek further details of the device and its sensitivity levels from the physician concerned and/or the manufacturer, and staff should be expected to co-operate in seeking this information.

Reasonable adjustment should be made to work practices in order to reduce any risks arising from interference to an acceptable level.

Some exposures to staff with AIMDs occur while working at height. A TSO may decide that staff with AIMDs and pregnant staff should not work at heights anyway, on grounds of general safety (e.g. the requirement for a high level of fitness, and the consequences if an implanted defibrillator fires while the worker is at height). However, a TSO may decide that such a blanket policy relating to all AIMDs is not appropriate and could possibly be discriminatory.

TSOs should also ensure appropriate information or controls for external personnel (e.g. contractors and visitors); sites where there is a possibility of exposure to EMFs high enough to cause interference with AIMDs should include a suitable warning of the possibility of interference.

ANNEX B: “CONTACT CURRENT” METHOD FOR ASSESSING ELECTRIC FIELD EXPOSURES

In situations where the electric field is highly non-uniform, spot measurements close to metallic structures can be very sensitive to the peak effect and can therefore significantly overestimate to actual exposure of workers. A possible way to solve this issue is to consider that when exposed to an electric field a worker can be considered as a voltage generator (see figure).

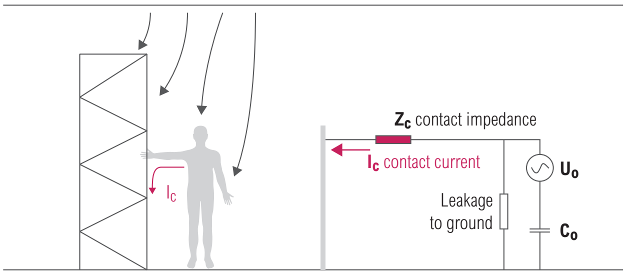
When a worker exposed to an electric fields has a permanent contact to the ground, the contact current is the short-circuit current of the voltage generator. It depends on the magnitude of the electric field and on the position of the body in the field and with regard to the ground plane. At ground level, the capacitance C_0 of a standing man is in the order of 150 – 200 pF and, therefore the contact current I_c remains independent from the contact impedance Z_c as far as it remains lower than $(2\pi.f.C_0)^{-1} = 10\,M\Omega$.

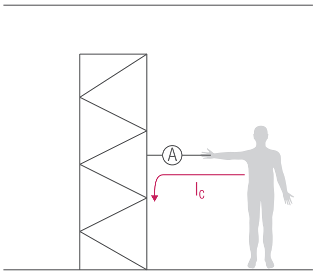
This condition is easy to comply with, and it also means that a direct measuring the contact current using a usual ammeter will give a result representative of the real contact current which can occur when a worker is connected to a ground structure (for example a worker with conductive shoes in a tower).

The direct measurement of the contact current is easy to perform considering that the contact impedance is not critical:

The usual coupling factor given in reference publications (e. g. CIGRE) is 15 µA per kV/m, corresponding to the maximum (conservative) coupling situation, i. e. a man standing in a vertical electric field. Therefore the High AL for electric field is equivalent to a 0.3 mA contact current and the LEF (as proposed by CENELEC) is equivalent to 0.5 mA.

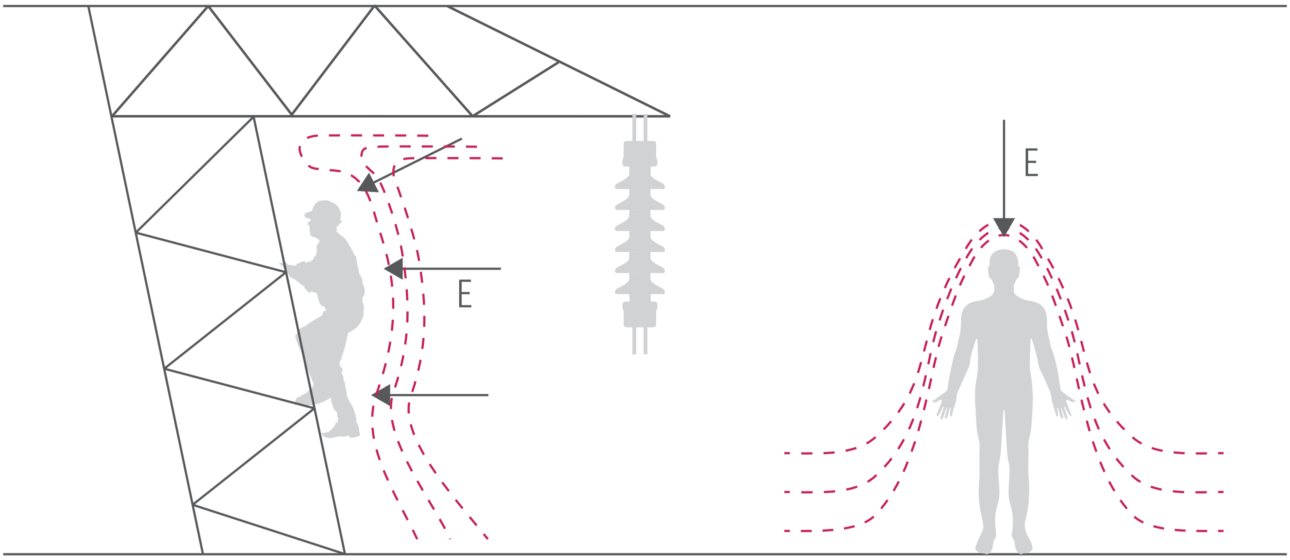
Reciprocally, any contact current from a worker to a grounded structure lower than 0.5 mA means that the corresponding exposure to the electric field (whatever uniform or not) is complaint.





