HVDC Cable Transmissions

ABB High Voltage Cables
ABB Power Systems

HVDC – an ABB speciality

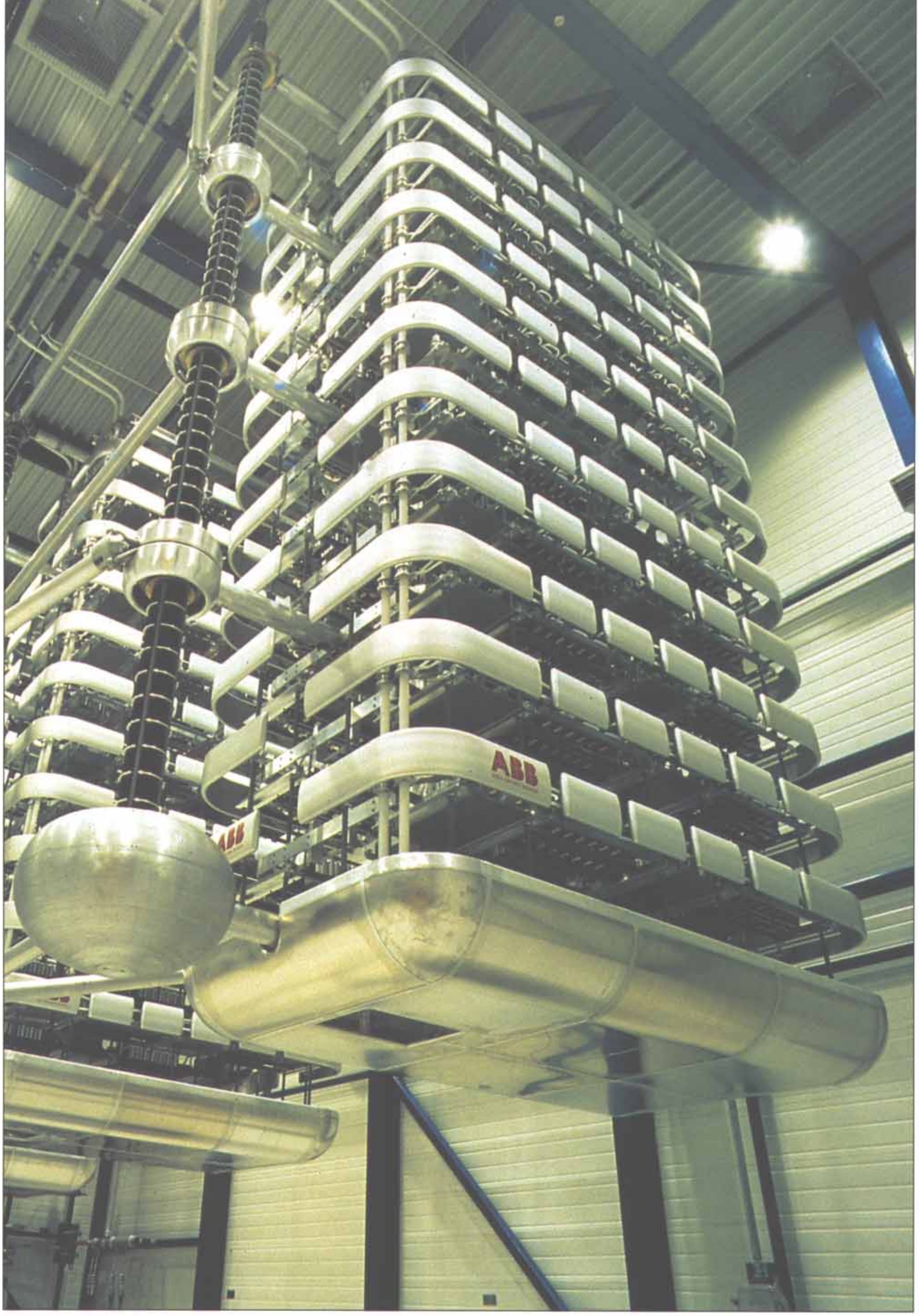
ABB is today one of the world's leading electrotechnical groups with more than 200,000 employees in 140 countries around the world. Among its various successful business areas, HVDC converter and cable technology are two important ABB specialities in the power transmission field. ABB introduced HVDC technology in 1954 with the pioneering power link between Gotland and the mainland of Sweden, and with the 450 kV, 600 MW Baltic Cable project, ABB remains at the forefront of HVDC technology.

Combined experience

ABB Power Systems is by far the world's leading supplier of HVDC converter stations, and ABB High Voltage Cables is the world's most experienced HVDC submarine cable manufacturer. The combined experience, know-how and resources of our companies, supported by a number of other related ABB companies, provide significant advantages for our customers. Together, we can provide a fully optimised HVDC cable transmission system on a turnkey basis, taking full responsibility for its timely completion and outstanding performance.

The recently developed HVDC 2000 converter station concept and the new generation of 800 MW HVDC cables represent the latest ABB contributions to progress in HVDC technology. In the following pages we present our cable transmission programme, our strengths and salient features, and our visions for the future.

