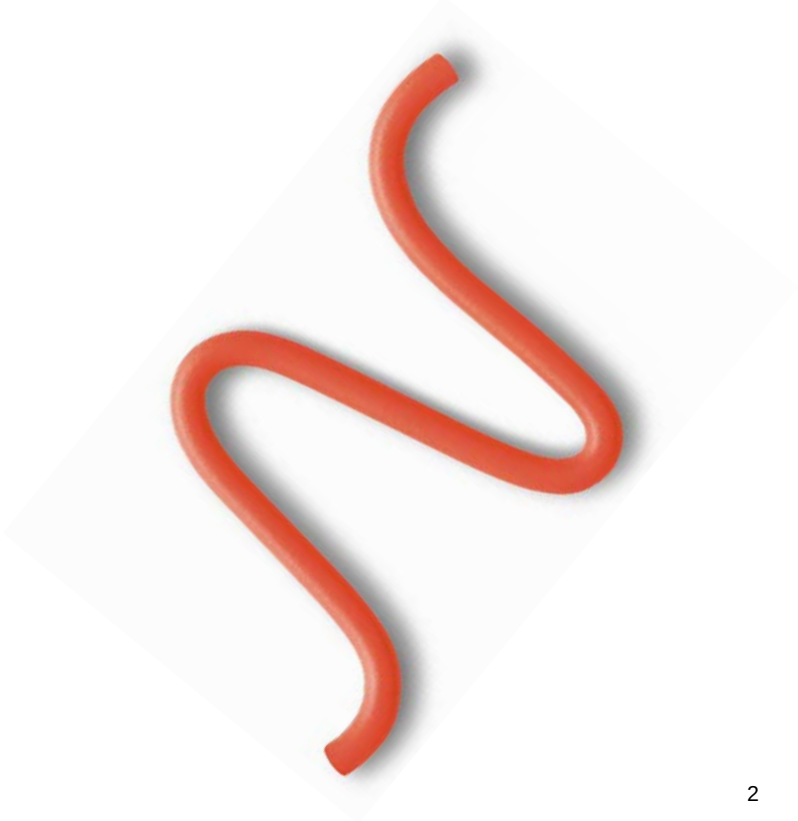
Lars Lervik
Discipline Responsible Paper Insulated Cables
Nexans Norway AS

– State of the art –

High Voltage Direct Current Mass Impregnated Cable Systems (HVDC MI Cable Systems)

