Living near High-Voltage Installations

Electrical and magnetic fields

TenneT
Taking power further

Introduction

In its role as an electricity transmission company, TenneT has been tasked by the Dutch government with supplying everybody in the Netherlands with electricity. We are the owner of the largest part of the high-voltage grid from 110 kilovolts (kV) throughout the Netherlands and from 220 kV in a large part of Germany.
We work with the utmost care on guaranteeing a reliable electricity grid. We also attach great importance to giving people an insight into the potential effects of living close to high-voltage lines. The possible effects of exposure to magnetic fields in relation to high-voltage electricity are a subject of public concern and discussion. By means of this brochure we want to give you greater clarity about electrical and magnetic fields. People are exposed to electrical and magnetic fields in a variety of ways, for example when they use an electric shaver, hair dryer, microwave oven or personal computer or when they watch television. But the same exposure occurs during transmission of electricity over high-voltage lines.
TenneT frequently receives questions about EM fields and their effects on human health. What are electrical and magnetic fields? Do they pose a health hazard? Has the government imposed a maximum field strength?
You will find in this brochure our answers to frequently asked questions. We also set out our policy on magnetic fields and explain how we deal with them in our everyday work.

If you still have questions after reading the brochure, you are welcome to phone our Service Centre on 0800-8366388.

ir. J.M. Kroon MBA
Chief Executive Officer

01

What are electrical and magnetic fields?

Electrical and magnetic fields occur during the production, transmission, distribution and use of electricity. The strength of electromagnetic fields is referred to as ‘field intensity’. The word ‘field’ is a term used in physics to denote the effect that an object has on its surroundings. By analogy we could call the heat generated by a heater or a radiator a heat field (or thermal field).

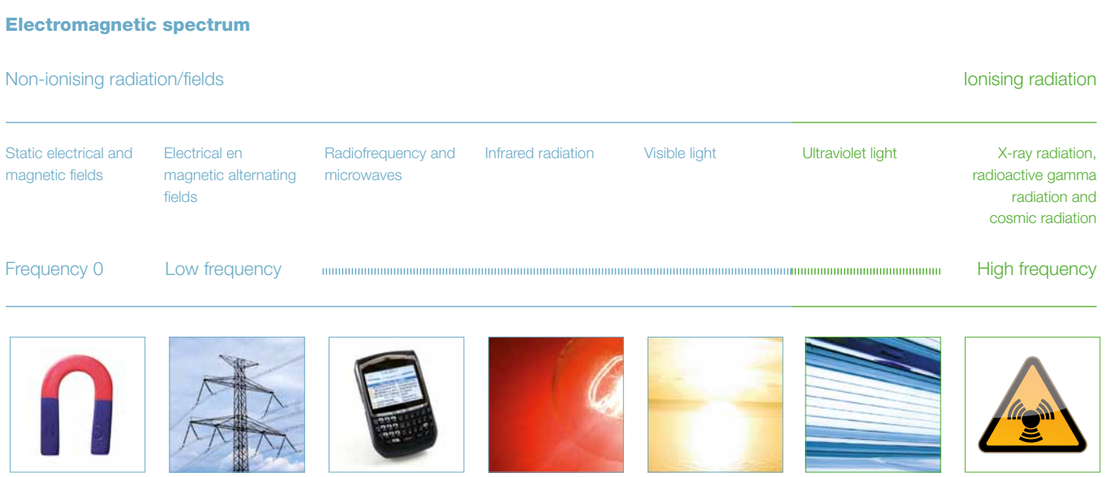
An **electrical field** occurs when there is a difference in voltage between an object and its surroundings. In other words: an electrical field is the consequence of attraction or repulsion of a certain electrical charge by another electrical charge.

When a light bulb is plugged into a power outlet and connected to the electricity grid, it creates an electrical field, even when the light switch is switched off. In short, anywhere where there are electrical lines, electrical fields exist. The electrical field is related to the voltage and is therefore expressed in volts. The electrical field is measured in volts per metre (V/m).

A **magnetic field** develops when there is an electric current. It is only when a light bulb lights up (i.e. when electricity flows through the wire) that a magnetic field occurs in addition to the electrical field. The magnetic field is related to the current that flows through the electric wire.

The magnetic field intensity is commonly expressed in microtesla, (μT) i.e. one millionth of a tesla.

