State of the art

High Voltage Direct Current Mass Impregnated Cable Systems (HVDC MI Cable Systems)
1. Introduction
2. Cable design HVDC MI Cable
3. Manufacturing flow chart
4. Type testing of cable systems
   - Mechanical testing
   - Electrical testing
5. Installation
   - Submarine installation
   - Land installation
6. Examples of projects
   - Recent projects
   - Coming projects
Nexans in Halden is Nexans worldwide competence centre for Submarine High Voltage Cables and Umbilicals

- Number of employees is approx. 870
- Manufacturing on five shift - 24/7, 365 days/year
- In-house full-scale mechanical and electrical testing facilities
- High Voltage Laboratory and Mechanical Test Centre

Full-scale electrical type test

Full-scale mechanical type test
HVDC MI Cable

- Bulk transmission of electrical energy over long distances
- Well proven technology
- Norway’s first HVDC submarine link installed in 1976
- MI cables are used for the highest DC-voltages, the highest installed voltage level is currently 525 kV (Skagerrak 4)
- NordLink and NSL are similar to the SK4-design
The Skagerrak projects

The Skagerrak HVDC Cables
Norway – Denmark

1976 – 2x250 MW
Skagerrak 1 & 2
250 kV, 800 mm² Cu

1993 – 500 MW
Skagerrak 3
350 kV, 1400 mm² Cu

2014 – 715 MW
Skagerrak 4
525 kV, 1600 mm² Cu
Characteristics of MI Cables

- The insulation consists of lapped paper
- The paper is impregnated with high viscosity oil (= cable mass)
- The insulation system is protected with a lead sheath
- Used solely for HVDC
A very short history lesson -
It all started in 1890

- The first cable with impregnated paper insulation manufactured
- Manufacturing length: 6 m
- Route length: 40 km
- Number of joints: approx. 7000

Submarine cable installation in the thirties

Submarine cable installation in the fifties
• Nexans in Halden manufactures High Voltage Mass Impregnated Cables with a voltage rating up to 525 kV

• Nexans has qualified 500 kV cable systems for 1200 m water depth according to the relevant Cigré recommendations
Example of Scope of Work
HVDC MI Cable System

Termination

Underground Cable

Submarine Cable

Underground Cable

Example of Scope of Work
HVDC MI Cable System

Termination

Underground Cable

Submarine Cable

Underground Cable

20 km

400 km

20 km

Termination

Underground Cable joints
Transition Joints Submarine/ Underground Cable
Flexible Factory Joints for Submarine Cable
Flexible Offshore/ Repair Joints for Submarine Cable

Typical Submarine Cable Project
HVDC MI
Submarine Cable Design

Corrosion protection and outer serving

Steel wire armor

Transversal steel reinforcement

Polyethylene sheath

Lead alloy sheath

MI insulation system

Copper conductor
HVDC MI Cables
Manufacturing flow chart
Drawing process:
Round wires are drawn to the desired shape and spooled to bobbins for use in the next process; the conductor stranding.
Conductor stranding:
The bobbins from the drawing process are loaded into the stranding machine.

In this process the conductor is manufactured and stored intermediately on a turntable (rotating platform)
**Paper lapping:**
The finished conductor is guided from the turntable to the paper lapping line where the insulation system is applied.

A 525 kV MI cable contains approximately 300 layers of paper.

The insulated core is guided directly from the paper lapping line into the impregnation vessel(s).
Drying and impregnation:
After the paper lapping is finished, the next process is to dry the paper and subsequently to impregnate the insulation system with cable impregnating mass.
To dry the paper effectively, the impregnation vessel is fully sealed, and vacuum in combination with heat is applied.
After the drying process the vessel is filled with impregnating mass, and the insulation system is fully impregnated.
Lead sheathing:
After the drying and impregnation process the moisture proof lead sheath is applied.
**PE-sheathing:**
The PE-sheath is applied directly above the lead sheath. This sheath acts as mechanical and corrosion protection of the lead sheath.
Armouring:
In the armouring process the mechanical protection of the cable is applied. Steel tapes, steel wire armouring and outer serving of bitumen and PP yarn is used.
Jointing:
Each manufacturing batch of Submarine Cable is jointed in front of the armouring machine, thus the armour is applied continuously over the factory joint.
FAT:
Factory Acceptance Test is performed to verify the integrity of the insulation system. A 525 kV cable is tested at 945 kV.
Load out:
After the Factory Acceptance Test is performed the submarine cable is ready for load out to the cable laying ship.
- Tensile bending test to simulate installation from the ship at maximum water depth
- Performed acc. to Cigré Electra 171 – three bending cycles at maximum tension
- Performed subsequent to the tensile bending test
- Performed acc. to Cigré Electra 189

