A pilot using water pressure to install 2 150 kV cable circuits in a horizontal directional drilling

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☐ **Young Researcher** (Proved full-time engineering and science university researchers and Ph.D.students under 35 YO)

ABSTRACT

The space required and available to install cables in a cable trench using open excavation is becoming less and less available. TenneT will therefore increasingly want to install cables using long-length directional drilling. The desired longer lengths of directional drilling will exceed 2000 metres. Traditionally, the cables are then pulled in with a winch wire. When pulling in the cables, the maximum tensile forces and the so-called side-wall pressure on the cables must not be exceeded, this influence the maximum cable length. Another possible installation method could be water pressure to float in cables. To build up experience a pilot was started.

KEYWORDS

Long cable lengths, horizontal directional drillings, water pressure, floating in cables, tensile forces.

INTRODUCTION

The cross-border grid operator TenneT owns about 1800 km of 110 kV and 150 kV cable and 80 km of 220 kV and 380 kV cable circuit in the on-land power grid of the Netherlands. In the coming years the cable length will continue to grow. The forecast of the grid expansion is about 3000 km.

Due to the limited areas to get permits, install and operated high voltage cables more and more horizontal directional drillings (HDD) will be in place. Also the HDD's will become longer and longer. TenneT is aiming for HDD's lengths of > 3000 meter.

At longer HDD lengths and big cable cross sections the maximum allowed pull force on the cables and side wall pressure will exceeded using a winch wire. Therefore alternative installation methods are needed and TenneT is actively looking for and piloting the new methods. One of the methods used is using water pressure to float in cable into the plastic ducts in the HDD's. This paper describes technical features of the technique, the pilot using this technology and lessons learned.

PILOT PROJECT DESCRIPTION

Scope

To enable the construction of a new residential area, part of the above-ground 150 kV overhead lines had partially to be undergrounded.

For this purpose, 2 times 7 plastic ducts (200/163 mm) with a length of over 1100 m and a maximum depth of approximately 25 m were installed with two HDD's. Traditionally, the 150 kV cables are installed in the pipes with a winch wire. In this 150 kV cable project, the water pressure method was used for the first time as an alternative to pulling in with a winch wire. The water pressure method is an innovative technique for 110 / 150 kV cables, where hydropower is used to force the cables through the plastic ducts. The tensile forces on the cable are mitigated by the water-powered propulsion of the water pressure method. A total of 6 cables were installed using a winch wire and 6 cables using the water pressure method.

Cable type

Two types of cables types were used, cable type 1 is a 87/150 kV cable with 1200 mm2 solid Aluminium core, having a diameter of ~ 93 mm and a mass ~ 8,8 kg/m. Cable type 2 is basically the same cable, but with an extra layer with optical fibre inside, having a larger diameter of ~ 98 mm and a mass of ~ 9.1 kg/m. The maximum pulling force is 24000 N (pulling head on core) and 8800 N (cable sleeve). The minimum bend radius is 1.46 m (installed) and 2.44 m (during pulling).

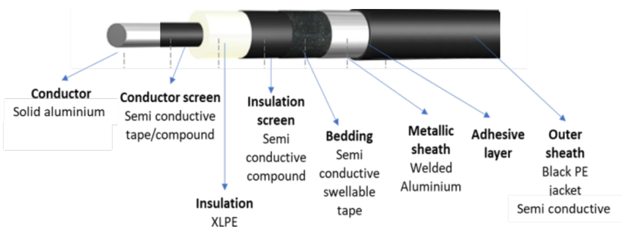


Fig. 1 Cable type 1 used in the pilot project

TECHNIQUES TO INSTALL WITH WATER PRESSURE

Traditional winch pulling

The traditional way to install cables into pipes is pulling them with a winch. For this first a pulling rope has to be installed. Also installation equipment and people are required at both ends of the pipe. Furthermore the capstan effect (friction of the cable under tensile load in bends) limits the cable lengths which can be installed in one pull. Synchronization between winch and drum pay-off is often troublesome.