Electromagnetic spectrum



Besides having a field strength, electrical and magnetic fields have a frequency. The frequency denotes how often each second the field changes direction. The various frequencies and their applications are located in the electromagnetic spectrum.

Some examples:

- earth magnetic field: 0 Hz. This field always points in the same direction.
- electricity supply: 50 Hz. This field changes direction in a cycle of 50 times per second.
- mobile telephony: roughly 1000 to 2000 MHz. This field changes direction in a cycle of 1 to 2 billion times per second.

The general rule is that the higher the frequency, the more energy the fields can transmit.

At frequencies higher than that of visible light (on the right of the spectrum), we refer to ionising radiation. This includes x-ray and radioactive radiation. Ionising radiation can transmit so much energy that it can directly damage human cells. At frequencies lower than that of visible light (on the left of the spectrum), we refer to non-ionising fields and radiation. This is where we find the fields of the electricity supply. Non-ionising radiation does not cause any direct damage to human cells. Depending on the frequency, there may be various effects when people are exposed to fields and radiation from the electromagnetic spectrum. This explains why the limit values that protect people against the effects of fields and radiation are entirely different for high-frequency fields than for low-frequency fields.

The light bulb is connected but not switched on: there is an electrical field.

The bulb is not only connected but is also switched on: there is now also a magnetic field.

Magnetic fields in µT

Appliance	(distances)	3 cm	30 cm	100 cm
	Electric shaver, hair clippers, hair dryer	10 to 200	0,1 to 5	< 0,3
	Microwave oven	10 to 100	1 to 10	< 1
	Drill, circular saw, sander, vacuum cleaner, mixer	10 to 100	0,5 to 5	< 0,5
	Alarm clock	10 to 60	< 0,4	< 0,4
	Oven, extractor	1 to 50	0,1 to 5	< 0,5
	Washing machine, dryer, dish washer	0,5 to 10	0,1 to 5	< 0,5
	Reading lamp (halogen)	0,5 to 5	< 0,5	< 0,1
	TV (at the front)	0,2 to 2	< 0,5	< 0,1
	PC monitor (at the front)	0,2 to 2	< 0,2	< 0,1

02

Electrical and magnetic fields with high-voltage lines and below-ground cables

We cannot usually see or otherwise perceive electrical and magnetic fields, but their strength can be measured. The field intensity depends on the voltage present (electrical field) or the electric current (magnetic field), but is also highly dependent on the distance between the field and the source. Just as with a heat source, the field strength with electrical and magnetic fields quickly decreases as the distance to the source increases.

At its highest voltage level, the Dutch electricity grid consists almost entirely of above-ground high-voltage lines. Numerous below-ground cables are also used at voltages of 150,000 V and lower. The lowest voltage level is almost entirely underground. These are the medium and low voltage cables found in residential districts and industrial areas.

Above ground

With a high-voltage line, the strength of the electrical field depends on the electrical voltage (the number of volts) and the distance to the conductors (wires). The electrical field is shielded by all kinds of different objects and materials, such as walls of buildings and trees. The magnetic field of a high-voltage line is related mainly to the amount of current that flows through it (the number of amperes) and the distance to the line. The values measured below the lowest point of a high-voltage line 1 metre above the ground are virtually always lower than 20 microtesla. As the magnetic field is independent upon the voltage, a line with a higher voltage does not by definition produce a higher magnetic field than a line with a lower voltage. However, lines with a higher voltage generally have a higher magnetic field because more electricity flows through lines with a higher voltage. Buildings and trees have hardly any effect on the strength of magnetic fields.

Below ground

Electrical fields play no role in underground high-voltage cables. The electrical field is completely shielded by the protective metal jacket around the cable and the earth above. At 1 metre above the ground, the underground cables usually have a higher magnetic field than above-ground high-voltage lines, but this value decreases as the distance to the connection becomes longer. This occurs faster than in the case of above-ground lines.

