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Ugotavljanje nenamernega vžiga vnetljivih atmosfer z radiofrekvenčnim sevanjem - Vodilo

Assessment of inadvertent ignition of flammable atmospheres by radio-frequency radiation - Guide

Leitfaden zur Verhinderung der unbeabsichtigten Zündung explosionsfähiger Atmosphären durch hochfrequente Strahlung

Evaluation des risques d'inflammation des atmosphères inflammables par des rayonnements de radiofréquence - Guide

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Assessment of inadvertent ignition of flammable atmospheres by radio-frequency radiation – Guide

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This Technical Report was approved by CENELEC on 2004-08-28.

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CENELEC
European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

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Foreword

This Technical Report was prepared by the Technical Committee CENELEC TC 31, Electrical apparatus for explosive atmospheres - General requirements.

The text of the draft was submitted to the formal vote and was approved by CENELEC as CLC/TR 50427 on 2004-08-28.

Contents

Introduction

Electromagnetic waves produced by radio-frequency (RF) transmitters (e.g. radio, television and radar) will induce electric currents and voltages in any conducting structure on which they impinge. The magnitude of the induced current and voltages depends upon the shape and size of the structure relative to the wavelength of the transmitted signal and on the strength of the electromagnetic field. When parts of the structure normally in contact are caused to break or separate momentarily (e.g. during maintenance or as a result of vibration) a spark may occur if the induced voltage and current is sufficiently large. If this happens in a location where a potentially flammable atmosphere may be present a hazardous situation can occur. However, the possibility of ignition will depend on many factors including whether the spark can deliver sufficient energy to ignite a particular flammable atmosphere.

This European Technical Report provides a systematic approach to assist transmitter operators, plant managers and all others concerned with a logical method for the assessment and elimination of RF induced ignition hazards.

The assessment procedures recommended in this European Technical Report are based on measurements of the powers and energy that can be extracted from typical structures, including cranes, and measurements of the minimum powers and energy that are required to ignite various flammable atmosphere gas groups.

The assessment procedures for probability of ignition recommended in this European Technical Report are based on the assumption that worst case conditions apply at all times. The critical features are the coincidence of the structure in resonance and the presence of the gas/air mixture in the optimum proportions for RF spark ignition. Deviation from these optimum conditions will result in significantly higher powers being required for ignition.

NOTE 1 Several studies have been performed which indicate that the power could be twice as great for an assumed risk as detailed in reference [1], if due allowance is taken for probabilistic effects. In order to achieve a probability of ignition comparable with other risks, it would be necessary for effective extractable power calculated to be twice the values determined according to this European Technical Report. The probabilistic elements could be taken into consideration following further research work and practical experience.

NOTE 2 If allowances for probabilities are to be applied then expert advice should be sought.

1 Scope

This European Technical Report provides guidance on assessing the potential ignition hazard from the inadvertent extraction of energy from electromagnetic fields, propagated from communication, radar or other transmitting antennas to plant where a potentially flammable atmosphere may be present. The frequency range covered by this European Technical Report is 9 kHz to 60 GHz. This European Technical Report does not apply to similar hazards arising from electromagnetic fields generated by other means, such as electric storms, electricity generating installations or other radiating electrical equipment, nor does it apply to any hazard arising within telecommunication or other electronic equipment.

NOTE 1 The methods of assessment from 9 GHz to 60 GHz are based on extrapolation of data for frequencies below 9 GHz.

NOTE 2 The ignition of dust is not covered in this European Technical Report. This European Technical Report also provides advice on how to mitigate the hazard in cases where the assessment indicates that a hazard may exist. This European Technical Report does not cover the hazards associated with the use of electro-explosive devices (EED) (see CLC/TR 50426), or the biological hazards of exposure to RF fields.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

Publication	Year	Title
EN 60079-0		*Electrical apparatus for explosive gas atmospheres — Part 0: General requirements* (IEC 60079-0)
EN 50020		*Electrical apparatus for potentially explosive atmospheres — Intrinsic safety "i"*
EN 60079-10		*Electrical apparatus for explosive gas atmospheres — Part 10: Classification of hazardous areas* (IEC 60079-10)

3 Terms and definitions

For the purposes of this European Technical Report the following terms and definitions apply.

3.1
circuit factor, Q_k
performance parameter for a structure acting as a receiving antenna (see [2])

NOTE Assuming the structure to be tuned to the transmission frequency f_t, Q_k is the ratio of f_t to Δf, where Δf is the difference between those frequencies, one above and one below f_t, at which the structure resonates when it is re-tuned so that the open circuit voltage at f_t has fallen by 3 dB. Q_k is closely related to the Q factor of a tuned circuit.

