



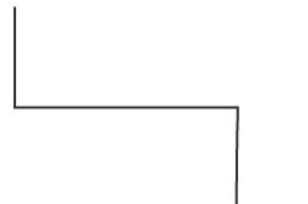
**(National Institute for Public Health
and the Environment)**

Guidelines for the calculation of the specific 0.4 microtesla zone in the vicinity of overhead high-voltage power lines

G Kelfkens, MJM Pruppers

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These guidelines have been drawn up at the request and for the account of the Ministry of Housing, Spatial Planning and the Environment, the Directorate General for Environmental Management, the Substances, the Waste Substances and Radiation Department, within the framework of project M/861020/05/EL 'Radiation Policy Support (BEST)'.



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1 Introduction

Goal

These guidelines lay down a method for the calculation of the specific 0.4 microtesla zone in the vicinity of an overhead high-voltage power line. The outlined approach is an elaboration of the policy recommendations for overhead high-voltage power lines as formulated by the State Secretary of VROM (Housing, Spatial Planning and the Environment) in October 2005.

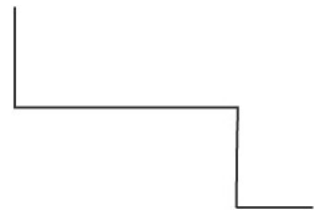
Target group

The guidelines are intended, first and foremost, for the grid administrators who want to stipulate the specific 0.4 microtesla zone around the overhead high-voltage power lines they manage in new situations, or in the event of technical measures affecting existing lines. In addition, the guidelines also offer other parties (local and provincial authorities, national government, and consultants) the possibility of calculating, or of having calculated, the specific 0.4 microtesla zone in a way which corresponds to the policy formulated.

The overhead high-voltage grid is a complicated system. That is why expertise in the field of electricity transport and distribution and knowledge of the software used is essential for calculating the specific 0.4 microtesla zone.

Structure

The guidelines are structured in three parts. The first part is a summary of the data required for the calculation of the specific zone. This is followed by details on the software currently used for the calculation of the 0.4 microtesla zone. The last part explains how the input data and the calculation results can be reported in a transparent and verifiable manner.



2 Data

2.1 Introduction

In order to allow a meaningful calculation of the specific zone in the vicinity of overhead high-voltage power lines, data is firstly required on the location for which the calculation has to take place. In addition, input data on the high-voltage power line are required for the software packages used for the calculation. This chapter summarizes the required data.

2.2 Location

2.2.1 Spatial plan

The party taking the initiative for a new spatial plan, or an existing one that is to be changed, indicates the location for which the calculation of the width of the 0.4 microtesla zone is to take place. This is done by stating the name of the high-voltage line(s) and the numbers of the pylons to be included in the calculation.

2.2.2 High-voltage line

New stretch

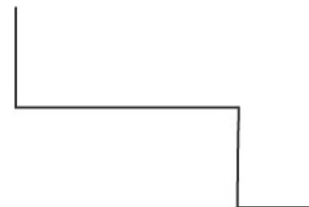
The party taking the initiative for a new stretch of an overhead high-voltage power line provides the relevant design details for the calculation of the width of the 0.4 microtesla zone. If different pylon types, conductor configurations, vector sequences, etc. are to be used on the intended path, this data is given separately for each sub-path. These guidelines exclusively describe how the width of the 0.4 microtesla zone is calculated. The optimal spatial adaptation of the power line stretch takes place within a wider context.

Existing stretch

In the event of changes to an existing overhead high-voltage power line which may, in principle, affect the width of the specific 0.4 microtesla zone, the grid administrator has to issue all the data referred to under **Error! Reference source not found.** in the situation as it is and in the intended new situation. By calculating the magnetic field zone for the original and the new situations, it can be demonstrated whether and to what extent, the width of the specific 0.4 microtesla zone is altered by the intended changes.

2.3 High-voltage power line

The calculation takes place at the level of a line section, between two consecutive pylons. The input data is recorded at the level of a line section and the calculation then applies to that line section. Often, the relevant data is the same for a number of consecutive line sections. In that case, a calculation for just one line section will suffice. The following data is relevant for each line section.