Today, Scandinavia has the largest number of HVDC cable links in the world. However, the technology is widespread, both elsewhere in Europe and in Asia and America. The North and South Islands of New Zealand are also interconnected by a submarine HVDC cable. ABB has participated in most of these projects.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HVDC Cable Transmissions

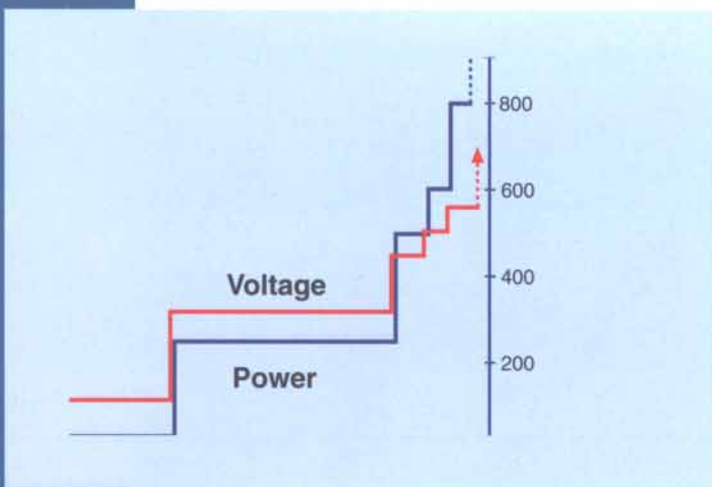
Submarine cable links have always been an important HVDC application. The world's first submarine HVDC cable transmission, the 20 MW interconnection between the island of Gotland and the mainland of Sweden, was built by ABB more than 40 years ago. Today, the combined transmission capacity of all HVDC cable links is more than 8,000 MW, and by the year 2005 the total capacity is likely to exceed 14,000 MW.

Increased interest in HVDC cable links

There are many reasons for the increased interest in HVDC cable links. The trend towards deregulation of power supply markets has made the establishing of several new cable interconnections feasible in recent years. Such interconnections are particularly profitable between systems with predominantly hydro generation and those with thermal generation. One important benefit is the possibility to defer or eliminate investments in peaking units in a thermal system, and in thermal units for dry year energy supply in a hydro based system. In addition, power can be exchanged in a daily or seasonal pattern based on differences in demand or power prices.

Many technical advantages

In addition to the economical and environmental benefits, HVDC cable transmissions offer many technical advantages such as lower losses, improved system stability and enhanced reliability. The availability of both converter stations and cables is extremely high today, well over 99%, and the dramatic increase in the rated power of submarine cables makes HVDC links even more economically competitive.



HVDC cable development.

Gotland – the world's first HVDC link connected the island of Gotland to the Swedish mainland by a 100 km HVDC cable in 1954.

Why DC for cable transmissions?

- For cable links longer than 40-50 km, DC provides **lower investment costs**. The saving gained from installing only one DC cable instead of three AC cables more than compensates for the cost of the AC/DC converter stations.

- DC cable transmissions have **lower losses** than a corresponding AC cable link. The converter station losses are normally as low as 0.6% per station, and DC cable losses are only around 0.3-0.4% per 100 km.

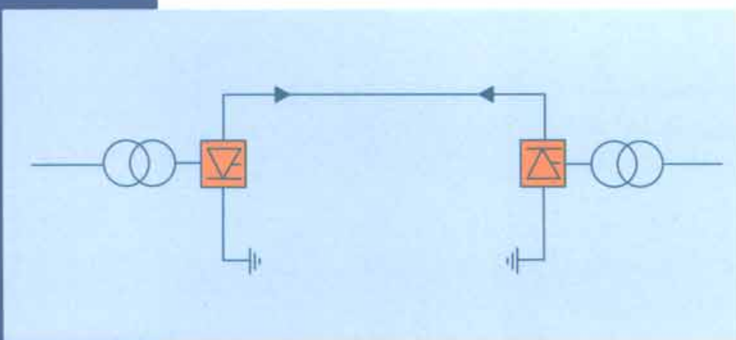
- Long AC cables produce high amounts of **reactive power**, requiring shunt reactors at both ends. In extreme cases the reactive current may seriously reduce the active power transmission capability. These drawbacks do not arise in a DC cable.

- DC links can connect two **asynchronous power grids** in cases where it is impossible or impracticable to establish a synchronous interconnection.

- The **high controllability** of the DC system can be exploited to improve the operating conditions of the interconnected grids.

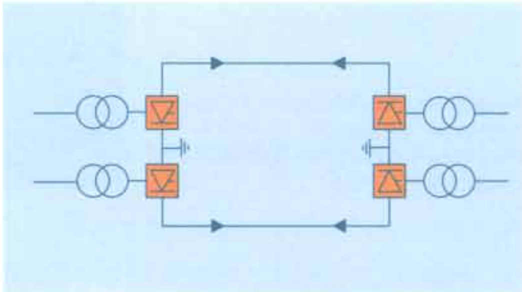
HVDC Cable Schemes

The basic HVDC cable transmission scheme is a monopolar installation using the sea for the return current. The sea return reduces the cost of the interconnection since only one cable is necessary between the two converter stations. The sea return also keeps losses to a minimum since the return path has negligible resistance. The only losses are associated with the voltage drops at the anode and the cathode. The electrodes have to be located away from the converter stations and the main HVDC cable in order to avoid corrosion and direct current pick-up in transformer neutrals. The good conductivity of sea water makes it easy to design the electrodes, and our extensive experience from many years of operation in several monopolar transmissions is excellent.