3.2
extractable power, P_{max}
power dissipated in a resistive load connected across a discontinuity in a structure acting as a receiving antenna

NOTE The extractable power reaches its maximum when the structure is tuned to the frequency of the transmitter (under these conditions the impedance of the structure presents a resistive value only, with no reactive components), and the load resistance is a value equal to that of the structure.

3.3
modulus match power, P_{mm}
maximum value of extractable power that can be achieved with a resistive load at a frequency to which the structure is not tuned (see [2])

3.4
structure efficiency
ratio of the extractable power that the structure can deliver to a matched load and the maximum extractable power delivered by a lossless short dipole in free space immersed in the same field

3.5
thermal initiation time
time during which energy deposited by the spark accumulates in a small volume of gas around it without significant thermal dissipation

NOTE For times shorter than the thermal initiation time the total energy deposited by the spark will determine whether or not ignition occurs. For increasingly longer times, the power or rate at which energy is deposited becomes the determining factor for ignition.

3.6
vulnerable zone
region surrounding a transmitter in which a potential hazard could arise within a hazardous area of a plant

3.7
far field
region, distant from the transmitter, in which the field strength is inversely proportional to distance in the absence of ground reflection

NOTE The inner limit of the far field is generally regarded as the distance *d* from the transmitter defined as follows. For frequencies up to and including 30 MHz, $d = 8H^2/\lambda$ where *H* is the height of the top of the antenna above ground and λ is the wavelength. At frequencies above 30 MHz, $d = 2W^2/\lambda$ where *W* is the width of the antenna.

3.8
near field
region close to the transmitter which lies within the far field region

NOTE In the near field region the dependence of the field strength on distance is complex and mutual coupling effects can also affect the value of extractable power.

3.9
flammable atmosphere
gas/air or vapour/air mixture capable of being ignited which can occur in a hazardous area

NOTE See EN 60079-10 for further information.

3.10
equivalent isotropically radiated power (EIRP)
product of the power supplied to the antenna and the antenna gain in a given direction relative to an isotropic antenna (absolute or isotropic gain)

3.11
effective field strength
value of electric field strength due to a single transmitter which is derived from the transmitter characteristics, modulation factors (see 6.5) and distance, and is used for the calculation of extractable power

3.12
antenna gain
gain produced by an antenna concentrating radiation in a particular direction

NOTE 1 The gain of an antenna is always related to a specified reference antenna.

NOTE 2 The gain, *G*, of an antenna in a particular direction is given by the equation: *G* = (1) where *R* is the power in Watts, W, that should be radiated from the reference antenna; *A* is the power in Watts, W, that should be radiated from the given antenna to give the same field strength at a fixed distance in that direction.

$$G = \frac{R}{A} \qquad (1)$$

where

R is the power in Watts, W, that should be radiated from the reference antenna;

A is the power in Watts, W, that should be radiated from the given antenna to give the same field strength at a fixed distance in that direction.

NOTE 3 The gain, which is often expressed in logarithmic form, is stated in decibels.

3.13
hazard
potential source of danger to life, limb or health, or of discomfort to a person or persons, or of damage to property

3.14
safe distance
distance outside which it is considered that there is no potential hazard

4 Symbols and abbreviations

4.1 Modulation codes

AM	Amplitude-modulated speech or music transmission. Carrier power quoted.
MCW	Amplitude-modulated tone transmission. Carrier power quoted.
TV	Amplitude-modulated video transmission. Peak power quoted.
R ( )	Pulse-modulated radar transmission. Peak power quoted. The number in brackets indicates the pulse duration in s where known.
FM	Frequency modulation.
FSK	Frequency shift keying.
GFSK	Gaussian frequency shift key modulation.
SSB	Single sideband transmission. Peak envelope power quoted.
CW	Continuous wave.
MSK	Minimum shift keying.
GMSK	Gaussian minimum shift keying.
CDMA	Code division multiple access.
PCM	Pulse code modulation.
PSK	Phase shift keying.
PM	Phase modulation.
DQPSK	Differential quadrature phase shift keying.

4.2 Polarization codes

V Vertical polarization.

H Horizontal polarization.

V/H Either vertical or horizontal polarization, or both simultaneously.

5 General considerations

5.1 Radio-frequency hazard

For a radio-frequency hazard assessment, detailed consideration should be taken of the conditions that have to be satisfied simultaneously for a hazard to exist. These are as follows:

NOTE 1 The simultaneous occurrence of these four conditions is unlikely.

NOTE 2 See [3] for further information.

a) electromagnetic radiation of sufficient intensity;

NOTE 3 An electromagnetic field of sufficient intensity may be generated by a fixed/mobile or portable transmitter, the magnitude of the field depending upon the transmitted power, the antenna gain and the proximity to the site under consideration.