10 positive load cycles
+945 kV (+1,8·U₀)

10 negative load cycles
-945 kV (-1,8·U₀)

10 load cycles with polarity reversals
±735 kV (±1,4·U₀)

Superimposed switching surge test
±525 kVDC, ±1050 kV impulse

Superimposed lightning impulse test
±525 kVDC, ±1050 kV impulse
C/S Nexans Skagerrak during load-out of a Submarine HVDC Cable at the Nexans manufacturing site in Halden Norway
Submarine Cable Installation

CAPJET – Cable burial by water jetting
The Underground Cable is transported to site on drums.

Because of weight and size restrictions, the maximum cable length of each drum is normally limited to less than 1000 m for a 525 kV HVDC MI Cable.
The Underground Cable is pulled from the drum into the trench or into pre-installed pipes.

Cable pulled through a PE-pipe into the jointing pit

Cable pulled in an open land trench
Between each installation length the joint is made in a controlled environment to secure the quality of the joint.
• For a 525 kV HVDC MI Cable the height of the porcelain insulator will be approx. 7 m

• If the termination is placed indoor, the height may be decreased
Nexans HVDC MI Cable Projects (2005 - 2015)

- Skagerrak 4
  - 525 kV HVDC
  - 130 km

- Fenno-Skan 2
  - 500 kV HVDC
  - 200 km

- Fenno-Skan 2
  - 500 kV HVDC
  - 200 km

- Kontek
  - 400 kV HVDC
  - 50 km

- EstLink 2
  - 450 kV HVDC
  - 145 km

- Valhall
  - 150 kV HVDC
  - 300 km

- NorNed
  - 450 kV HVDC
  - 320 km

- SAPEI
  - 500 kV HVDC
  - 240 km

- Cometa
  - 250 kV HVDC
  - 240 km

Total 2005 - 2015: > 1600 km
Nexans HVDC MI Cable Projects (2015 - 2021)

- **Skagerrak 4**
  - 525 kV HVDC
  - 130 km

- **Fenno-Skan 2**
  - 500 kV HVDC
  - 200 km

- **Valhall**
  - 150 kV HVDC
  - 300 km

- **Kontek**
  - 400 kV HVDC
  - 50 km

- **SAPEI**
  - 500 kV HVDC
  - 400 km

- **Cometa**
  - 250 kV HVDC
  - 240 km

- **NordLink**
  - 525 kV HVDC
  - 720 km

- **EstLink 2**
  - 450 kV HVDC
  - 145 km

- **NSL**
  - 525 kV HVDC
  - 500 km

- **NorNed**
  - 450 kV HVDC
  - 320 km

- **Mon.Ita**
  - 500 kV HVDC
  - 200 km

- **Maritime Link**
  - 200 kV HVDC
  - 350 km

- **SOBI**
  - 350 kV HVDC
  - 100 km

- **Total 2005 - 2015:**
  - > 1600 km

- **Total 2015 - 2021:**
  - > 2070 km

---

*Note: The map shows projects in various locations including Canada, with distances and voltage ratings for each project.*
Examples of Nexans projects – Mon.Ita

- HVDC Interconnection between Montenegro and Italy
- Contract value: 340 M€
- 400 km 500 kV HVDC MI Cable
- Manufacturing ongoing in Halden
- Commercial operation starts in 2018

Campaign 1:
- 148 km cable from Pescara (Ita) to KP 148

Campaign 2:
- 158 km cable from Jaz (Mon) to KP 232

Campaign 3:
- 87 km cable from KP 232 to KP 148
Examples of Nexans projects – Nord.Link

- HVDC Interconnection between Norway and Germany
- Contract value: 500 M€
- 724 km 525 kV HVDC MI Cable
- Type Testing ongoing in Halden
- Commercial operation in 2020
Examples of Nexans projects – NSL

- HVDC Interconnection between Norway and England
- Contract value: 350 M€
- 500 km HVDC MI Cable
- Engineering is started
- Commercial operation in 2021
Many thanks for your attention!