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Referentie

Position paper

Aspects of security of supply and grid safety in the 380 kV grid

Responsible and innovative underground cable installation

Summary

- **Use of 380 kV cable limited because of grid safety risks**
- **Innovation: installation of 20 km of cable below ground in Randstad 380 kV project**
- **Study by Delft University of Technology: monitoring of system behaviour**
- **Policy principle: 380 kV preferably above ground, 150 kV and lower may be installed below ground**

There is widespread public support for underground installation of new high-voltage lines. On account of system risks, TenneT has nevertheless decided in principle to construct new high-capacity transmission lines (with a voltage level of 380 kV) above ground for the time being. This decision is based on technical arguments related to grid operation, including the fact that underground cables have a negative impact on grid safety, and increase outage risks. This document explains these matters.

Proven technology and innovation

The highly integrated European 380 kV transmission grid has been constructed almost entirely above ground, with the exception of certain short, special-purpose grid sections where cables are used, for example when crossing a waterway. In light of public calls for underground installation, TenneT wants to gain more experience with this method of construction in the near future, but obviously without taking any irresponsible risks. The 380 kV grid is fast becoming a grid for very large transmissions subject to stringent availability and controllability requirements. This imposes specific demands on grid safety, for instance with respect to component failure and maintenance of the grid’s stability. So for the time being 380 kV cables can be used only to a limited extent, given their specific characteristics and system behaviour, and the absence of sufficient (international) experience with the system behaviour of cables.

At year-end 2008 the Minister of Economic Affairs took a decision regarding the route of the Randstad 380 kV project. The decision also established which line sections would be constructed above ground and which would be installed below ground. The minister reached her decision in the knowledge that about 20 kilometres out of a total of more than 80 kilometres could be installed underground in this project. The minister followed TenneT’s recommendation. There was a responsible weighing up of the pros and cons of above-ground and below-ground construction have been carefully considered while taking account of the current state of the art.

In this project TenneT is striving for maximum use of underground 380 kV cable without taking unacceptable reliability risks. TenneT wants to gain experience with cable by monitoring its operation and behaviour and studying system behaviour. By installing more than 20 kilometres of dual-circuit 380 kV cables with a transmission capacity of 4000 amperes per circuit, the Netherlands will rank among the top countries in the world as regards 380 kV cables. Together with Delft University of Technology and foreign partners, TenneT is planning to set up a programme for monitoring the system's behaviour over a period of 6 to 8 years to gain information for further grid expansion. Pending the research results 380 kV connections in the Dutch transmission grid will be confined to a maximum of 20 km.

System behaviour of cables
The technical behaviour of a cable differs from that of an overhead line. The cable can be made manageable by adding compensating equipment. The major challenge in operating a high-voltage grid is to assure an uninterrupted supply of electricity. The generated electrical energy must be able to reach users at all times. It is important to manage the voltage level and the size of the transmissions, and to maintain a constant frequency level. This is easier to accomplish when the grid is constructed mainly above ground and has fewer components than when the grid is underground and the required compensation equipment has been added to it.

A grid consisting of above-ground lines and cables with extensive use of compensation equipment results in uncertainty regarding the grid's voltage stability. Experience shows that voltage instability is the main reason for large-scale black-outs in high-voltage grids. Technically, it is possible to install cables over a greater length. However, further research is needed to determine the technical and operational feasibility of underground cable links over large distances in meshed 380 kV transmission grids.

State-of-the-art 380 kV cable
There are international technical requirements for installations that prescribe behaviour in fault situations, but 380 kV cable systems remain difficult to manage. Therefore, developments in this field must be monitored closely. In the course of time, this problem was resolved in grids with voltage levels up to 150 kV, but it is much more challenging in 380 kV grids. The complexity also depends on the grid's design: the length of its connections, the number of circuits and the grid's capacity. For that reason great caution is exercised internationally when using cable over large distances in the 'arteries' of the European electricity transmission grid.

Despite the international wariness, TenneT has opted to use 20 kilometres of cable for the northern and southern ring of the Randstad 380 kV project. Internationally, this represents an enormous challenge. Pending the results of the research by the Delft University of Technology into monitoring the system behaviour of 380 kV cables TenneT wants provisionally to stick to the 20-kilometre maximum for all arteries in the Dutch 380 kV grid. The findings of the research are expected to be known within 6 to 8 years.