NOTE 4 Intense electromagnetic fields are also generated by the intentional radio frequency sources in industrial, scientific and medical (ISM) equipment. Field strengths in the order of 10 V/m may be present in the near vicinity of the equipment.

Typical characteristics of industrial equipment are:

2,5 GHz to 10 kW 915 MHz to 100 kW	industrial microwaves
27 MHz to (10 to 50) kW 13,56 MHz to (10 to 50) kW	welding or drying techniques

b) presence of a structure capable of behaving as a receiving antenna. Only structures in a hazardous area (as defined in EN 60079-10) should be considered (see Clause 7 and Clause 8);

c) existence of a mechanism whereby the received energy or power can be delivered as a spark;

d) presence of a flammable atmosphere (see Clause 8).

All conducting structures behave as receiving antennas, but the magnitude of induced current and voltage depends upon the method of construction and the configuration. Experience gained in practical measurements on structures has shown that for frequencies up to and including 30 MHz, the loop configuration is the most efficient receiving system (see [4]). At higher frequencies all structures are large compared with a wavelength and their behaviour is conveniently treated by the use of long dipole theory. The behaviour of these structures is described in Clause 7.

The generation of a spark is dependent upon the appearance of a small discontinuity in a receiving structure, for example when parts of a structure normally in contact are caused to separate, either during maintenance or at any time by flexing, mechanical vibration or similar actions.

The spark energy required to ignite a flammable atmosphere depends upon the nature and composition of the flammable atmosphere. In making the assessment, it is assumed that the composition is at its optimum for ignition to take place. This in itself provides a margin of safety under most circumstances, since the energy required for ignition of a particular atmosphere generally increases rapidly as its composition moves away from the optimum.

5.2 Philosophy of systematic method of approach

This European Technical Report is based on a series of graded assessments, each requiring a progressively more detailed analysis.

The initial assessment procedure is designed to eliminate from further consideration those locations where it is highly unlikely that a hazard exists. It is based on “realistic worst case” estimates of the radius of the zone around different classes of transmitter within which a hazard might result from the presence of a structure in a hazardous area.

If the initial assessments indicate that a hazard might exist, the full assessment procedure given in 10.4 should be followed. This provides a method of computing the maximum power available in any spark produced, based on more detailed information about the actual transmitter and plant and their relative location. This calculated power should then be compared with the minimum power required to ignite the particular flammable atmosphere concerned (see Table 2, Table 3 and Figure 4).

When this procedure is followed, it will quickly become apparent whether the available information is adequate for an assessment to be made with a high degree of confidence or whether additional information is required from practical measurements on site. If doubt exists, then expert opinion should be sought (see Annex A).

The assessment procedures in this European Technical Report determine whether ignition is possible under worst case conditions. No account is taken of any effects that could influence the probability of ignition. An inherent safety factor exists for many circumstances.

The assessment procedures recommended in Clause 10 apply generally to most circumstances. For cranes, mobile transmitters and oil rigs the special considerations described in Clause 12 should be taken into account.

5.3 Responsibility for making the hazard assessment

The radio-frequency (RF) environment is becoming increasingly severe, with the proliferation of transmitting sources, increased transmitter powers and the exploitation of new techniques.

NOTE 1 Legislation, (for example in the UK see [5]), requires that employers safeguard both their employees and others who may be placed at risk by their activities. Hence, both operators of RF transmitters and users of plant in which a flammable atmosphere may be present have a responsibility to ensure safe operation.

NOTE 2 Particular locations such as mines and quarries may exist where additional responsibilities are placed on the owners and managers.

Operators of a proposed plant in which a flammable atmosphere may be present should send details to the transmitter operators and request information about relevant transmitters in the locality of the site. If a potential hazard is indicated, the plant operator should then use the assessment procedures given in this European Technical Report, in consultation with the transmitter operators concerned.

Similarly, the operator of a proposed new (or altered) transmitter should contact all operators of plant with potentially flammable atmospheres within the vulnerable zone for their transmitter, and use the procedure given in this European Technical Report to assess the potential hazard at each location.

Where both plant and transmitter already exist but an assessment is required, the plant operator should be held responsible for ensuring that an assessment is made. If for some reason relevant information cannot be made available to the body responsible for the assessment, the responsibility for having an assessment carried out should be assumed by the body unable to release the necessary information.

NOTE 3 As an aid to those who need to make a hazard assessment but do not have the necessary technical resources, a list of sources of information and specialist organizations capable of providing consultation or test facilities is given in Annex A.