2.3.1 General data

2.3.1.1 Line name

The line name is the geographical designation of the overhead high-voltage power line or of the new path to be created.

2.3.1.2 Pylon number and location

Each line section is demarcated by two pylons. The numbers of these pylons and the location are recorded (using national triangulation coordinates). If the pylon locations for a new path are not yet known, a more general determination of location must be chosen.

2.3.1.3 Pylon type

The grid administrator uses the line name and pylon numbers provided to determine the type of pylons. A diagram with dimensions must be supplied for each type of pylon. In the case of a new stretch, this will be a sketch. The diagram must show:

- the configuration of the circuit (triangular, horizontal, vertical, etc.)
- for each circuit: the height (above ground level) of the bundle conductors and the lateral distance of these conductors from the (imaginary) centre line of the pylon
- the height (above ground level) of each earth wire and the lateral distance of these wires from the (imaginary) centre line of the pylon

2.3.1.4 Field length

The grid administrator records the field length (distance between the pylons of the line section in question). In the case of a new path, this means an estimate which is as accurate as possible.

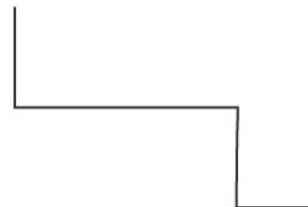
2.3.1.5 Sag at 10 °C

During construction of the line, the conductors are tensioned to a certain sag. The grid administrator records this sag by indicating the sag for the line section at 10 °C¹. This 10 °C is used as a reference during construction of the line. The actual sag when tensioning the conductors is then adjusted according to the temperature at that moment.

2.3.1.6 Number of circuits

An indication has to be given of the number of circuits for which the line has been designed. This number may exceed the actual number of circuits at the time of the calculation.

¹ In the calculation (EPC-400), this sag is converted into the sag which belongs to the standard conditions as laid down in NEN 1060: outside temperature 30°C, wind speed 0.6 metres/sec, ingress of sunlight 1000 W/m² and draft current.



2.3.2 Circuit data

The grid administrator records the following data for each circuit.

2.3.2.1 Voltage

The voltage for which the circuit has been/is being designed. If the current operating voltage is 150 kV, but the design voltage is 380 kV, 380 kV must be indicated.

2.3.2.2 Design load

The design load of the circuit in MVA. The design load is the product of the design voltage and the design current times $\sqrt{3}$.

$$S_{\text{des}} = I_{\text{des}} * U_{\text{des}} * \sqrt{3}$$

S_{des} : design load (volt.ampere)

I_{des} : design current (ampere)

U_{des} : design voltage (volt)

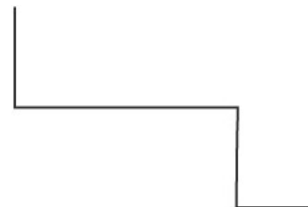
The design voltage for existing overhead high-voltage power lines is derived from the Capacity Plan 2005-2012, as submitted on 1 December 2005 to the Directie Toezicht Energie [Office of Energy Regulation] (DTe) of the Netherlands Competition Authority. In the course of 2006, this will be available from the DTe (at www.dte.nl). In the case of a new stretch, the design load is derived from the design details.

2.3.2.3 Circuit designation

The name and colour coding for the circuit as used by the grid administrator, or as the grid administrator wants to use for a new path.

2.3.2.4 Current

The current transported through an overhead high-voltage power line changes in strength every hour, day, week and season. Because epidemiological investigations have established links between long-term exposure and possible effects on people's health, it is chosen to base the calculations on the average value of the current over a period of a year. Because the calculated zone width also has to be relevant for the future, it is also chosen to estimate an upper limit for the annually averaged current expected in the future. This estimate is based on the current for which the circuit has been designed and the annual averages observed in 2003. An analysis of the currents during 2003 for all 380 kV and 220 kV circuits shows that an annually averaged current corresponding to approximately