Simplified single-line diagram of a typical modern monopolar HVDC cable link.

It is, of course, also possible to use a metallic return conductor in the form of a medium voltage cable between the two stations. However, this gives a higher investment cost as well as higher losses.



Simplified single-line diagram of a bipolar HVDC cable transmission.

A further development of the monopolar transmission scheme is a bipolar configuration. In addition to the doubled transmission capacity, this arrangement also results in a higher transmission reliability.

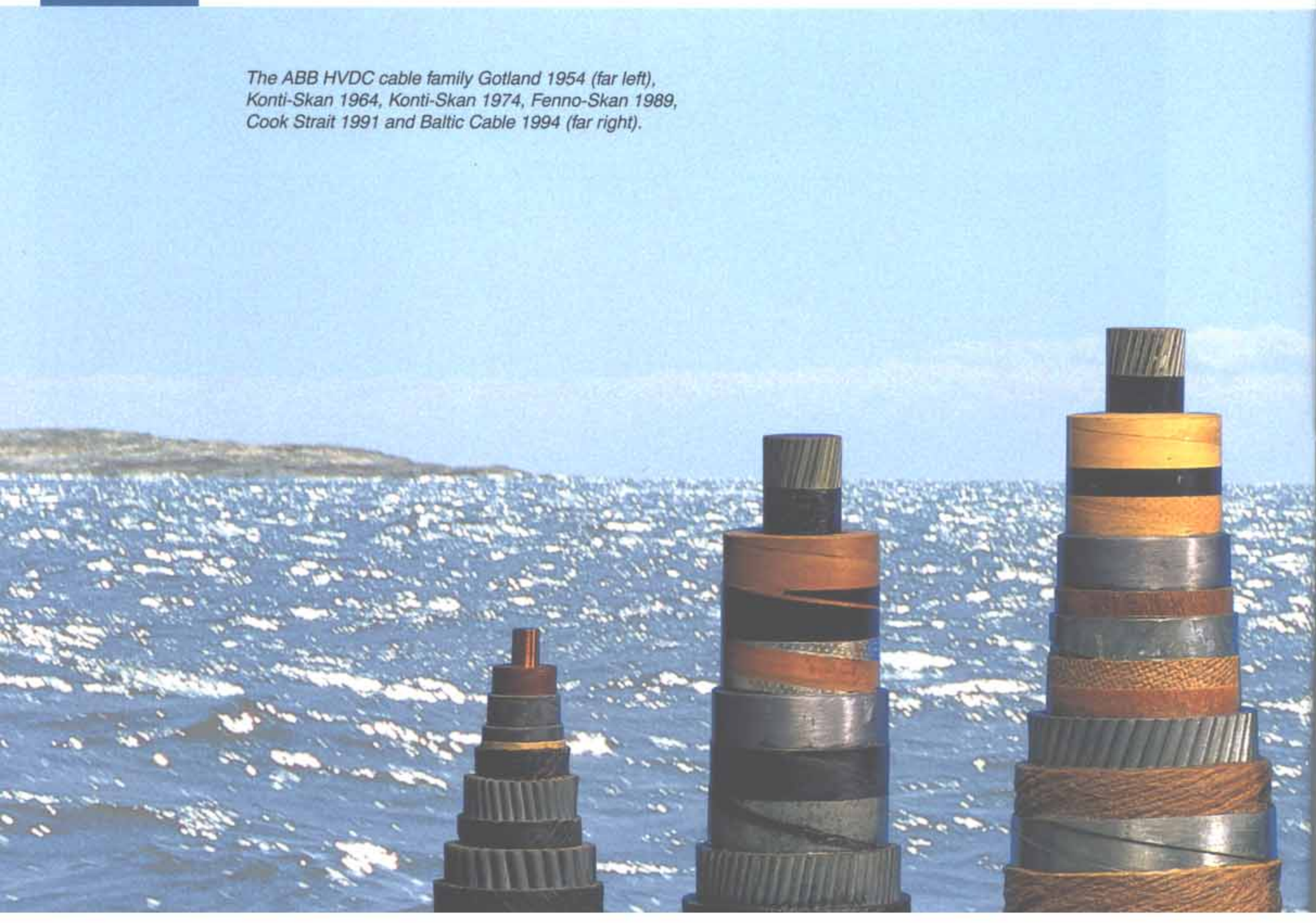
The choice of rated voltage and rated current for an HVDC cable transmission is an optimisation procedure where the cost functions for both the converter stations and the cable, as well as the transmission losses, need to be considered. ABB's experience in both fields makes it possible for us to find the optimum parameters in each particular transmission case, providing our customers with the most cost-efficient system possible.

HVDC Cable Technology

The design of HVDC cables is complex and difficult, and a great deal of experience and research work is required for the successful development of a reliable cable. The thermal and pressure dynamics, for example, are of great importance. Under load a thermal expansion pressure is built up in the insulation. When there are changes in the load, corresponding changes take place in both the temperature and pressure, resulting in various movements of the materials in the cable, all of which affect its electrical properties.

Testing

Testing is an important and integral part of cable development, and ABB has introduced dedicated equipment and many new methods in order to test cables thoroughly for their intended use. Today, testing under simulated real operating conditions, complete with on-site ambient temperatures, incorporating frozen end technology to correctly simulate long cable behaviour, can be performed in our laboratories.



