

Operation and maintenance of DC-links

The Skagerrak HVDC System

Statnett owns and operates close to 9 700 km high voltage transmission lines and submarine cables and in addition 81 transformer-, switchgear-, and compensator stations. The transmission lines operate at nominal voltages of 132, 300 and 420 kV. The Maintenance Division is responsible for all maintenance of Statnett's installations, based on a balance between cost efficiency and grid availability. The HVDC department is responsible for the Norwegian HVDC land installations and the full length of submarine cables from Norway to Denmark.

History of the Skagerrak HVDC Scheme

The three Skagerrak submarine cables with a total capacity of 1040 MW, connect the Norwegian hydro based power system with the thermal based system in Denmark. Statnett as the Norwegian owner has operated and maintained these HVDC-systems since Skagerrak 1 was commissioned in 1976, followed by Skagerrak 2 in 1977 and Skagerrak 3 in 1993. Skagerrak 1 and 2 work in parallel as two independent monopoles, connected in series with Skagerrak 3.



Old generation of thyristor valves.



New generation of thyristor valves.

Main data	Skagerrak 1	Skagerrak 2	Skagerrak 3
Commissioned:	1976	1977	1993
Capacity:	270 MW	270 MW	500 MW
DC-voltage:	250 kV	250 kV	350 kV
Cable cross section:	800 mm ² Cu	800 mm ² Cu	1400 mm ² Cu
Length of submarine cable route:	124 km	124 km	124 km
Maximum sea depth:	540 m	540 m	540 m
DC overhead lines Norway:	28 km simplex	28 km simplex	28 km duplex
Converter valves:	1728 thyristors Forced air	1728 thyristors Forced air	720 thyristors Water cooled

Filtering: 2 High Pass (90 MVar each) and 2 Low Pass filters (83 MVar each).
Sea electrode Norway: 61 graphite electrodes placed in wooden structures with coke backfill.

All submarine cables are mass-impregnated with counterhelical double steel armouring.



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Focus areas

In the 25 years since Skagerrak 1, Statnett has focused on energy availability and total lifetime cost. This is reflected in a high degree of emergency preparedness, in personnel training and development, in system for operation and maintenance and supplier market development.

1. Reliability Controlled Maintenance

Statnett has developed a system for Reliability Controlled Maintenance (RCM) to increase system reliability and availability, especially as the installations increase in age. Through a comprehensive analysis Statnett has streamlined the maintenance work to meet the new challenges and is now implementing this as a new computer based system.

2. Emergency preparedness for submarine cables

Since 1976 Statnett has had 7 repairs on Skagerrak submarine cables. Due to difficult weather conditions in the Skagerrak area, the Maintenance Division has initiated several R&D -projects to gain time-saving procedures to pin-point location of faults, cable tracking and repairs within small weather windows. Down to 100 m laying depth, typical installation time per joint is 48 hours.

Statnett is member of the Nordic Cable Repair Group (NCRG). The main objective of the group is to exchange experience as well as co-operate actively on all aspects of maintenance and repairs planning, and finally repair preparedness on submarine cables between the Nordic countries.

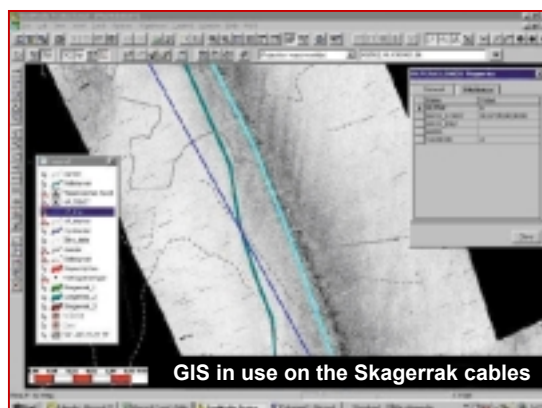


3. Survey and trenching operations

The combination of heavy fishing activity along the cable corridor and varying seabed conditions, from outcropping till to moving sand dunes, means that the Maintenance Division has experienced great challenges in achieving a safe operation of the submarine cables. Statnett has carried out several surveys for sub bottom cable positioning and to reveal cable exposures, obstacles and trenching conditions along the cable route for planning of trenching and repair operations. All survey and trenching information is incorporated in our Geographic Information System.

4. Geographic Information System

Statnett has built up a data based Geographic Information System (GIS) to handle all information regarding the submarine cables, from pre-surveys, other more recent surveys, routing information, trenching, cable faults and -repair, etc. This system is the main tool for more efficient maintenance planning, fault location and -repair, in addition to reducing outage time in an emergency situation.



Highly qualified staff

The Skagerrak systems represent two generations of HVDC systems, requiring upkeep of knowledge from the 70s and from the 90s, in addition to the new trends in HVDC technology.

With over 20 years of experience with operation and maintenance of the Skagerrak HVDC systems, the Maintenance Division represents one part of Statnett's unique combination of skills and qualities important for successful engineering, manufacturing, operation and maintenance of HVDC systems.

Responsible personnel in the Maintenance Division has background from R&D, design, manufacturing and operational experience in all aspects of submarine cable repairs.

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