1. The Three Cable Sections

Cables are laid along 14.5 km of the connection – in three sections.

1.1 Tebbestrup-Hornbæk (Gudenådalen)

A couple of kilometres south of the river Gudenåen at Randers, a cable transition compound is built at Tebbestrup. Here the line changes from being an overhead line to underground cables. From Tebbestrup to cable transition compound Hornbæk, two 400 kV circuits are buried, a 150 kV circuit as well as one or two 60 kV circuits on part of the section. The section from Tebbestrup to Hornbæk is 4.5 km long.

Figure 1 (map)

North of the compund Tebbestrup, the line crosses an undulating woodland area. Permission was not granted for digging open trenches for the cables through the woods, and it was not possible to move the circuit to another cable route. Controlled directional drillings were therefore made beneath the woods. The circuit was installed using directional drilling with pipes through which the cables were then pulled. It was difficult to carry out the directional drillings because of the undulating countryside and the soil conditions. It was even necessary to bore at a depth of 6 m for an approx. 10 m long section. A single directional drilling was made for each 150 and 400 kV cable as well as one for the three 60 kV cables, i.e. 10 directional drillings in all. Each boring was 220 m long.

Directional drilling profile. Figure 42

Crossing Gudenåen as well as roads, railway and river was carried out with one directional drilling per circuit. Three pipes were simultaneously pulled after the directional drilling.

Drawing illustrating the concept. Figure 10

It is extremely wet in Gudenådalen. Prior to construction it was necessary to dig trenches along both sides of the cable route. A drainage pipe was also laid to dewater the trench. Numerous pumps were in operation around the clock during the works.

Within a few years the authorities plan to allow the area to flood so it can return to being wet meadowlands. This means that the cables will lie in an area which is under up to 1 m of water. The cables that were used have aluminium sheaths which protect against water.

Map of the area to be flooded. Figure 48

At compound Hornbæk, which lies approx. 2 km north of Gudenåen at Randers, the 400 kV line continues as an overhead line to the cable transition compound Katbjerg.

There are five 400 kV joints on the Gudenådalen section. The shields of the 400 kV cables are cross-bonded to achieve maximum transmission capacity. There is no phase transposition. The 4.5 km are divided into three parts, each 1500 m long. Each part consists of two cables which are joined without shield interruption. In every other joint the shields are interrupted where the shields cross between the cables, thereby minimising the shield currents in the overall system.

Drawing with part sections and joints. Figure 47

In joint no. 2 south of Gudenåen as well as in joint no. 4 north of Gudenåen, the shields lead from the joint to a link box where the actual crossing takes place. The link boxes are sealed and buried together with the cables. It is not possible to inspect link boxes or surge arresters in the boxes.

The cables lie in a flat configuration with a phase spacing of 300 mm. The spacing between the two 400 kV circuits is 6 m.

Circuits. Figure 21

Beside the cables empty pipes have been laid through which fibre-optic cables have been flushed. The fibre-optic cables can be used for telecommunications – and in future for distributed temperature monitoring of the cables.

1.2 Katbjerg-Bramslev (Mariager Fjord)

Compound Katbjerg lies south of Mariager Fjord between Hobro and Mariager. Bramslev is on the northern side of the inlet. The section between Katbjerg and Bramslev is 2.5 km long.

Map. Figure 2

The cables lie in agricultural land from Katbjerg to a point immediately south of the inlet. The banks down to the shore of the inlet are very steep. It was therefore not possible to lay the cables in an open trench. Instead directional drillings were made and the cables pulled in pipes down to the shore.

Slope with directional drilling. Drawing. Figure 15

On the northern side of the inlet individual directional drillings have been made, traversing a slope and crossing a road. Elsewhere the cables have been laid in open trenches.

Crossing the inlet is a chapter in itself. At the crossing point, the inlet is about 700 m wide. The maximum water depth is only 12 m. The tender for the cabling work did not specify a particular solution as to how the cables should be laid across the inlet. Of the various alternatives, it was decided to opt for a technically straightforward solution which was both financially and environmentally the most attractive.

Profile of the inlet. Figure 14

The solution involved sinking pipes onto the floor of Mariager Fjord. The pipes were joined together in sets of three using ballast blocks. The size and weight of the ballast blocks and the spacing between them was determined so that the pipes and the ballast blocks remained buoyant on the surface until they were towed into place. By filling the middle pipe with water, the pipe system sank to the floor of the inlet. The entire operation involved making three pipe rafts.