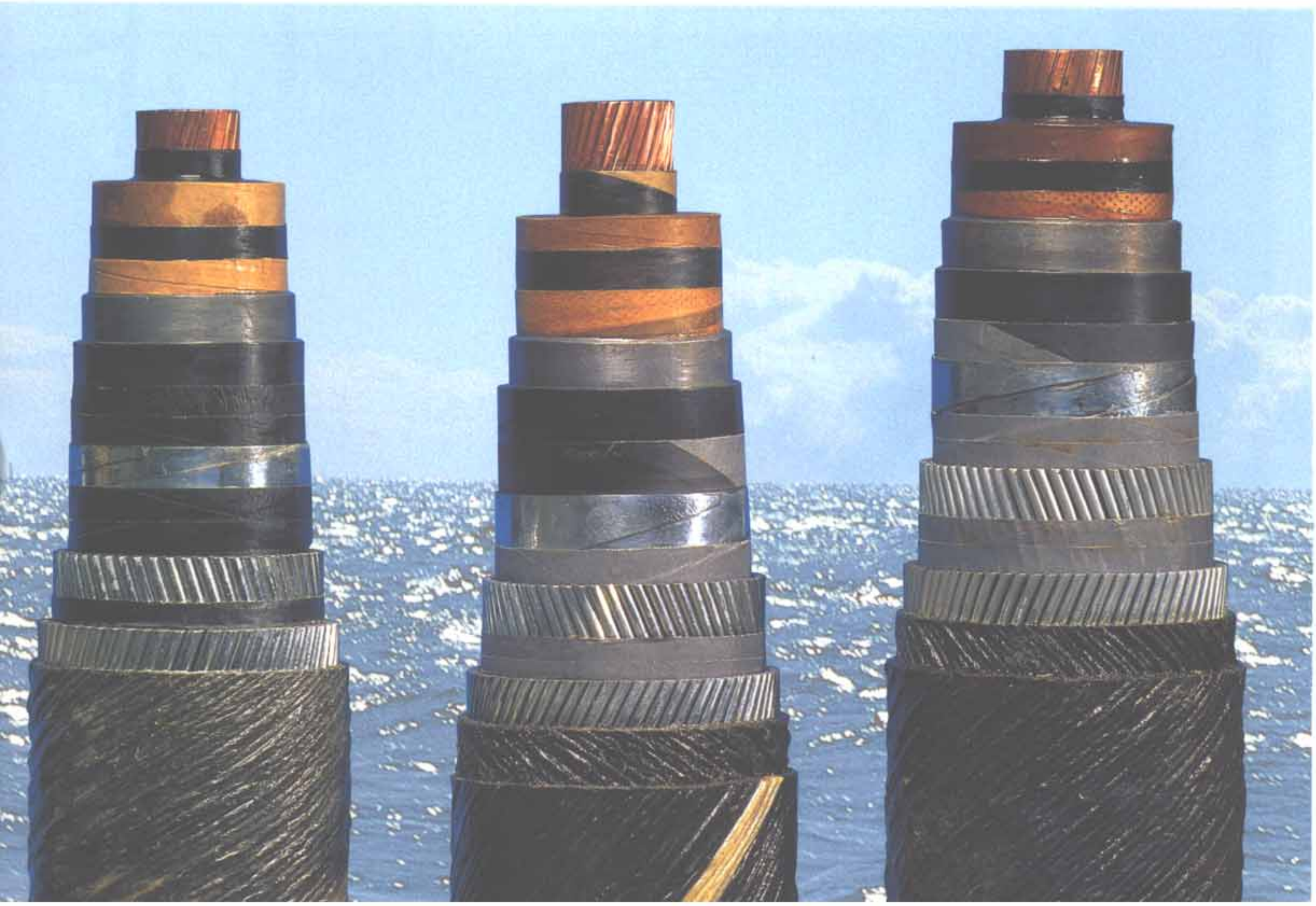
The ABB HVDC cable family Gotland 1954 (far left), Konti-Skan 1964, Konti-Skan 1974, Fenno-Skan 1989, Cook Strait 1991 and Baltic Cable 1994 (far right).

ABB at the forefront of HVDC development

Based on over 50 years of research and development, supported by experience from our many successful HVDC projects, ABB today has a thorough understanding of design criteria and related issues, allowing us to remain at the forefront of HVDC development.

Cable for 800 MW at 500 kV

Our latest cable design is for 800 MW at 500 kV, but our conventional technology permits us to set our sights a good deal higher. In addition to this, we are also investigating several new methods of increasing voltage and power ratings. This research involves both new production methods and new insulation materials, such as extruded HVDC cables and laminated insulation paper (PPLP). 1000 MW cables are well within reach, and ABB will continue to push the limits forward.



Converter Station Technology

Simple and straightforward design

Perhaps the most striking characteristic of most of the modern converter stations in HVDC cable projects is their simple and straightforward design.

Functional specifications have allowed ABB to develop a very successful basic design, which has been used with only minor modifications in several recent projects. This has resulted in very economical transmissions with low operating costs and a high level of reliability.