Limit values

An international panel of experts, called the International Commission for Non-ionizing Radiation Protection (ICNIRP), recommends limit values for exposure to electrical fields. The value is 5000 V/metre (ICNIRP). The limit value that ICNIRP recommends for magnetic fields is 100 microtesla.* The value of the magnetic field strength in cables with voltages from 110,000 to 380,000 V varies greatly and can be as much as 0.5 microtesla to over 100 microtesla. However, TenneT makes sure that nobody is exposed to magnetic fields greater than 100 microtesla

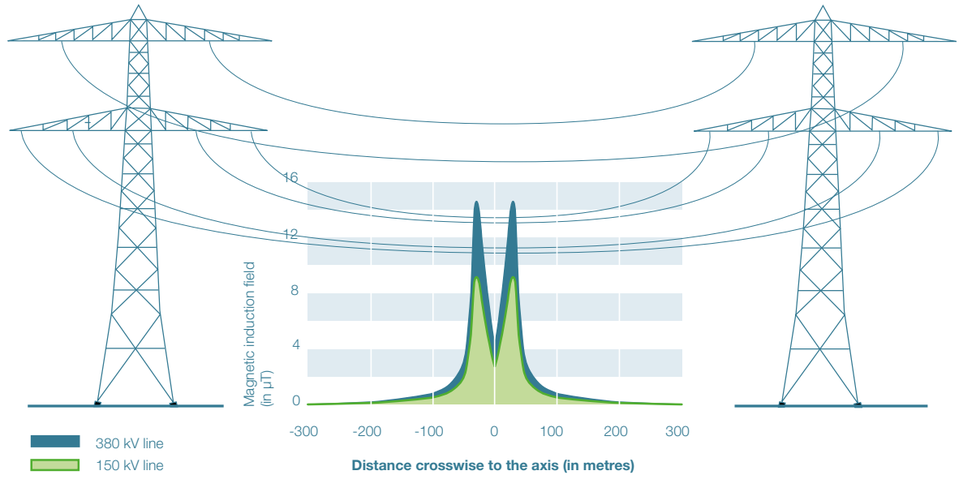
* ICNIRP recommendation from 1998

Overview of magnetic field strengths below high-voltage lines
Values beneath the lowest point of the conductors

Live high-voltage lines (stated in volts)		
	Magnetic field strength beneath the lowest point, 1 metre about ground level (in microtesla)	**Transmission capacity per circuit** (in ampere)
380.000	2 - 15	2.500 - 4.000
220.000	1 - 10	1.250 - 2.500
150.000	1 - 10	800 - 2.000
110.000	1 - 10	600 - 2.000
Wintrack (stated in volts)		
380.000	5 - 15	4.000

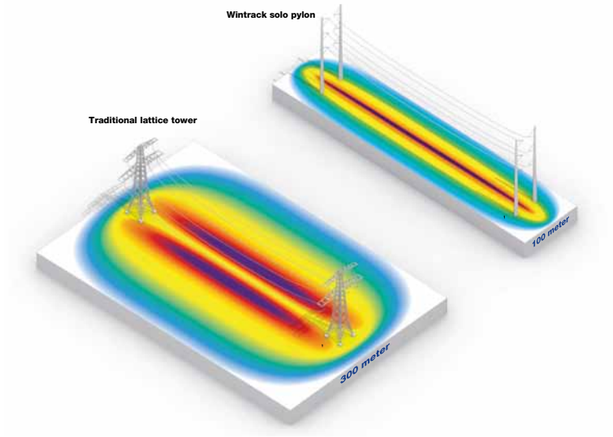
Combination lines (stated in volts)		
	Magnetic field strength beneath the lowest point, 1 metre about ground level (in microtesla)	**Transmission capacity per circuit** (in ampere)
380.000/220.000	2 - 20	4.000/2.500
380.000/110.000	2 - 16	4.000/600-800
Wintrack combi (stated in volts)		
380.000/150.000	4 - 15	4.000/1.150
380.000/220.000	5 - 20	4.000/4.000
380.000/380.000	5 - 20	4.000/4.000