Pipes being sunk down onto the bottom of the inlet. Figure 13

This operation avoided the need for an uncertain and costly directional drilling. Also, it was possible to lay the pipes without markedly disturbing the floor of the inlet. And it was possible to draw a non-armoured submarine cable through the pipes running along the bottom of the inlet in just the same way as cables are pulled through pipes on land.

The cables had to be pulled through 700-metre-long pipes without resting on rollers. They were therefore supplied with a cable sheath which was a little thicker than normal. In addition, the pipes were filled with water before the cables were pulled, so the buoyancy of the cables in the water reduced the friction in the pipes.

Cable in water-filled pipe. Figure 12

The cable system is single-point bonded. The cable shields are earthed at the cable transition compounds Katbjerg and Bramslev. In joint no. 2 north of the inlet the shields are interrupted and led out to link boxes. In each link box there are surge arresters between the shield and earth.

Drawing of the section and joints. Figure 25

The Katbjerg-Bramslev section has three joints in all. Joints nos. 1 and 3 are joints without shield interruption.

A continuous earthing cable (or equipotential cable) is laid together with each circuit, which reduces the zero-sequence impedance of the circuit. The earthing cable is earthed in the Katbjerg and Bramslev transition compounds. It is also earthed at joint no. 2 where the cable shields are earthed via surge arresters.

Earthing cable. Figure 49

The cable running beneath Mariager Fjord distinguishes itself from the land cable in that its water barrier is a lead sheath instead of an aluminium sheath. It was decided to use a lead sheath on this section as the cable pipes are filled with salt water. However, the lead sheath means that the cable is significantly heavier and harder to handle when being pulled through the pipe.

The cables lie in a flat configuration. On land the phase spacing is 300 mm while under the inlet it is 1 m. The spacing between the two 400 kV circuits is 6 m. The spacing between a 400 kV circuit and a 150 kV circuit laid in parallel is also 6 m.

Drawing showing circuits. Figure 22

Empty pipes for fibre-optic cables have been laid alongside the land cables. Once the system was established, fibre-optic cables were flushed into the pipes. They serve two purposes. They are partly used for communications and they can also be used for distributed temperature monitoring along the cables.

The submarine cables were supplied with fibre-optic cables built into the shield. At joints nos. 1 and 2, at the transition between land and submarine cable, the built-in fibre-optic cables are spliced together with the conventional fibre-optic cables which are laid in plastic pipes.

1.3 Skudshale-Gistrup (Indkildedalen)

South of Aalborg is the 400 kV substation Ferslev, which is an important node. The 400 kV line from Aarhus to Aalborg is led into this important node. From here it continues to the substation at the Nordjyllandsværket power station. The last of the three cable sections, Skudshale-Gistrup, is part of this connection.

Map. Figure 3

The line continues as an overhead line from Ferslev and runs north to the cable transition compound Skudshale. Here, the new line is established as a double cable connection to the cable transition compound Gistrup. From Gistrup the line continues as an overhead line to the Nordjyllandsværket substation.

The section from Skudshale to Gistrup runs through a water catchment area and through a plantation where growing conditions are relatively poor because of a chalk layer just beneath the surface of the soil. This part of the cable route is quite unlike the low and very damp area through Indkildedalen which makes up the longest cable section, 7.5 km in all.

Drainage pipes were laid before cable trenches were dug in the wet areas. Drains have also been laid on top of the cables to prevent the soil from becoming soft in the years immediately following the cable laying.

The cables lie in a flat configuration along the entire section. All directional drillings beneath roads, rivers and other transverse lines are also performed as flat configurations. Along this section, one pipe has been pulled through each directional drilling. In the deep directional drillings, the cables have been pulled so they sit so far apart from each other that they can release the heat emitted during heavy current loads more effectively.

Circuits. Figure 23
Directional drilling with cables in flat configuration. Figure 19

The cable shields are cross-bonded. The phases have not been similarly crossed. The section has eight joints. Joints nos. 1, 2, 5 and 7 feature shield interruption with the shields being led out into link boxes where they are crossed. In joint no. 3 the shields are led out into link boxes for earthing. The two boxes at joint no. 3 are placed above ground as a cabinet. This provides access to the bonding. This is necessary for subsequent control measurements of the shield’s isolation properties in relation to the earthing. The other link boxes are buried together with the cables.

Cable and joints. Figure 24

Joints nos. 4, 6 and 8 feature no shield interruption.

Empty pipes for fibre-optic cables have been laid alongside the cables. The fibre-optic cables have been flushed and will partly be used for communications and partly for monitoring cable temperature.