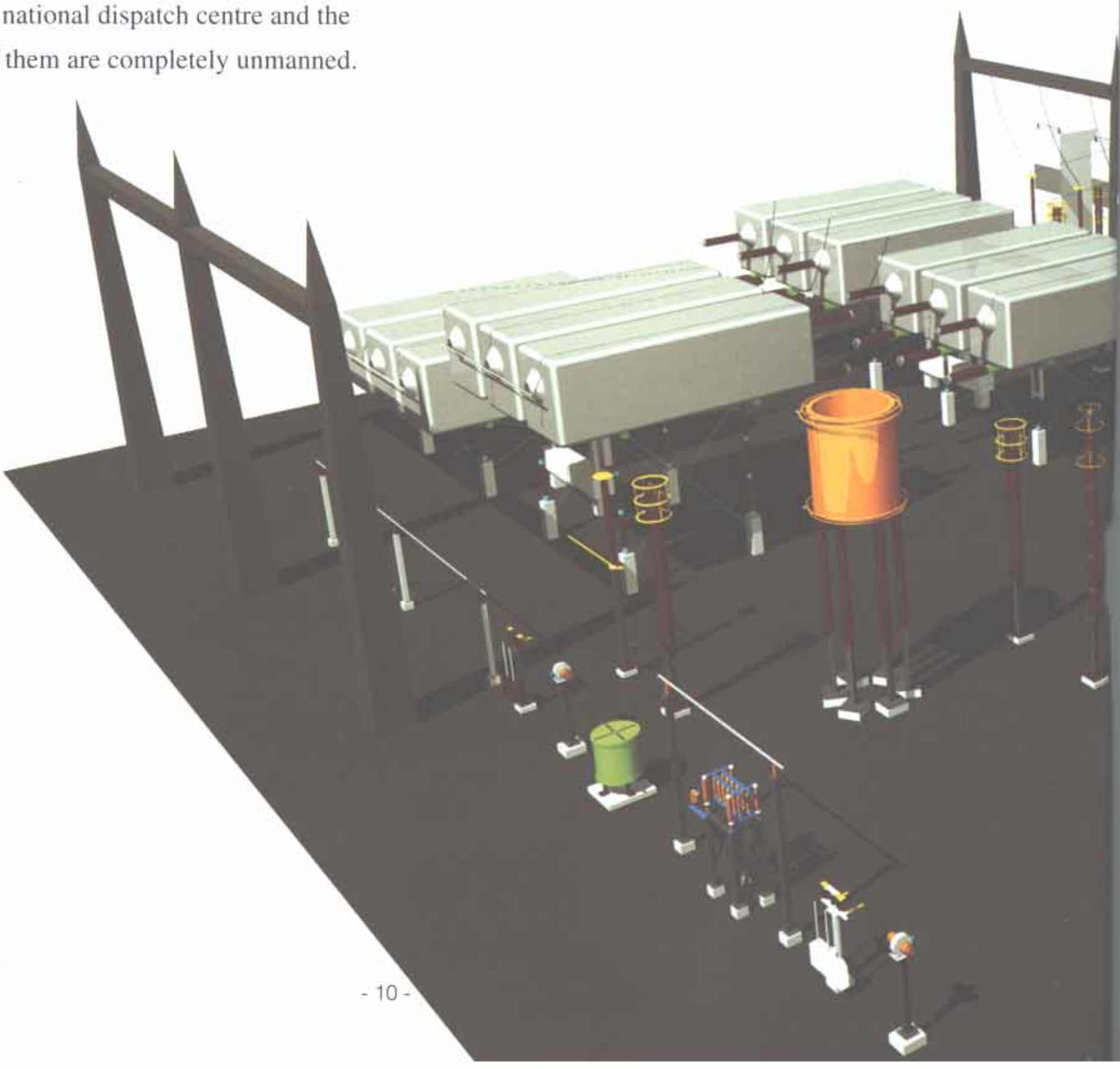
The stations are all remotely controlled from a regional or national dispatch centre and the majority of them are completely unmanned.

New developments

ABB has recently introduced a new generation of HVDC converter stations incorporating our latest developments affecting a number of technical areas. Our new system is called HVDC 2000.

Our goals in developing HVDC 2000 are to give our converter stations:

- reduced life cycle cost
- improved performance and even longer lifetime
- a further reduction in complexity
- reduced area requirements
- reduced construction time.