Traditional lattice tower

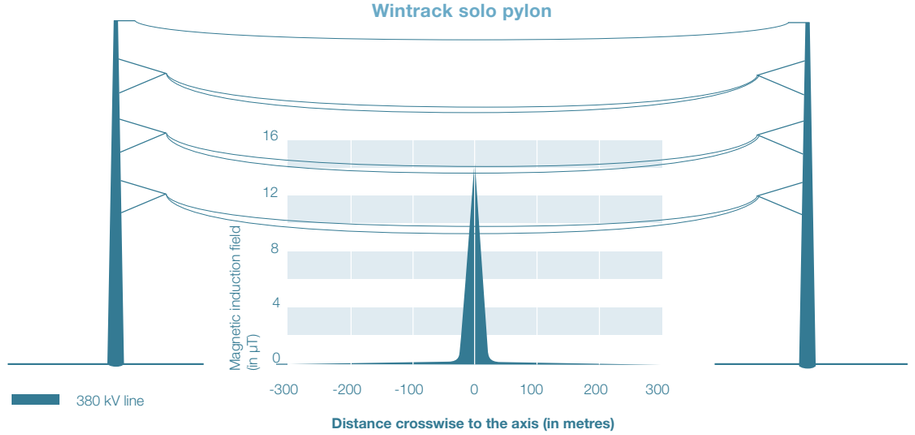


Magnetic fields

The graph shows a cross-section of the lowest point of a section of high-voltage line between two pylons and the measured magnetic field. The size of the magnetic field depends greatly on the amount of electricity that flows through it and the position of the conductors in the pylon, but also on the distance to the high-voltage line. As these images show, the field strength immediately below the lowest point of a line is significantly higher than in the proximity of a pylon and at some distance from the line.



Wintrack solo pylon



03

Electrical and magnetic fields and health

Scientific research
A lot of research has been conducted since the 1970s into the potential effect of magnetic fields on human health. The research has shown that is unlikely that electrical and magnetic fields caused by high-voltage lines or cables in the residential and working environments are harmful to health. It is clear, however, that when high and very high field strengths occur – although they do not occur in normal residential and working environments – there may be effects that potentially cause nuisance and theoretically may be harmful to health. Independent organisations have proposed limit values to protect people against these effects. Internationally, the most frequently applied limit values are those of the International Commission for Non-Ionizing Radiation Protection (ICNIRP). These are the limits that the European Union recommends. In the Netherlands, the government's policy on electrical and magnetic fields is also based on these limit values.
For members of the public, these limit values are at least 5 to 50 times lower than the lowest field value at which it has been demonstrated that they can cause effects. Research performed with test animals, cell cultivation and human volunteers has never established a causal relationship between exposure to these fields (with strengths lower than the limit values) and various diseases. Nor is any biological mechanism known that explains how a certain disease can be caused by exposure to electrical or magnetic fields.
A large number of epidemiological studies have been carried out to study a possible statistical relationship between, for example, exposure to magnetic fields and different diseases. Such studies try to find out, for instance, whether people living near high-voltage lines are more likely to have or to develop certain diseases than people living elsewhere. Most population surveys exhibit no statistical relationship between living close to high-voltage lines and any type of disease. But indications have been found that point to a tenuous albeit statistically significant relationship between living near high-voltage lines and leukaemia in children. This does not mean that high-voltage lines cause leukaemia in children. It is entirely conceivable that the found indications result from other factors or from errors in estimating exposure, or are based on coincidence. ICNIRP and the Health Council of the Netherlands have come to this same conclusion.

Government policy on high-voltage lines
The Dutch government's policy adheres to ICNIRP limit values, as recommended by the Council of the European Union. The applicable value is 5000 V/metre (ICNIRP) for electrical fields. The recommended limit value for magnetic fields is 100 microtesla. The Netherlands does not set limit values by law. Given the epidemiological indications, the Dutch government has decided to apply the precautionary principle and to formulate supplementary policy for new situations involving high-voltage lines.

In October 2005, the former Ministry for Housing, Spatial Planning and the Environment ('VROM') recommended in a letter sent to provincial governments, municipal authorities and managers of high-voltage lines the avoidance as far as reasonably possible of new situations where children spend prolonged periods of time in an area around above-ground high-voltage lines where the annual average magnetic field exceeds 0.4 microtesla.
This concerns:
- new above-ground high-voltage lines or modifications to existing lines;
- new buildings (homes, etc.) in the proximity of existing above-ground high-voltage lines.

Most population surveys exhibit no statistical relationship between living near high-voltage lines and any kind of disease.

The advice of the Ministry of Infrastructure and the Environment (VROM's successor) applies only to new situations because, even after many years of research, there are no indications of a causal relationship between exposure to magnetic fields of high-voltage lines and the occurrence of leukaemia in children*.

* As mentioned elsewhere in this brochure, it is correct that indications have been found for a tenuous albeit statistically significant relationship between living near high-voltage lines and leukaemia in children. However, a causal relationship has not been established between exposure to electromagnetic fields and various diseases. Nor is any biological mechanism known that explains how a certain disease can occur through exposure to electrical or magnetic fields.

TenneT is committed to installing and managing its high-voltage lines carefully and responsibly.