Agenda
IEEE PES 12.11.2015

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*



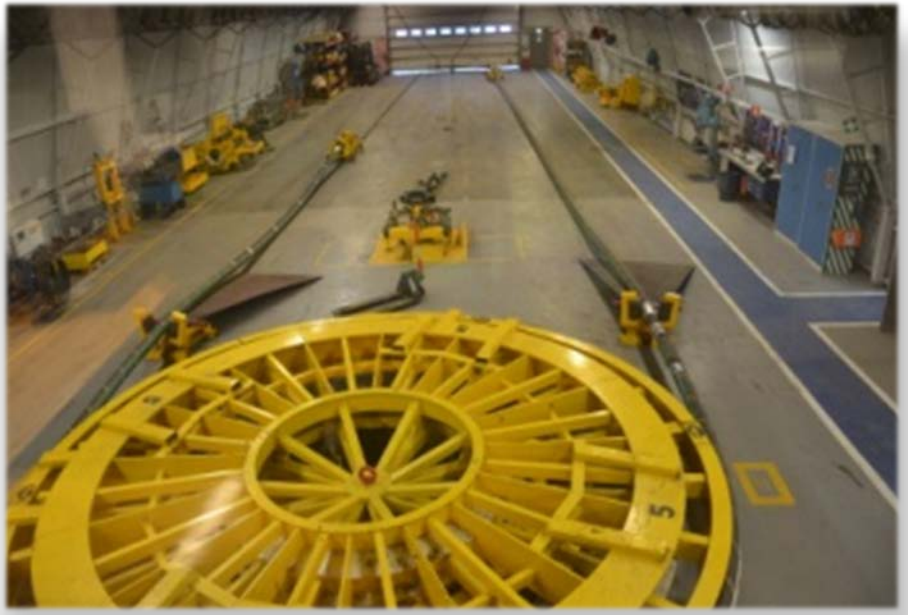
The Halden Plant

- 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

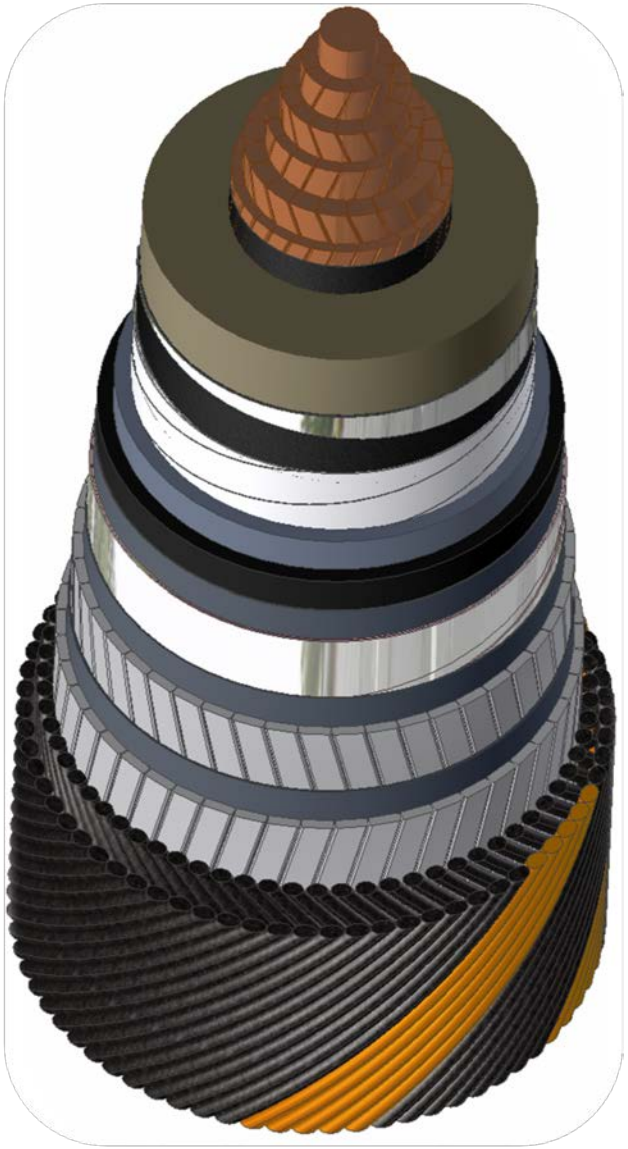
- High Voltage Laboratory and Mechanical Test Centre