Fault risks with 380 kV cable
The annual number of faults (frequency) in above-ground lines and cables is very small and statistically roughly the same (0.00353 and 0.00657 faults/kilometres/year). If a fault occurs the connection must be restored quickly to avoid impairment of the redundancy built into the grid. A subsequent fault may have serious consequences and a power outage will cause major damage. It has been calculated that a one-hour power outage in the Randstad region would cost society approx. EUR 72 million. (source: SEO 2003).

Experience gained with cable connections has shown that a cable circuit is out of operation for 2 to 20 days after each disruption, but in practice there will also be far longer repair times. It takes far less time to repair failure in above-ground connections: 8 to 48 hours. In addition, not all incidents in above-ground lines result in circuit outage because of the self-repairing characteristics of these lines. In the event of an incident (i.e. a short circuit caused by a lightning strike), a line can quickly switch itself off and automatically run a test before switching itself on again. With an underground cable, this is more complex and an automatic restart is risky.

Costs
The investment costs of installing cable for a 380 kV line section are high. On average, these costs are approx. four to eight times higher than the costs of investing in above-ground lines, depending on the transmission capacity and route-related aspects. For 380 kV, the difference is estimated to amount to some EUR 10 million per kilometre.

Policy framework: above-ground and below-ground construction
TenneT, the Dutch national Transmission System Operator, manages approx. 9,000 kilometres of high-voltage connections of 110 kV and higher. Together with the cross-border interconnections, these lines comprise the national transmission grid. These ‘highways’ of the electricity system are essential for the security of supply. The grid is scheduled to undergo major expansion in order to accommodate new power plants, off-shore wind parks and the rapid increase in the number of combined-heat-and-power plants in the horticultural sector. When constructing new connections, TenneT takes environmental considerations into account, as well as security aspects, costs and the grid’s technical capabilities. In doing so, we develop new and creative solutions where appropriate. In the Randstad region, we use innovative Wintrack pylons with reduced magnetic field intensity for above-ground construction.

The government recently approved the third Electricity Supply Structure Plan (SEV III), which includes this exchange principle, and places a cap on the total length of the grid’s above-ground high-voltage lines of 110 kV and higher. This means that new 380 kV lines can be realised above ground, provided that elsewhere a high-voltage line of the same length is moved, combined or installed below ground at another location. In this way, the total length of the above-ground lines remains the same. Moreover, this integral approach ensures that underground cable will be used where it is relevant and efficient to do so, as in the case of difficult intersections with waterways, in the proximity of built-up areas and in areas of exceptional ecological value. It is technically less complicated and much cheaper to install 110 kV and 150 kV lines below ground. The implementation of this policy framework is currently being worked out.
According to the most recent scientific views, aboveground high-voltage lines have no influence on the harmful health effects of particulate matter. They can sometimes charge particulate matter with electricity, but too little to let it cling more than normal to the lungs, respiratory tract and skin. The parties involved in building new high-voltage lines regularly discuss particulate matter. TenneT is tackling the subject seriously by commissioning research together with the Ministry of Housing, Spatial planning and the Environment. This document summarises the studies and provides background information about particulate matter.

Research by RIVM and KEMA 2007

RIVM
Even the very latest scientific views point out that aboveground high-voltage lines have no influence on the harmful health effects of particulate matter. High-voltage lines can sometimes charge particulate matter electrically, but too little to cling more than normal to the lungs, respiratory tract and skin. This is what the National Institute for Public Health and the Environment concluded after conducting a literature search commissioned by the Ministry of Housing, Spatial Planning and the Environment.

The reason for the research was the concern that exists about the health of those who live both near a busy main road and close to a high-voltage line. The concern stems from scientific publications that claim that electrical discharges at high-voltage wires can charge particulate matter. This is said to cause more particulate matter to attach itself to the lungs, respiratory tract and skin. It is claimed that this could aggravate the effects of particulate matter (through cardiac and respiratory disorders).

Measurements demonstrated the occurrence of electrical discharges at high-voltage lines, the charging of particulate matter and the dissemination of the extra-charged particulates by wind. However, a plausible case was not made for the extra precipitation of particulate matter in the lungs, respiratory tract or skin. A lot of extra charging of particulates only causes extra precipitation in the respiratory tract at a charge ten times higher than can occur at a high-voltage line.

The findings of the National Institute for Public Health and the Environment (RIVM) are in line with those of the Netherlands Health Council in 2001 and the World Health Organisation of June 2007. Therefore, the Ministry of Housing, Spatial planning and the Environment sees no reason to amend its precautionary policy concerning high-voltage lines.

KEMA
In 2007 KEMA technical consultants performed more detailed research on behalf of TenneT into the influence of high-voltage lines and stations on the quality of air.