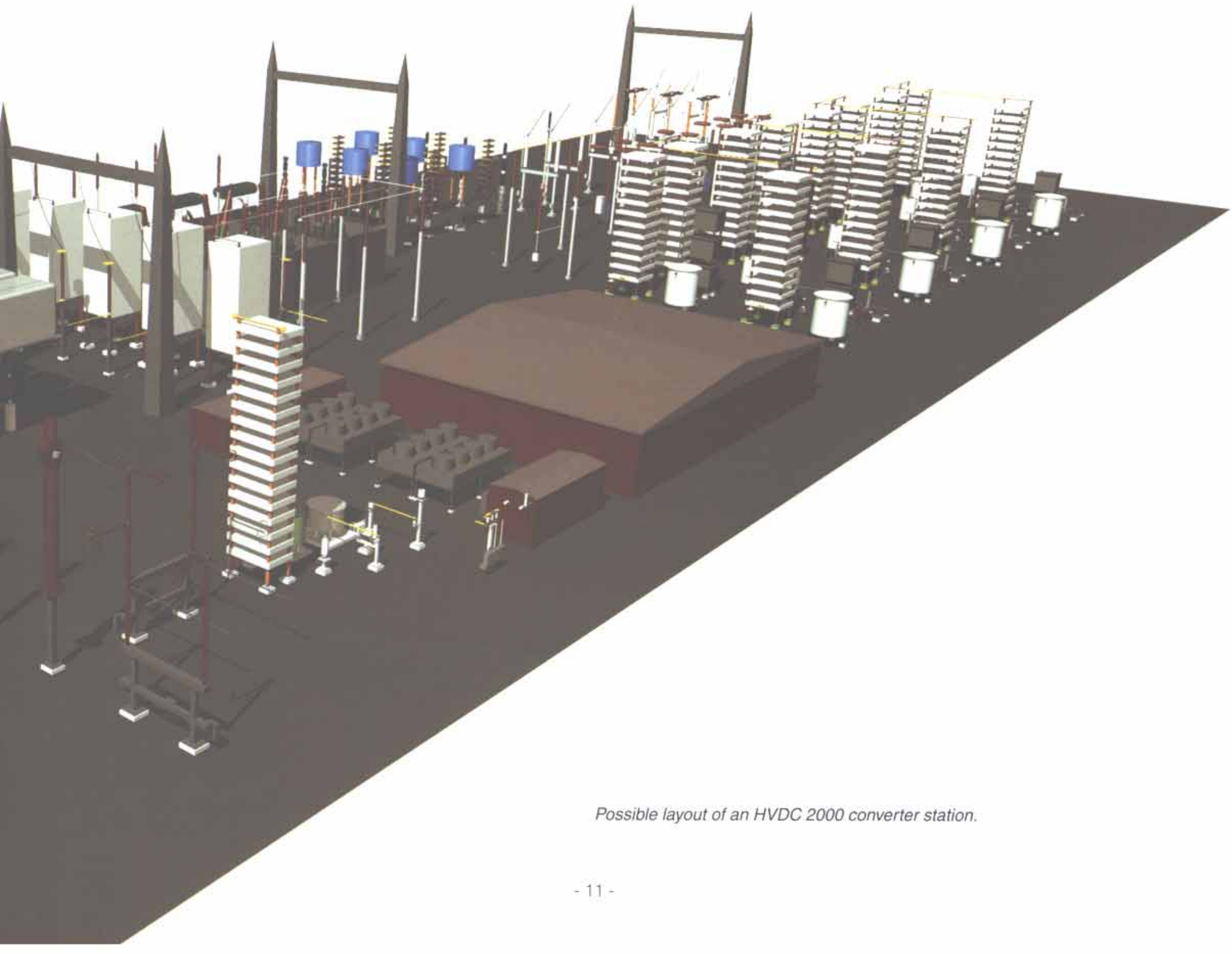


The key elements in the HVDC 2000 system are:

- capacitor commutated converters, CCC
- ConTune® actively tuned AC filters
- active DC filters
- outdoor HVDC valves
- optical current transducers
- fully digital MACH® control system
- deep hole ground electrodes.

Of special interest in HVDC cable transmissions is the use of CCC technology. The capacitor commutated converter provides far more stability in the control of very long DC cable links than the traditional converter does. In addition, there are major improvements in stability when the DC link is connected to AC networks with low short-circuit capacity.

It is our firm belief that the new features in the HVDC 2000 concept will become standard components in future HVDC converter stations.



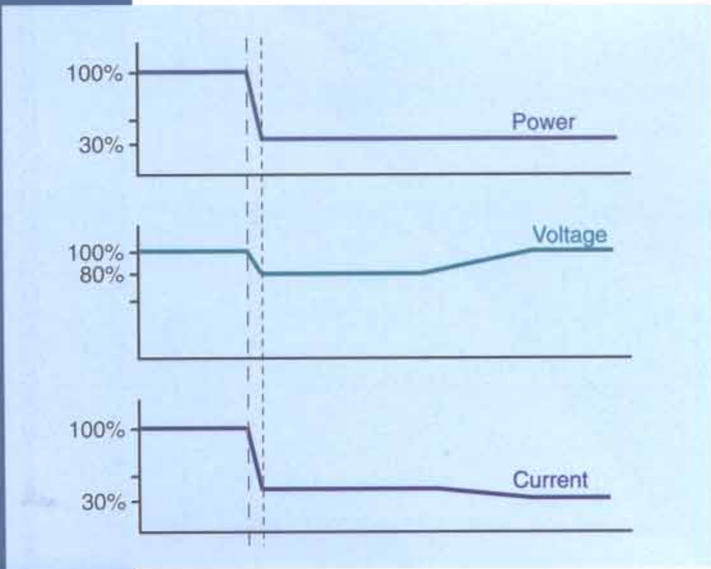
Possible layout of an HVDC 2000 converter station.

Performance Optimisation

Cooperation between ABB Power Systems and ABB High Voltage Cables has resulted in many technological breakthroughs, two of which are important control features optimising HVDC cable performance: CDVC, Cable Dependent Voltage Control, and CLPS, Cable Load Prediction System.

Cable Dependent Voltage Control

CDVC is a function reducing dielectric stresses on the cable when it is off-loaded and the pressure inside the cable insulation drops. Pressure drops could lead to a reduction in the strength of the insulation. Large load reductions are therefore achieved through a combination of voltage and current reductions. The DC voltage is initially reduced to a typical figure of 80% and, after a time delay, the voltage is gradually raised again to the nominal value.



