1. 400 kV Cable Project Aarhus-Aalborg – General Outline

1.1 Introduction

Electricity cannot be stored. Production must correspond to consumption, placing demands on the transmission grid. Denmark's geographical location between the European continent and the rest of Scandinavia is of considerable strategic importance as far as electricity transmission is concerned.

Map of Europe

Denmark is situated between two large electricity transmission grids:
Zealand and the other islands in eastern Denmark are together with Norway, Sweden and Finland connected in one synchronous grid, while Jutland and Funen are connected to the Central European grid.

Map of Denmark, the transmission grid with international interconnections. Figure 37

Eltra is responsible for the overall security of supply and plans, builds, operates and owns the transmission grid. This film focuses on the western part of Denmark for which Eltra is responsible.

The transmission grid is a 400 kV grid of ring connections which are connected to the primary power stations in Aabenraa, Fredericia, Esbjerg, Odense, Aarhus and Aalborg as well as to Germany. The connections to Norway and Sweden are d.c. connections. There are two important nodes in the 400 kV grid where the connections to Norway and Sweden start from: Tjele near Viborg and Vester Hassing near Aalborg.

The 400 kV transmission grid in Jutland and on Funen has been built up from the mid-1960s to the 1980s. Already at the end of the 1980s Eltra was seeking permission to build the line from Aarhus to Aalborg in order to complete the 400 kV ring. This would significantly reduce the vulnerability of the grid to major faults. Moreover, it would increase the possibility of transmitting large volumes of power through Jutland.

The blue report (= Principles for establishment…) Figure 40

In the 1990s an agreement was signed with the Danish authorities on principles for the establishment and restructuring of high-voltage circuits. It meant that 400 kV transmission lines could still be constructed as overhead lines. However, sometimes shorter cable sections could be laid in urban areas as well as in areas of special natural beauty. It was also agreed that in connection with the expansion of the 400 kV grid an attempt should be made to reorganise the 60 kV and 150 kV grids. This could happen

partly by decommissioning lines, and partly by bringing together the circuits and suspending them on fewer towers. This approach has been followed with the establishment of the 400 kV connection between Aarhus and Aalborg which was commissioned in 2004.

1.2 400 kV Aarhus-Aalborg Connection

Overhead lines being removed. Figures 38 and 39

In order to be able to construct the 400 kV connection between Aarhus and Aalborg, the following conditions had to be met:

- the line had to be routed west of the woodlands Rold Skov along the motorway
- an existing 150 kV overhead line between Aarhus and Aalborg had to be removed
- the overhead lines around Aalborg had to be reorganised
- no new overhead lines would be established across Mariager Fjord, in Gudenådalen at Randers or through Indkildedalen south of Aalborg
- the existing overhead lines across Mariager Fjord, Gudenådalen and through Indkildedalen had to be removed.

These conditions meant that the three sections of the 400 kV line had to be established as cable connections, 14.5 km in all. At the same time the parallel 60 kV and 150 kV lines also needed to be run underground.

Map of Gudenådalen, Mariager Fjord and Indkildedalen

The three cable sections were

- Gudenådalen
- Mariager Fjord
- Indkildedalen.

The Gudenådalen valley is approximately 3 km wide at Randers. The river itself is 100 m wide, and the valley floor is very flat and wet.

Mariager Fjord is approx 700 m wide with a maximum water depth of 12 m. It has a soft floor, the upper layer of which consists of organic material. The inlet suffers from oxygen depletion, and particularly stringent environmental requirements were set on the part of the authorities.

Several thousand years ago, Indkildedalen was also an inlet. It is now agricultural land, but there is an idea that it might be used as a green recreational area in the future. The soil is very wet.

1.3 Overhead Line and Cable

The three cable sections are part of an overhead line with considerable transmission capacity.

Each 400 kV overhead circuit consists of duplex steel reinforced aluminium conductors with a cross-sectional area of 772 mm^2. The standard transmission capacity of such a circuit is 2,760 A. The standard conditions are:

- Air temperature of 20° C
- Wind speed of 0.6 m per sec.
- Irradiation of 900 W per m^2.

Fact box with the above information

The cable sections are dimensioned on the basis of current requirements – not on the basis of the possibilities offered by the overhead lines. This means that the cables in the 400 kV connection restrict transmission capacity. However, the cables have been dimensioned so that in practice they do not cause congestion.

In the tender documents for supplying cables, the requirement was for a transmission capacity of min. 2 x 700 A under standard conditions, which are:

- The cables are buried in the ground
- The cables are laid at a depth of min. 1.2 m
- Thermal resistivity of the surrounding soil is 1 kelvin metre per watt.
- The soil temperature is 15° C.

Fact box with above info

The cable connections should be installed as double cable circuits. In other words, two cable circuits are laid in parallel with a spacing of 6 m. This achieves the following:

- the potential for large transmission capacity for the completed circuit without having to purchase expensive cables with a large cross-section.
- considerably improved security of operations. Should a fault occur on one of the circuits, in the space of just a few hours it can be disconnected from the grid and the line can continue to operate at half transmission capacity until the cable has been repaired.

Drawing showing the two circuits and the possibility of continuing with one circuit if a fault occurs on the other. Figure 4

The requirement for a continuous transmission capacity of only 700 A for each circuit assumes that the cable can be subjected to a significantly higher load for several hours if the previous load has been lower than what the cable is actually designed to carry. And this is nearly always the case in practice.