Under certain conditions (as with coroner discharges) particulates present in damp outdoor air can be charged electrically through the presence of electric fields. This can change their precipitation behaviour, i.e. where they come down and cling to a surface. This might possibly influence the harmful health effects of particulates. Literature on this subject mentions two ways in which aerosols - charged solid particles and liquid droplets floating in the air – may be capable of affecting health:

1. Increased cardiac and respiratory disorders and lung cancer caused by increased deposits of charged aerosols in the respiratory tract and lungs. However, there are no indications of a heightened occurrence of such disorders or lung cancer among people residing in the proximity of high-voltage lines or switching and transformer stations. If this hypothetical effect were to exist, it would be too small to demonstrate even by means of an epidemiological study.
2. Increased skin cancer caused by higher precipitation of charged aerosols on the skin. The charged particulates consist in part of radioactive decay products of radon; however, this radiation hardly ever reaches the base layer of the skin. There are no indications of a heightened risk of skin cancer among persons residing in the proximity of high-voltage lines.

The assumption of possible harmful health effects by air-polluting products influenced by high-voltage connections is based on a real physical phenomenon: the electrical charging of particulates in the air. There are no biological indications that such charged particles are actually more harmful to health than uncharged particles. Even if this effect were to exist, it would be too small to demonstrate even by means of an epidemiological study. Moreover, there are no epidemiological indications of a heightened risk of cardiac or respiratory disorders, lung cancer or skin cancer among people residing in the proximity of high-voltage lines and stations.

Background information about particulate matter

Particulate matter consists of particles smaller than 10 micrometers that float in the air. It is a constituent part of air pollution and harmful to health. Particulate matter stays floating in the air. Its size and origin differ so there is a varying chemical composition. More attention has been directed towards this form of air pollution due to the discussion about global solar eclipse, because it is even said to be capable of having consequences for the climate.

What is particulate matter and what does it do?

Particulate matter (or PM_{10}) is an umbrella name for all kinds of small particles that occur in the air: from grains of sand and soot particles to pieces of worn-off car tyres or road surfaces. Particulate matter can also occur through reactions between different gases in the air. The average concentration of particulate matter in the Netherlands is higher in the south, near large cities and close to industrial areas. PM is the usual abbreviation for particulate matter. Depending on the cross-section of the particulates, they are called either PM10 for particles with a cross-section up to 10 micrometers or PM2.5 for those with a cross-section up to 2.5 micrometers.

Particulate matter consists of:
Primary matter - This goes straight into the air as particles.
Secondary matter - This is formed through conversion processes in the air from sulphur dioxide (SO_2), nitrogen oxide (NO_x) and ammonia (NH_3);
Unmodelled particulate matter – This is particulate matter that is difficult to measure and difficult to tackle, mainly of natural origin (sea salt, soil dust, a hemispherical contribution from outside Europe and residues of water and biomatter).

Origin of particulate matter

Model calculations show that at least 45% of particulate matter constituents are of anthropogenic origin (caused by mankind). Two-two thirds of this comes from foreign sources and one-third from the Netherlands. From this it follows that (at least) 15% of the total particulate matter concentrations can be influenced by Dutch policy. The other 55% consist largely of contributions of sea salt, soil dust, the large-scale hemispherical background and unknown and possibly incorrectly modelled anthropogenic sources. High-voltage lines or stations do not emit particulate matter, so they are not source. However, corona ions form at both and they are capable of electrically charging aerosols in the air. Consequently, there is an indirect effect.

Health effects

Particles smaller than 10 micrometers penetrate the respiratory tract when breathed in.

Therefore, airborne particulate matter can lead to health complaints and even premature death.
Epidemiological studies show that in the Netherlands between 2300 and 3500 people die early each year due to the acute effects of exposure to particulate matter. Based on the long-term effects of chronic exposure to particulate matter, it is possible that as many as 12,000 to 24,000 people in the Netherlands could die prematurely each year. Prolonged exposure to particulate matter can result in health problems and possibly early death. Diseases that can be caused or aggravated by particulate matter include cardiac and lung diseases, bronchitis and asthma. Statistically, there has been a general increase in recent decades in the number of respiratory disorders (CARA) among young children.

When breathed in the small floating particles end up in the lungs. Larger particles are retained in the nose and excreted via the mucous membrane. In 2004 it is estimated that between 1700 and 3000 people in the Netherlands died prematurely because of the acute effects of breathing in particulate matter. In the long term the general consensus is that 10% of all fatalities will be caused by particulate matter. A few risk groups are extra-sensitive to particulate matter, such as the elderly, children and people with respiratory disorders.