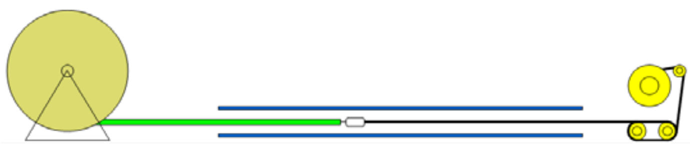


Fig. 2 schematic overview 'winch pulling'

Looking at possible drawbacks using traditional winch pulling (for long length HDD's) in the pilot project water pressure was used. Using water pressure, three kind of techniques can be used: Floating (no pig used), WaterPushPulling (with pig) and FreeFloating (2 pigs, one in front of and one behind the cable, moving the cable by the sole action of water, loose from the machine, like "tube post"). Below these techniques are globally described for more details see reference [1-8].

Floating

In the first technique, called Floating, water under pressure is injected into the pipe with cable, creating a high speed (higher than the cable speed) water flow, while at the same time the cable is pushed into the pipe (and pulled from the drum). The high-speed water flow creates a distributed drag force propelling the cable. This distributed force locally compensates the friction between cable and pipe, avoiding axial force build up in the cable, hence eliminating the capstan effect. The same trick as with cable blowing, a technique used worldwide today to install optical cables into pipes. Extra beneficial effect with Floating is the buoyancy of the water, reducing the friction between cable and pipe. With this technique extremely long installation lengths can be reached (with Low Voltage cables already 10 km has been reached, and with optical cables 12.4 km), also in trajectories with many (preferably smooth) bends. Moreover, there is the benefit of single point entry (installation equipment, cable drums and people), reducing operation and labour costs considerably. The technique is user and cable friendly (low forces, no cable wear) with compact equipment and does not suffer from synchronization problems with the cable drum. With the present equipment a comfortable cable speed of 20 m/min can be used (but also less when required).

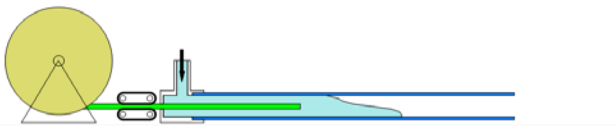


Fig. 3 schematic overview 'Floating'

WaterPushPulling

The second technique, called WaterPushPulling, is mainly the same as Floating, except that a pig is mounted at the head of the cable. Now all forces exerted by the water under pressure are concentrated at the cable head and the water flows with the same speed as the cable. The latter makes it possible to still use relatively small pumps for larger diameter pipes (e.g. larger than 100 mm internal diameter). The relatively high pulling force at the cable head also enhances passing sharp bends. But, the capstan effect is back again. Fortunately, pipe trajectories for energy cables are rather straight and buoyancy has not vanished. With balanced pushing and pulling forces (still lower than with winch pulling) installation lengths can also be very long (3.3 km reached with cables with aluminium core), usually much longer than with winch pulling. When using a "sonic head" (pig with valve that opens at adjustable pressure) the advantages of Floating and WaterPushPulling can be combined and optimized to the pipe trajectory, even when the latter is extremely curved and with small bend radii (a 82 mm 3x36 kV cable could be installed over 646 m into a HDPE pipe with internal diameter of 102 mm, wound in 46 coils with continuous bend radius of 2 m).

Fig. 4 schematic overview 'WaterPushPulling'

FreeFloating

The third technique, called FreeFloating, is maybe the most appealing one. It starts after a cable has been entirely installed by WaterPushPulling, with a special pig used. Then the pipe is extended at the entry side such that the cable is entirely inside, and with some space to insert a rear pig. Next the pipe is closed and water under pressure admitted. The rear pig is "communicating" with the front pig such that they share the water pressure. In this way the cable is effectively PushPulled by the sole action of water, loose from the machine, and travels further like "tube post". The cable can be placed at any desired location. There is in fact no limit how far the cable can be transported, as the water pressure difference is mainly effective at the pigs. There might be some viscous pressure loss over the feed length of pipe, but this can be reduced at wish by reducing the cable (and water) speed. In fact, higher cable speeds are reached with FreeFloating (e.g. 40 m/min) than with WaterPushPulling, when the pipe is not too narrow and not too long.