6 Transmitters and transmitter output parameters

6.1 Types of transmitter

This clause provides information on various types of transmitter and transmitting systems. This information is necessarily rather brief for certain types of radar and other military equipment but basic details are given and further information may be sought from the specialist organizations listed in Annex A. Typical types of antenna are shown in Figure B.1.

6.2 Frequency range

The main frequency range covered in this guide is 9 kHz to 60 GHz. The types of transmitter considered include the following:

a) radio and television broadcast transmitters in specific bands in the range 0,15 MHz to 1 000 MHz;

b) fixed and mobile transmitters for communication purposes, private, commercial and amateur, in specific bands above 0,4 MHz and for military use above 0,15 MHz;

c) radar, in specific bands at 220 MHz, 600 MHz and above 1 GHz;

d) navigational equipment, non-directional beacons, etc., from 9 kHz upwards.

6.3 Transmitter output power

Transmitter output power from several watts up to megawatts may be encountered depending on the frequency range and the application. The method of specifying the power varies, which is significant for hazard assessment when highly directional antennas are in use and when considering different modulation systems. In general, values are specified in the technical documentation for either the carrier or the peak power output from the transmitter together with the antenna gain, although the product of the two is often quoted in the technical documentation to give the equivalent isotropically radiated power (EIRP).

6.4 Antenna gain

The reference antenna is often an isotropic antenna that radiates uniformly in all directions. Although this is a purely hypothetical concept it is nevertheless very useful for reference purposes. When the gain of an antenna relative to an isotropic reference antenna is stated in decibels it is denoted by dBi. In practice, the gain of an antenna is often expressed relative to a half-wave dipole which itself has a gain of 1,64 (or 2 dB) relative to an isotropic antenna. In special circumstances other reference antennas may be used, for example a short monopole. It is therefore important that the reference antenna is correctly specified. The maximum gains for typical antennas are listed in Table B.1, Table B.2 and Table B.3.

6.5 Modulation factors

6.5.1 General

Most transmissions are modulated in order to convey information or to enable them to carry out specific tasks (for example, radar). The characteristics of the principal modulating systems are described in 6.5.2 to 6.5.5. A modulation factor, m, is necessary for calculating the effective field strength E in 10.4.3. Modulation factors are listed in Table 8 for different types of modulation.

NOTE Radio-frequency transmission may be unmodulated in which case the radiated power is constant and the power quoted in the technical documentation should be used. Such transmissions are sometimes referred to as continuous wave (CW).

6.5.2 Frequency modulation (FM)

For frequency modulation the frequency of the transmission is varied to carry the information but the output power remains constant as with CW transmissions. Frequency shift keying (FSK) and gaussian frequency shift keying (GFSK), minimum shift keying (MSK) and gaussian minimum shift keying (GMSK) are forms of frequency modulation. Phase shift keying (PSK) and phase modulation (PM) are treated similarly in that no allowance for modulation is necessary since the output power is not affected by the modulation.

6.5.3 Amplitude modulation (AM)

6.5.3.1 General

The amplitude of the transmission is varied to carry the information. This information may consist of speech or music or a coded transmission or it may be a television picture waveform.

6.5.3.2 Speech and music

When speech and music are transmitted, the power quoted in the technical documentation is that of the unmodulated or carrier transmission but the instantaneous field strength at the modulation peaks may be up to two times greater when the speech or music is at its loudest volume. Since the duration of the modulation peaks may exceed the thermal initiation time of the gas, it is necessary to make some allowance for the power increase (modulation) when making an assessment. As a result of experience gained with amplitude modulated broadcast transmitters, a modulation factor, *m*, of 1,4 should be used for calculations of effective field strengths for RF ignition effects (see [6] and [7]).

6.5.3.3 Coded transmissions

A version of amplitude modulation used for Morse and other coded transmissions is known as modulated continuous wave (MCW). For modulated continuous wave, whereby the carrier is fully modulated by a continuous tone, a modulation factor, *m*, of 2 should be used.

6.5.3.4 Television transmissions (TV)

For television transmissions the peak power is usually quoted in the technical documentation but in this case no allowance for modulation is necessary, because the mean power is approximately equal to the peak power.

6.5.4 Single sideband (SSB) operation

For single sideband (SSB) operation the peak envelope power is usually quoted in the technical documentation and a value of 0,7 for the modulation factor, *m*, should be used.

6.5.5 Pulsed radar

Pulsed radar consists of pulses transmitted at frequent intervals. The transmissions are characterized by a peak power P_o, a mean power P_m, a pulse duration *t* (in s) and a pulse repetition rate of *n* pulses per second. These are related by the equation:

$$P_o = \frac{P_m}{nt} \qquad (2)$$

where

nt is the duty cycle.

The peak power, P_o, should be used for assessment purposes and no additional allowance for modulation should be considered (see [8] and [9]).