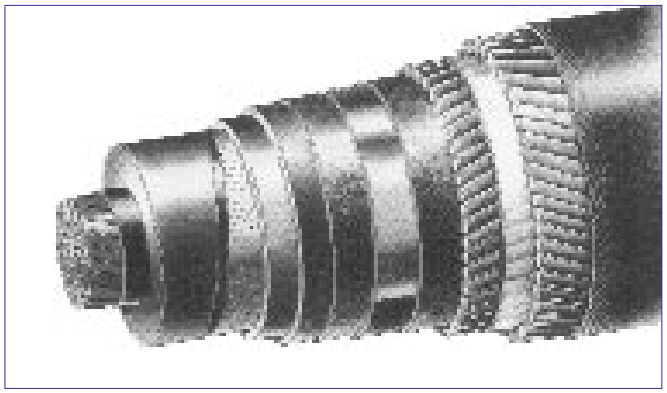
CABLE



General

The cable is the component which limits the power transmission capacity in a submarine HVDC cable link.

The cable in the Baltic Cable link is the most powerful – 600 MW – and longest – 250 km – HVDC cable ever built.

The contractor for the design, qualification, manufacturing and installation is ABB High Voltage Cable in Sweden.

Design

Double armoured, lead sheeted massimpregnated paper insulated cable.

- conductor size:	1600 mm^2
- insulation thickness:	19 mm
- weight:	56 kg/meter
- outer diameter:	131 mm
- BIL (LI/SI):	990/855 kV

Testing

Before the cable manufacturing could start, the cable design and the manufacturing process had to be qualified. This took place by manufacturing and testing of short cable lengths of different design. These test cables had to pass an extensive mechanical and electrical test program. Some of those tests were performed by Baltic Cable alone and some of them together with ABB HVC before the design of the cable for the Baltic Cable Project was selected.

The cable with the selected design has been type tested with the following main criteria:

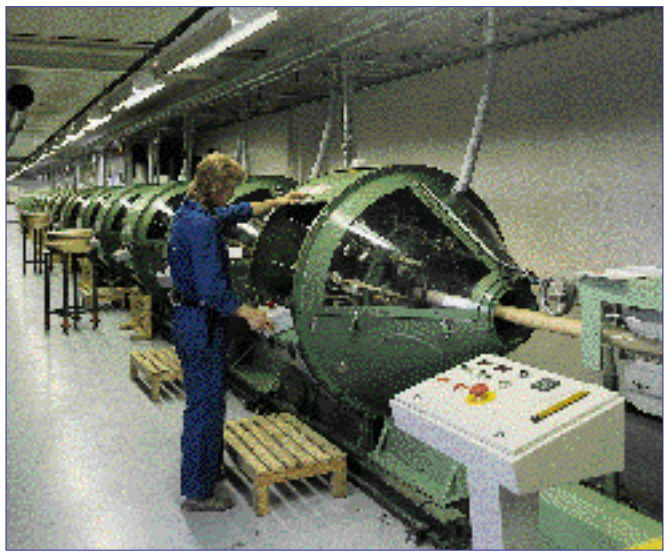
mechanical:	10 meters bending diameter
	64 kN tension
load cycling:	1.8*U_0 during heating
	1.6*U_0 during cooling
switching impulse:	1.9*U_0
lightning impulse:	2.2*U_0

A lot of information tests were also performed, such as pressure measurements, partial discharge measurements, leakage current measurements and long time stability test. All tests were performed under different ambient conditions.

Cable manufacture

The cable manufacturing is quite a complicated process which must be extremally well controlled. The tolerances are very small and all material must meet thoroughly specified demands. Due to the high complexity in establishing a good insulation, one has to avoid introduction of too many joints. Therefore, cable manufacturing has to be performed in extremely long lengths.

The 19 mm cable insulation must withstand the same electrical stresses as an overhead line which needs 6 meters of air insulation. To manage this more than 250 layers of a special paper lapped on the conductor. Every paper has to meet the specification and be placed in the right position and angle and have the right tension in relation to all the other 250 insulation papers. The manufacturing of 250,000 meters of cable was performed in two parallel production lines 24 hours per day, 7 days per week for 1.5 years.