Full-scale electrical type test

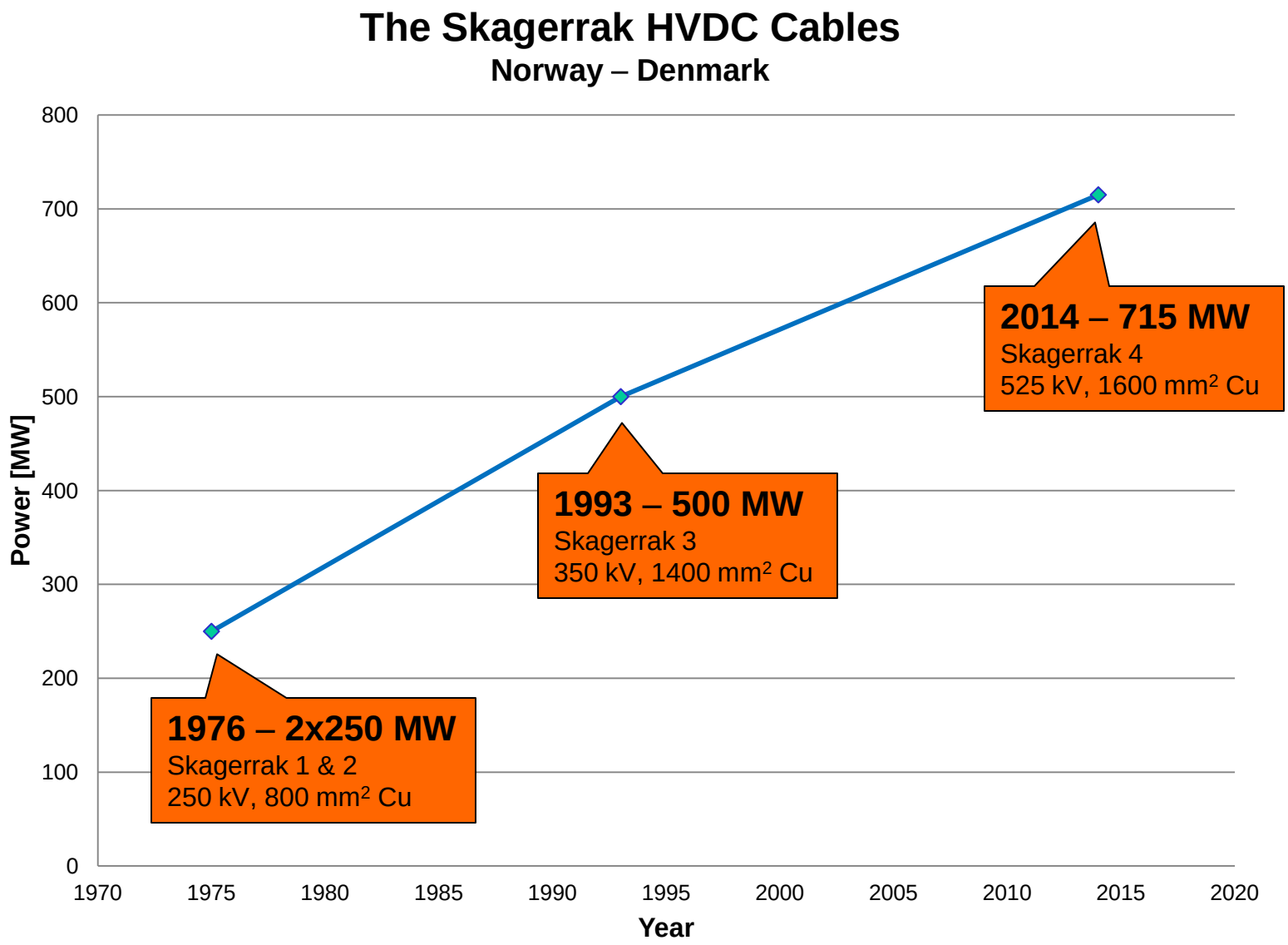
Full-scale mechanical type test



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 HVDC Cables
Norway – Denmark
Power [MW]
800
700
600
500
400
300
200
100
0
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
Year
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

What is a Mass Impregnated Cable?