ANNEX C: ASSESSMENT METHODS FOR ELECTRIC FIELD EXPOSURES ON TOWERS WITH LIVE CIRCUITS

Section 5.3.2 explained that when climbing on towers past live conductors, electric fields can be high, and can certainly be above the High Action level and Limit Equivalent Field. Measurements in the vicinity of tower steelwork (which cause strong local perturbations) and possibly perturbed by the person making the measurement (who cannot be distanced from the measurement point as easily as at ground level) are unreliable, but fields of 30 kV/m or even higher have been measured on 400 kV towers. However, the field is aligned, broadly speaking, horizontally through a linesman's vertical body (see figure), an orientation where the coupling is less strong then the reference one (person standing at ground level and exposed to a vertical field). So the field measurements in excess of the Action levels does not necessarily indicate exceeding of the exposure limits values.



Alternative assessment methods are available.

» A simple approach is to scale the Action level or the Limit equivalent field by the ratio of the height of a person to their thickness, a factor of perhaps 4. This factor very approximately represents the ratio of the coupling in the two geometries. The High Action level would thus become perhaps 80 kV/m, and the exposure is likely to be deemed compliant.

» A second approach is outlined in the CENELEC Standard and based on measurements by EPRI is to use the total contact current as a proxy for the effect of the electric field, as explained I annex B. This total contact current has been measured both for the reference case of a person standing vertically in a vertical field, and for a worker leaning out 30° from a tower leg in a horizontal field (see figure above), and can therefore be used to scale from one to the other. EPRI's finding is that a horizontal field of 10 kV/m in a tower results in a contact current 38 % smaller than from a 10 kV/m vertical field at ground level. In other words an exposure to a 20 kV/m vertical field at ground level is equivalent to a 32 kV/m horizontal exposure in a tower. This approach therefore allows to exceed the HAL, but requires to analyse the coupling of the field to the body for the work positions in towers.

» A third approach would be to perform numerical dosimetric calculations specific to the exposure scenario. However, no such calculations have yet been published.

It is likely that, using one of the above alternative methods, this activity will be demonstrated to be compliant, and therefore no further action is needed.

ABBREVIATIONS

AIMD	Active Implanted Medical Device
AL	Action Level
CNS	Central Nervous System
EC	European Commission
ELV	Exposure Limit Value
EMF	Electromagnetic Fields
ENTSO-E	European Association of Transmission System Operators for Electricity
HAL	High Action Level
HVDC	High Voltage Direct Current
LAL	Low Action Level
LEF	Exposure-Limit-Equivalent-Field
PNS	Peripheral Nervous System
TSO	Transmission System Operator

UNITS

A	Ampere, unit of electrical current; it measures the amount of electrical charge that flows in an electrical circuit per 1 second. 1 A = 1,000 mA (milliampere); 1 mA = 1,000 µA (microampere); 1 kA (kiloampere) = 1,000 A
F	Farad, unit of electrical capacitance, the ability of a body to store an electrical charge; 1 pF (picofarad) = one trillionth (10^{-12}) F
Hz	Hertz, unit of alternating current (AC) or electromagnetic (EM) wave frequency; 1 Hz = one cycle per second. 1 Mhz (megahertz) = 1,000,000 Hz; 1,000 Mhz = 1 GHz (gigahertz)
Ω	Ohm, unit of electrical resistance; 1 MΩ (megohm) = 1,000,000 Ω
T	Tesla, unit of electric field strength; 1 T = 1,000 mT (millitesla) or 1,000,000 µT; 1 µT (microtesla) = 1,000 nT (nanotesla)
V	Volt, unit of electric potential; 1 kV (kilovolt) = 1,000 V
V/m	Volt per meter, unit of electric field strength; an electric field of 1 V/m is represented by a potential difference of 1 V existing between two points that are 1 m apart.

AUTHORS

FRANCOIS DESCHAMPS
RTE, France

CHRISTOPH DÖRNEMANN
Amprion, Germany

VINCENT DU FOUR
ELIA, Belgium

EDWARD FRIMAN
Svenska kraftnät, Sweden

ARIANNA GUARNERI
Terna, Italy

MIKA PENTTILÄ
Fingrid, Finland

KLEMENS REICH
APG, Austria

JOHN SWANSON
National Grid, UK

CONTACT

ENTSO-E AISBL · Avenue de Cortenbergh 100 · 1000 Brussels – Belgium
Tel +32 2 741 09 50 · Fax +32 2 741 09 51
info@entsoe.eu · www.entsoe.eu