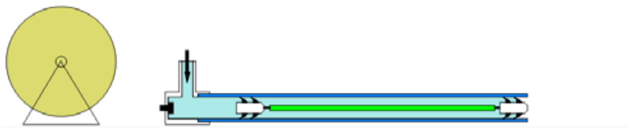


Fig. 5 schematic overview 'FreeFloating'

PREPARATIONS

Coefficient of friction

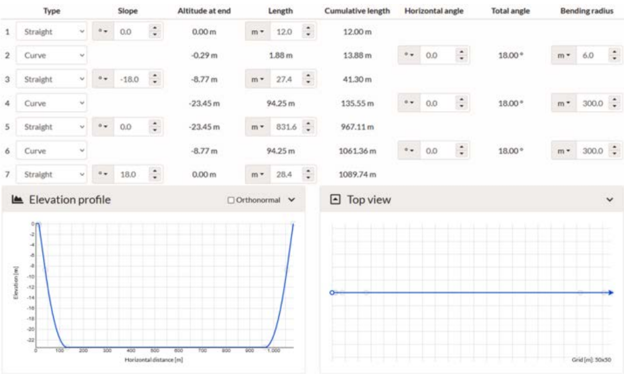
The high voltage cables have a semi-conductive outer layer, and therefore show a relatively high coefficient of friction (COF) with the duct.

Samples of cable and pipe were measured with a "Sloped Duct Test" [9] to measure the coefficient of friction (COF) between them. Before lubrication a COF of 0.30 was measured, after lubrication of the pipe 0.19 and after also lubrication of the cable 0.11.

Fig. 6 set-up for slope test to determine the COF

Trajectory parameters

The trajectory parameters were obtained with help of the HDD drill drawings. With use of the available software the following is obtained:



	Type	Slope	Altitude at end	Length	Cumulative length	Horizontal angle	Total angle	Bending radius
1	Straight	° 0.0	0.00 m	m 12.0	12.00 m			
2	Curve		-0.29 m	1.88 m	13.88 m	° 0.0	18.00 °	m 6.0
3	Straight	° -18.0	-8.77 m	m 27.4	41.30 m			
4	Curve		-23.45 m	94.25 m	135.55 m	° 0.0	18.00 °	m 300.0
5	Straight	° 0.0	-23.45 m	m 831.6	967.11 m			
6	Curve		-8.77 m	94.25 m	1061.36 m	° 0.0	18.00 °	m 300.0
7	Straight	° 18.0	0.00 m	m 28.4	1089.74 m			

Fig. 7 HDD trajectory parameters

Simulations of forces

Above parameters were used for theoretical calculations of the to be expected forces. In the figures below the results are shown of WaterPushPulling and Floating.

Note: the figures represents that the cable is already at the end of the duct (pulling force along the cable given by the blue line and the red line the pig pulling potential).