30% of the capacity, is a good future-oriented estimate of the annually averaged current through a circuit. For these voltage levels, we therefore assume:

$$I_{cal} = 0,3 * I_{cap_2005} \quad (\text{for 380 kV and 220 kV circuits})$$

I_{cal} : current used as input for the zone calculation

I_{cap_2005} : current related to the capacity of the connection as laid down in the Capacity Plan 2005-2012

The current related to the capacity laid down in the Capacity Plan 2005-2012 is calculated according to:

$$I_{cap_2005} = S_{cap_2005} / (U_{cap_2005} * \sqrt{3})$$

S_{cap_2005} : capacity in Capacity Plan 2005-2012 (volt.ampere)

U_{cap_2005} : operating voltage in Capacity Plan 2005-2012 (volt)

Currently, insufficient data is available on the regional grids (voltage levels 150 kV, 110 kV and 50 kV) to allow a detailed analysis of the load. That is why an annually averaged current has been assumed for these circuits which corresponds to 50% of the capacity laid down in the Capacity Plan 2005-2012. For these grids, the calculation is therefore based on:

$$I_{cal} = 0,5 * I_{cap_2005} \quad (\text{for 150 kV, 110 kV and 50 kV circuits}).$$

2.3.2.5 Protective earth resistance

The protective earth resistance does not have to be included in the calculation.

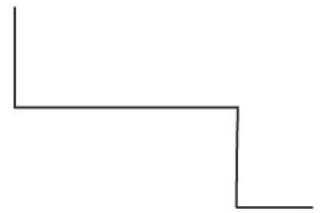
2.3.2.6 Phase

The phase angle is laid down for each phase wire, for example: 0°, 120° or 240°.

2.3.2.7 Characteristics of conductors

Here data on the construction of the conductor are supplied. The standard conductor is aluminum with steel inner sheath. The dimensions are laid down as a diameter, for example:

Aluminum : 240 mm²
Steel : 40 mm²



2.3.2.8 Bundle conductors

The number of sub-conductors which make up a conductor bundle and the distance and position between these conductors.

2.3.3 Earth wires

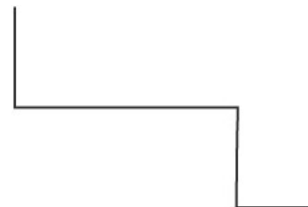
2.3.3.1 Number and position

The number of earth wires and the position at which the earth wires have to be connected to the pylon (height and lateral distance of the suspension point of each earth wire).

2.3.3.2 Characteristics of earth wires

This is where the data on the construction of the earth wires is laid down. The standard assumption is an aluminum conductor with a steel inner sheath. The dimensions are laid down as a diameter, for example:

Aluminum	: 44 mm ²
Staal	: 32 mm ²



3 Calculation

3.1 Introduction

A number of commercial software packages are available for the calculation of the magnetic field strength in the vicinity of an overhead high-voltage power line. At the moment these packages have not explicitly been assessed in regard of their suitability for the calculation of the 0.4 microtesla zone and no comparative research has been carried out into these software packages. In the Netherlands, the three software packages described in **Error! Reference source not found.** are the ones most often used for the calculation of magnetic field strengths. These packages cannot directly calculate the width of the 0.4 microtesla zone. For this to be done the profile of the magnetic field needs to be exported and processed.

3.2 Calculation of the magnetic field

3.2.1 Software

The following software packages are suitable for the calculation of the magnetic field strength. At the moment, these three packages are regarded as equivalent.

EFC-400

Software from *Forschungsgesellschaft für Energie und Umwelttechnologie* (FGEU, mbH, Berlin, Germany).

CDEGS

Current Distribution, Electromagnetic Fields, Grounding and Soil Structure Analysis. Software from Safe Engineering Services & technologies ltd., Quebec, Canada.

ATP

Alternative Transient Program

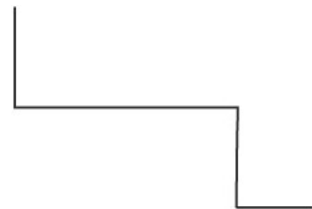
European EMTP-ATP Users Group (EEUG), Osnabrück, Germany.