Another matter that needs to be considered is that measures taken in existing situations tend to be far-reaching (sometimes requiring people to move and the demolition of homes) and cost a lot of money, even though it is uncertain whether magnetic fields caused by high-voltage lines are harmful to health. In new situations, it is often easier to make allowance for sensitive amenities like housing and schools without this involving significant extra costs. All other situations are subject to ICNIRP's recommended value of 100 microtesla.

Magnetic field zone around existing high-voltage lines

The new policy presented the government with an opportunity to provide on the Internet further information about the magnetic field zone around existing high-voltage lines. The information can be found at www.rivm.nl/ hoogspanningslijnen/ netkaart. With a view to modifying zoning plans in the proximity of existing high-voltage lines, this information can give an initial indication about the zone of 0.4 microtesla. The 'specific zone' pivotal to government policy has to be calculated using a mathematical method prescribed by the government in a guidance document (RIVM, version 3, 2009).

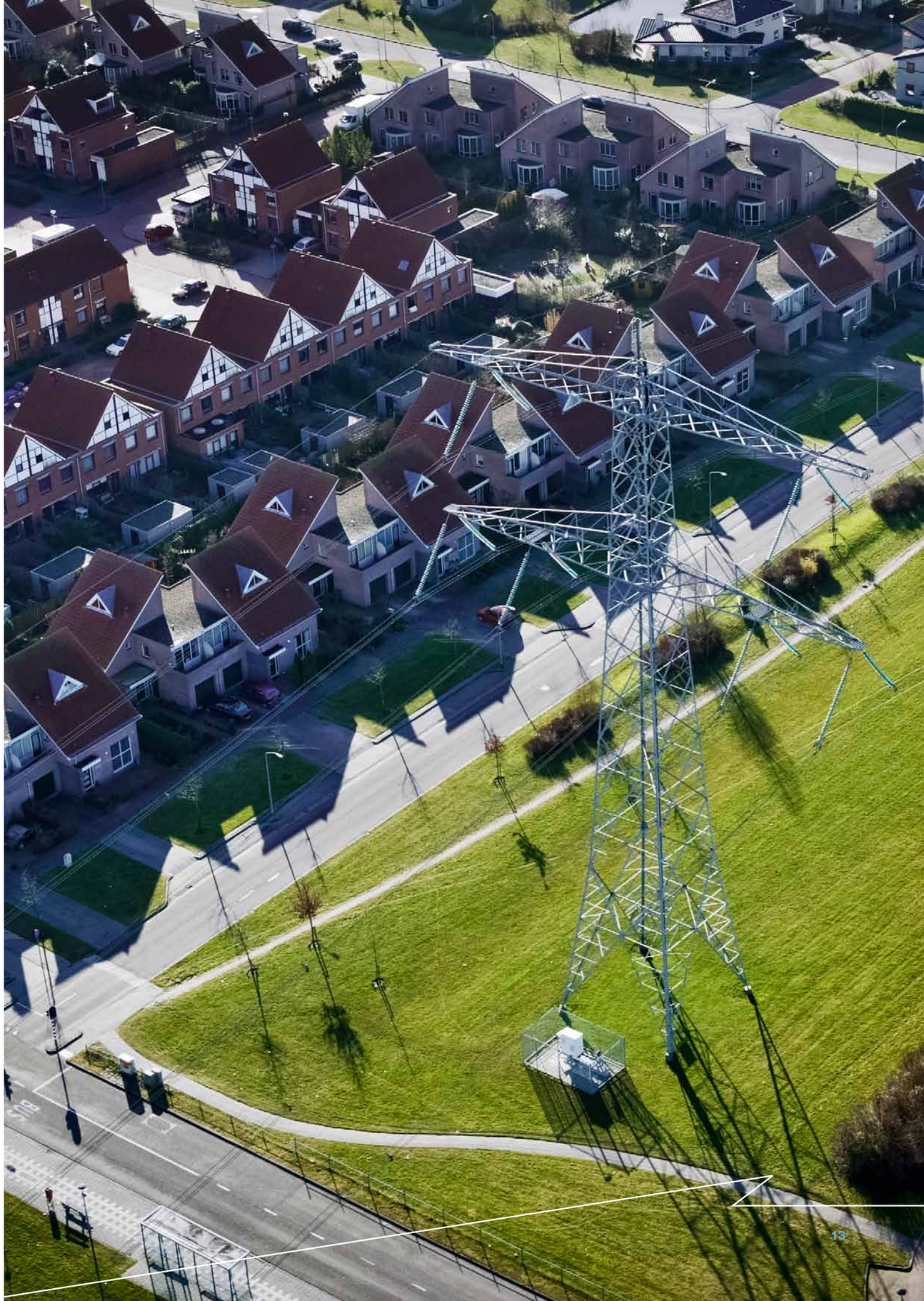
What is TenneT's policy?