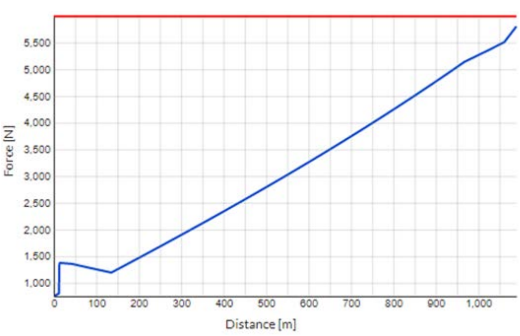


Fig. 8 WaterPushPulling: 2.85 Bar, 190 daN push → COF 0.27

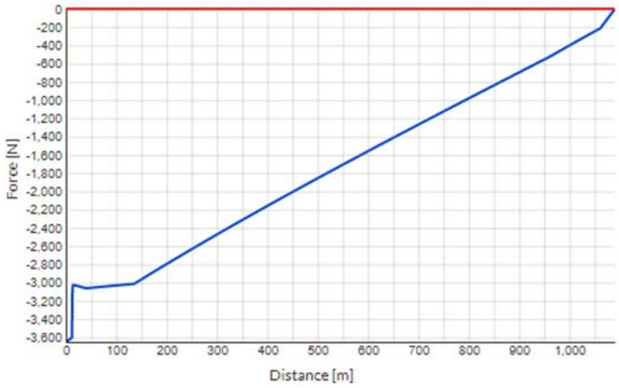


Fig. 9 Floating: 0.33 Bar, 440 daN push → COF 0.21

INSTALLATIONS

For the project installation was done by WaterPushPulling. A set-up equipment is shown in the figure below. The total footprint of the water pressure equipment and cable drum is small in size and can be fitted in nicely.

Fig. 10 footprint of water pressure equipment and cable drum

In the figure below a detailed picture is shown of the water pressure equipment itself.

Fig. 11 water pressure equipment

It was easy going with relatively low pushing force and water pressure. For example the 98 mm cable (with optical fibre) of circuit 2 phase 8 was installed with a pushing force of 190 daN and 2.85 bar water pressure (600 daN on the pig) at the end. When the pig came out the water pressure dropped to 0.33 bar (70 daN on the pig), while the flow increased from 200 to 300 l/min, and the pushing force increased to 440 daN. Here feeding the excess cable length was done in Floating mode until the cable was fed into the first cable puller. This assistance can be recognized by the drop in pushing force after the peak. Later the pushing force could be reduced further by lowering the speed of the pushers for a better match with the speed of the cable pullers. The COFs for WaterPushPulling and Floating were obtained from theoretical simulation and the slope test. In the figure below the operational chart is shown where the pushing force is plotted over distance.

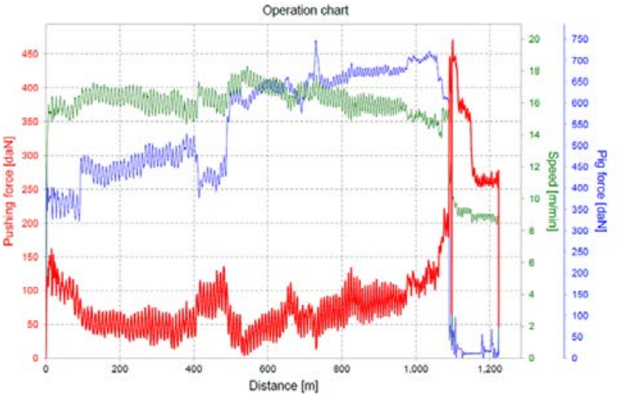


Fig. 12 operational chart – data from pilot project

CONCLUSIONS

The water pressure with the WaterPushPulling technique was used for the first time in The Netherlands with 150 kV cables.

An initial evaluation of this field trial has shown that the water pressure method has been successful. Below are a number aspects listed of the applied water pressure method:

- The cables can be installed at a speed of 18 m/min.
- The cable drums, installation equipment and crew only need to be present on the entrance side of the route / HDD.
- Outside the directional drilling, 150 m of additional cable length has been installed by Floating in the cable trench.
- The installation is done with low forces (typically 300 daN pushing force and 600 daN pulling force due to the water pressure of approximately 3 bar). In the future, with greater forces and water pressure, at least double cable lengths are expected.

PERSPECTIVES

TenneT will look for near future possibilities to demonstrate water pressure technique on HDD's with longer length and possibly greater depth. In addition, it can be investigated whether cable can be installed in two successive HDD's, the so-called through-floating.

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