3.2.2 Input data

If a program requires more input parameters than stated under **Error! Reference source not found.**, average data for the Netherlands is entered for these extra parameters.

3.2.3 Calculation of the magnetic field strength

Using the set of input parameters, the program calculates the magnetic field strength in the vicinity of the high-voltage line 1 m above ground level. In most situations only one overhead high-voltage power line is relevant. In these cases a ‘one-dimensional’



calculation is sufficient. If there is more than one high-voltage line in the area for which the calculation is taking place, a two-dimensional calculation has to be carried out.

One-dimensional calculation

In order to eventually be able to determine the width of the 0.4 microtesla zone of one overhead high-voltage power line, a calculation is required of the magnetic field strength as a function of the distance (step size at least 1 m), perpendicular to the high-voltage line, at the centre of the sag (in the middle between two pylons), at a height of 1 m above ground level² The calculation is carried out until the distance to the high-voltage line increases such that the strength of the magnetic field has decreased to less than 0.1 microtesla. The profile of the strength of the magnetic field thus acquired is saved for further processing. At the same time, the distance and the strength of the magnetic field at that distance are saved in addition to the general data on the calculation situation.

Two-dimensional calculation

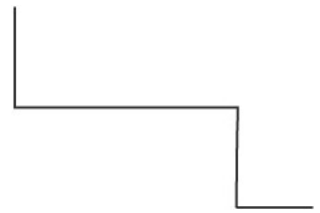
Situations can occur in which the calculation of a single profile of the strength of the magnetic field is insufficient. This is, for example, the case in the event of intersecting overhead high-voltage power lines, two parallel lines or a high-voltage line which branches off. In that case the area in which the magnetic field is stronger than 0.4 microtesla cannot be indicated as a simple distance. In this situation, a two-dimensional calculation is required in which the magnetic field strengths from both paths are added up as vectors at each location. The 0.4 microtesla zone is then shown in detail on a map of the surrounding area. This is then used to check whether sensitive designated uses are located inside the 0.4 microtesla zone. This map is also the calculation method end product. There is no need saving or carrying out any additional processing of a distance profile.

3.2.4 Determination of zone width

The profile with the magnetic field strength as a function of the distance forms the basis for the final calculation of the zone width. By means of interpolation, this profile is used to determine at which distance(s) from the centre of the overhead high-voltage power line the magnetic field strength value of 0.4 micro is reached. Because the profile is usually not symmetrical, this is done on both sides of the high-voltage line. The distances to the centre of the overhead high-voltage power line thus calculated are rounded to the nearest multiple of 5 m³. If these (rounded) values for the distance to the centre line are the same on both sides, then this value directly indicates half the width of the specific 0.4 microtesla zone. A zone width of 2 x 80 m means that the zone – calculated across the ground from the centre of the high-voltage line – extends to 80 m on both sides. If these (rounded) values for the distance to the centre line are different on both sides, then both values must be indicated separately. An indication of which value belongs to which side of the line is given using the name ('colour') of the corresponding circuit.

² For the sake of simplicity, no account is taken of the fact that the contour of the 0.4 micro tesla zone is actually curved and is wider at the middle point between the pylons than in the vicinity of the pylons.

³ In other words, 97.5 and 102.4 are rounded off to 100 m and 102.6 to 105 m



4 Reporting the results

The calculation results, the software used and the input data are recorded in a standardised manner. The ensuing report contains, first and foremost, the name of the overhead high-voltage power line, the numbers of the pylons involved and, for each line section, the (rounded) distance of the 0.4 microtesla contour on either side of the high-voltage line to the centre of the line. For example:

Results of the calculation of the 0.4 microtesla zone

name of the overhead high-voltage power line: location AAA to location BBB		
line section	distance 0.4 microtesla contour to centre of the line (m)	
pylon numbers	black circuit side	withe circuit side
50-51	65	80
51-52	70	90
52-53	70	90
53-54	65	80

Software package

EFC-400, version 5.1

Input data

Here all the data under 2.3 (including construction diagrams of the pylons) are listed.