TenneT is committed to installing and managing its high-voltage lines carefully and responsibly. So in addition to the engineering and economic interests involved in a transmission network, TenneT makes allowance for the wider public interest. TenneT does this by being clear and transparent about the field strengths that actually occur with high-voltage lines. On request TenneT measures and calculates the field strengths of its high-voltage lines and shares the information with authorities and local residents, the population at large and employees who work on high-voltage lines. The company also takes action by:

- supporting the development of knowledge of magnetic fields and health effects;
- initiating and conducting research into technical possibilities for limiting exposure. The development of the Wintrack pylon is a good example.

When planning and routing high-voltage lines, TenneT must apply basic principles designed to minimise the long-term exposure of persons to magnetic fields.
In practical terms, this means:

- bundling a new high-voltage line with existing infrastructure, thus keeping the high-voltage line outside residential areas;
- combining where possible high-voltage lines of different voltage in the same pylon, thus limiting as far as possible the area of exposure to magnetic fields;
- avoiding as far as possible buildings that are occupied permanently or semi-permanently close to high-voltage lines;
- considering supplementary measures in specific situations, such as:
  - altering the line height;
  - modifying the design;
  - cabling;
  - making compulsory purchases.



Glossary

Frequency
Number of changes of direction per second (cycle) in an alternating current.

Alternating Current (AC)
This is the type of electricity (electrical energy) supplied to households and industry by means of the electricity grid.

Hertz
A unit that expresses the number of changes of direction per second (cycle).

Microtesla (µT)
One millionth part of a tesla. This is the unit we generally use to express magnetic fields. Strictly speaking, microtesla denotes magnetic induction, but in practice it is frequently called the magnetic field strength.

Ionising radiation
Radiation is an umbrella name for energy (sometimes very high energy) in the form of electromagnetic waves or particles. Ionising radiation is sufficiently energetic to eject an electron from the outermost shell of an atom. This gives the atom in its totality a positive charge instead of a neutral charge; the atom is ionised, and becomes an ion. You cannot see, hear, taste, smell or feel the radiation.

Electricity
Electric current is the movement of electrons (negative electrical charges) in a conductor, for example a live steel wire. The intensity of the current is expressed in ampere (A).

Voltage
Electrical voltage is the difference of potential between two points in an electrical circuit. Volt is the unit of electrical potential. It is expressed in volts (V) or in kilovolts (1 kV = 1.000 V). The strength of an electrical field is expressed in volts per meter (V/m) or in kilovolts per meter (kV/m).

Field
An electrical field occurs when there is a difference in voltage between an object and its surroundings. A magnetic field develops when there is an electric current.

Capacity
Capacity is the product of voltage and current and is expressed in watts (W) or kilowatts (kW) (1 kW = 1000 W).

Further information

If you wish to learn more about electrical or magnetic fields, you can contact the following organisations:

Dutch

Health Council of the Netherlands (De Nederlandse Gezondheidsraad)
www.gezondheidsraad.nl

Ministry of Infrastructure and the Environment (Ministerie van Infrastructuur en Milieu)
www.minienm.nl

Dutch National Institute for Public Health and the Environment (RIVM)
www.rivm.nl

Knowledge Platform for Electromagnetic Fields (Kennisplatform Electromagnetische velden)
www.kennisplatform.nl

English

The International Commission for Non-Ionizing Radiation Protection (ICNIRP)
www.icnirp.org

World Health Organization (WHO)
www.who.int, under ‘Health topics, Electromagnetic fields’

National Grid
http://www.emfs.info

Council of the European Union
htttp://ec.europa.eu/health, under ‘Health & Environment, Electromagnetic fields’

TenneT is Europe's first cross-border grid operator for electricity. With approximately 20,000 kilometres of (extra) high voltage lines and 36 million end users in the Netherlands and Germany we rank among the top five grid operators in Europe. Our focus is to develop a Northwest European energy market and to integrate renewable energy.

Taking power further

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