- 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

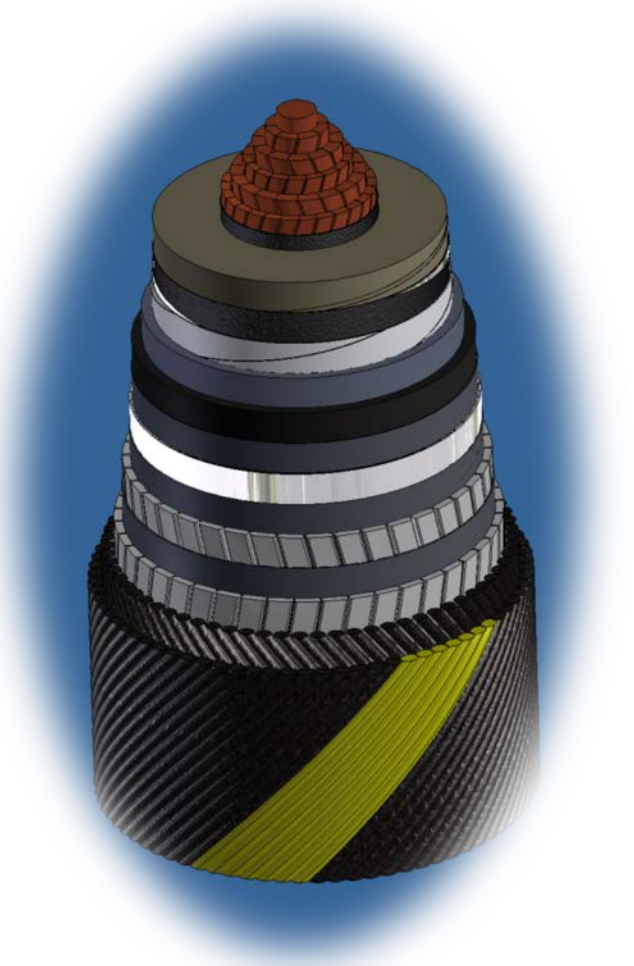
- The first cable with impregnated paper insulation manufactured
- Manufacturing length: 6 m
- Route length: 40 km
- Number of joints: approx. 7000

Submarine cable installation in the thirties

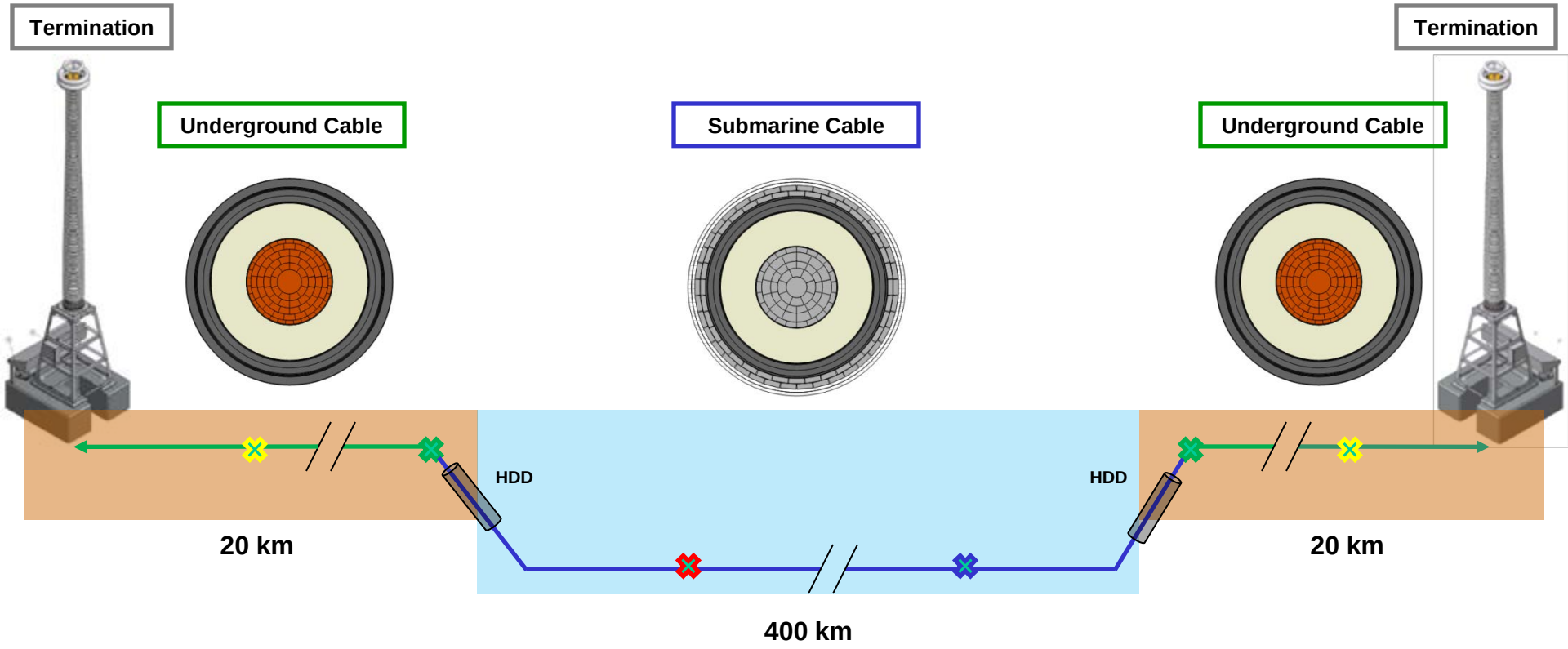
Submarine cable installation in the fifties