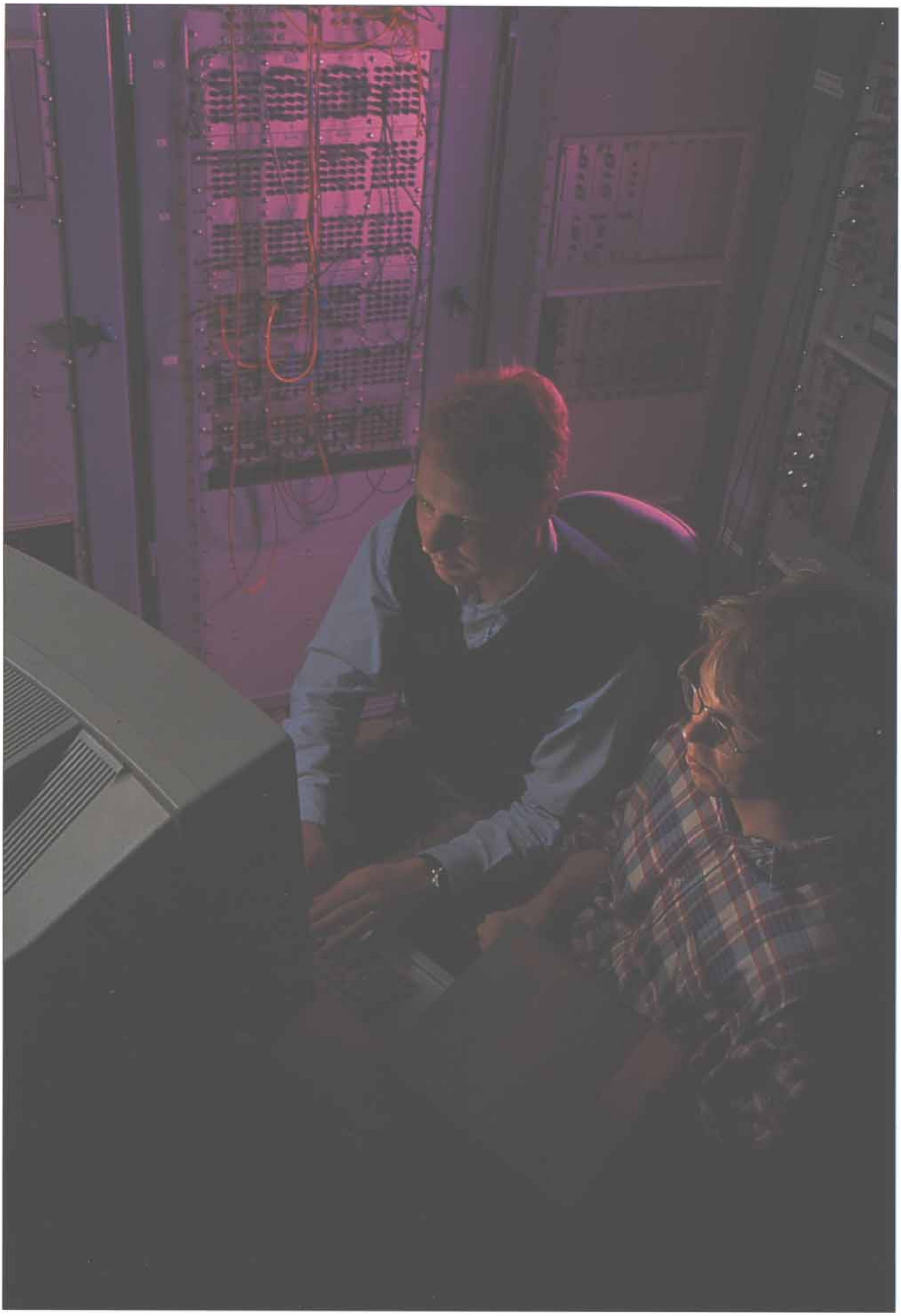
Cable dependent voltage control.

CDVC is a facility that has helped to increase the power and voltage rating of HVDC cables, thereby making it possible to design more powerful HVDC cable transmission schemes.

Cable Load Prediction System

CLPS gives the operator information about both the current 15-minute overload capacity of the cable and its continuous overload capacity. CLPS entails on-line measurement of the cable surface temperature and the temperature of the surrounding soil.

The CLPS algorithm includes a mathematical model of the thermal behaviour of the cable as a function of operating history, present temperatures and actual load. The CLPS system ensures that the maximum operational benefit from the cable link is gained without the risk of damaging the cable. The 15-minute overload capacity can be used as a spinning reserve for the interconnected networks, while the continuous overload capacity makes it possible to increase power transmission above the rated value at low ambient temperatures.



Gotland 1 – the world's first HVDC link

In 1954, the island of Gotland was electrically connected to the Swedish mainland by a 100 km HVDC cable. This successful project was made possible by the concurrent ABB development of mercury-arc AC/DC conversion valves and the HVDC cable. Originally rated 20 MW at 100 kV, the interconnection had its voltage rating stepped up to 150 kV in 1970 to meet increased electricity demands, and it was now possible to transmit 30 MW. The cable was operated at its new rating until 1987, when it was replaced by a new cable with a higher capacity. Close scrutiny of the original cable revealed astonishing proof of ABB quality: the 32-year-old cable was, in electrical terms, as good as new.