After the paper lapping the cable was placed into a big impregnation tank, where the paper was dryed under vacuum before the impregnation itself with oil took place. It is important that the paper during the impregnation will be processed in a very good manner. The paper has to be extremely dry and the gas content must be as less as possible before the oil will be let into the tank to fill up the paper under pressure. The temperature is also an important parameter in the process.

After the cooling of the impregnated cable a lead jacket and a polyethylene jacket have been sheeted on the cable. This operation is a continuous process which gives a jacket without any discontinuity. Also here the tolerances are small, specially the gap between the paper and the lead jacket.

The lead and polyethylene sheeted cable was then armoured with different layers of steel tapes and steel wires.

Quality Assurances

Due to the increased complexity in the manufacturing process the quality assurance work is one of the most important activities. Qualified measurement methods have for example been introduced to follow the manufacturing process in detail. To ensure that the production lengths got the same high quality as the type tested cable lengths, ABB HVC have worked out a qualified quality assurance programme based on particular experiences from the Fenno-Skan and New Zealand projects.

To get an understanding of the complexity it can be noted that the total amount of insulation paper used for our 250 km HVDC cable corresponds to a paper length 12 times around the globe. Every cm of paper has to meet the specification and be placed in the right position, angle and tension in relation to all the other insulation papers.

Cable installations

The installation of 5.5 km HVDC land cable as well as the 2 times 23 km electrode cables in Sweden was finalized in the summer of 1993. To avoid introduction of additional joints the 5.5 km HVDC cable has been laid in one length. To be able to fulfil this operation, 100 synchronized cable pushing machines and 2000 cable rollers were needed. Furthermore, a pier was built out to the barge 250 meters in the sea, to be as independant of bad weather as possible.

The cable laying in river Trave was also completed during the summer 1993. Due to restrictions in obtained permissions in Germany, the installations of the cables became very complicated operations. To be able to reach the site of the converter station in Herrenwyk, Germany, the cables had to be laid 12 km up in river Trave, more or less the whole distance close to the shoreline and in a length of two km the cables were laid on extremely shallow water, on some places less than 1 meter. The HVDC cable and the electrode cable had to be installed in parallel with a distance of 2.5 meters. Furthermore, the cables have been installed in tubes, drilled close to each other under a channel crossing in river Trave for a length of 300 meters and 7 meters below the river bottom. To avoid thermal limitations in this section forced water cooling is installed. To continuously control the temperature of the HVDC cable in the tubes and at a distance of 1.2 km in addition, the cable is equipped with a fibre-optic distributed temperature system.

The HVDC cable laying in Baltic Sea is carried out in two lengths with a sea joint in between during the summer 1994 by the cable laying vessel Skagerrak. The sea electrode cable to the cathode in Baltic Sea on German side, is also in this place for 15 km installed in parallel to the HVDC cable with a distance of 2.5 meters. On both German and Swedish sides the cables are buried into the sea bottom out to an approximate water depth of 5 meters which corresponds to approximately 500-600 meters from the shore.

CDVC

Cable Dependent Voltage Control (CDVC) will be a control mode for minimizing stresses in the HVDC cable after a load reduction, by lowering the DC voltage. The voltage control will take into account the thermal, mechanical and dielectric features of the cable. The controller will comprise a simple model of the cable heat dynamic, which will have a time constant of several hours. It will also include an integrator that will estimate the additional heat dissipation in the cable, following an increase of the load. The latter will be to control the return to full voltage.

CLPS

The control system will include an algorithm to continuously calculate the present loading capability of the converter station, including the HVDC cable. The cable portion is called Cable Loading Prediction System (CLPS). As for the cable the calculation is based on temperature measurements on the cable as well as in the ground. The capability for both continuous operation and next 15 minutes will be calculated.

Main data

Rated power U_0:	600 MW
Rated voltage:	450 kV
Rated current:	1335 Amp
Length of HVDC cable:	12 km in river Trave, Germany 231 km in Baltic Sea 5.5 km on land, Sweden
Length of electrode cables:	20 km in Baltic Sea, German side 12 km in river Trave 2*23 km on land, Sweden
Spare cable:	5 km HVDC cable stored on a turn table
Maximum water depth:	45 meters

Contractor

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