Fenno-Skan – crossing the Baltic Sea at 400 kV

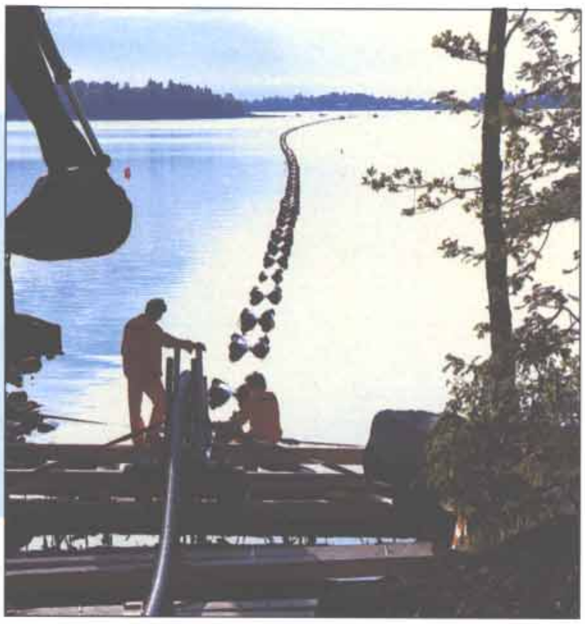
A major step in HVDC development was taken in 1989 with the laying of the 400 kV Fenno-Skan cable between Sweden and Finland. The 200 km cable link crosses some of the areas of the Baltic Sea most exposed to icing, and several new features were introduced, e.g. the keystone-shaped compact copper conductor. Cable dependent voltage control (CDVC) was also used in this project for the first time. Furthermore, the control system includes several other advanced functions. The converter stations are unmanned and the entire link is remotely controlled.

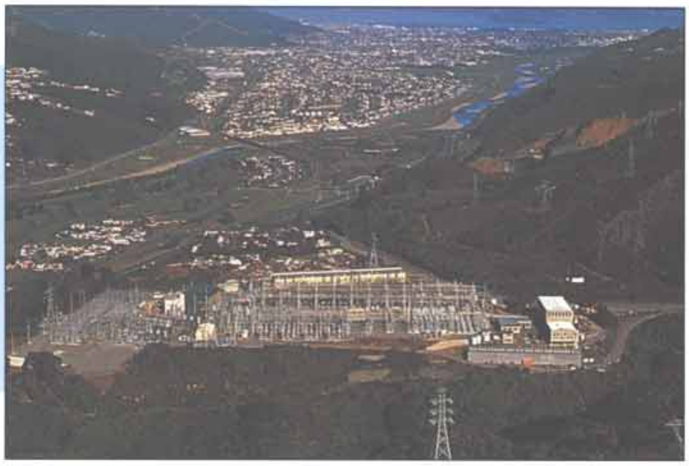
Cook Strait – linking up New Zealand with 1240 MW

In 1991 the HVDC link between the North and South Islands of New Zealand was upgraded by ABB from 600 MW to 1240 MW. The existing link, with its mercury-arc valves, was modified to operate in a bipolar hybrid scheme together with a new thyristor converter. ABB also supplied 350 kV cables for the submarine crossing, reaching depths of over 300 m in areas exposed to very strong currents.

Baltic Cable – an ABB success story

The Baltic Cable project was unique in many ways. It involved the world's longest and most powerful submarine HVDC cable transmission, commissioned in 1994, and having a complete ABB turnkey under-taking proved vital to the rapid and successful completion of the project. At 450 kV, the 55 kg/m cable exchanges 600 MW between the NORDEL and the UCPTE grids.





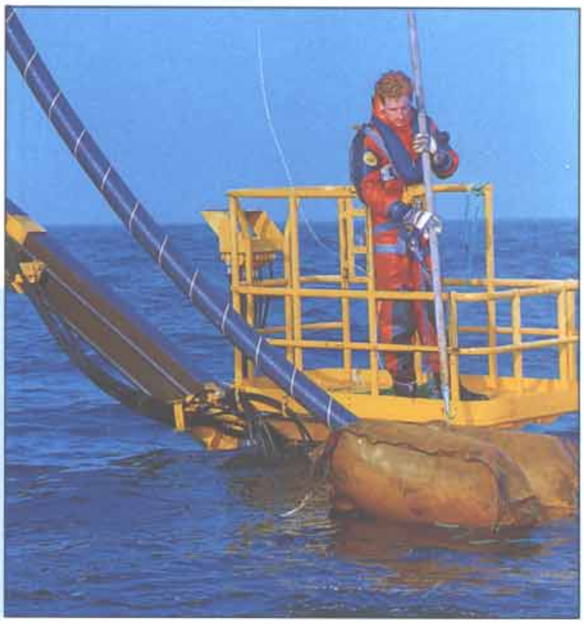


ABB Power Systems and ABB High Voltage Cables together possess unique experience and know-how in the HVDC technology field, especially as regards application. Backed by the entire ABB organisation, we take responsibility for complete turnkey deliveries, with the firm conviction that we will bring each project to a successful and timely completion.

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