- 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



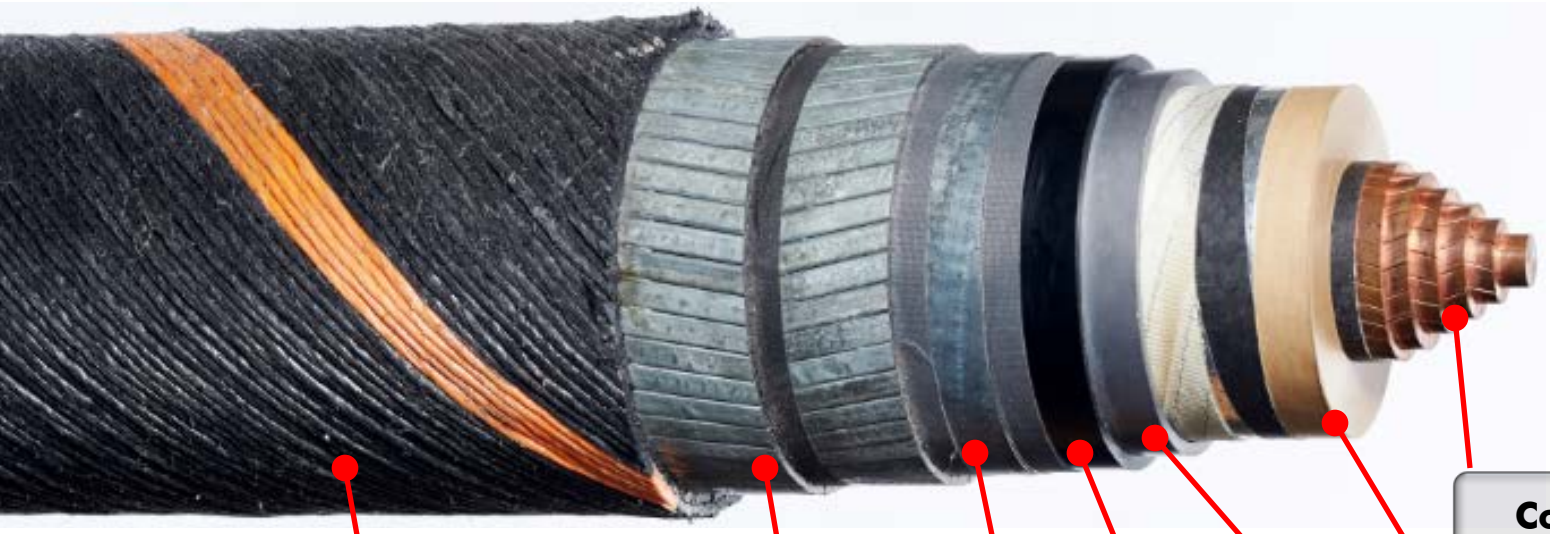
Example of Scope of Work
HVDC MI Cable System



- Underground Cable joints
- Transition Joints Submarine/ Underground Cable
- Flexible Factory Joints for Submarine Cable
- Flexible Offsore/ Repair Joints for Submarine Cable

Typical Submarine Cable Project

HVDC MI
Submarine Cable Design



Copper conductor

MI insulation system

Lead alloy sheath

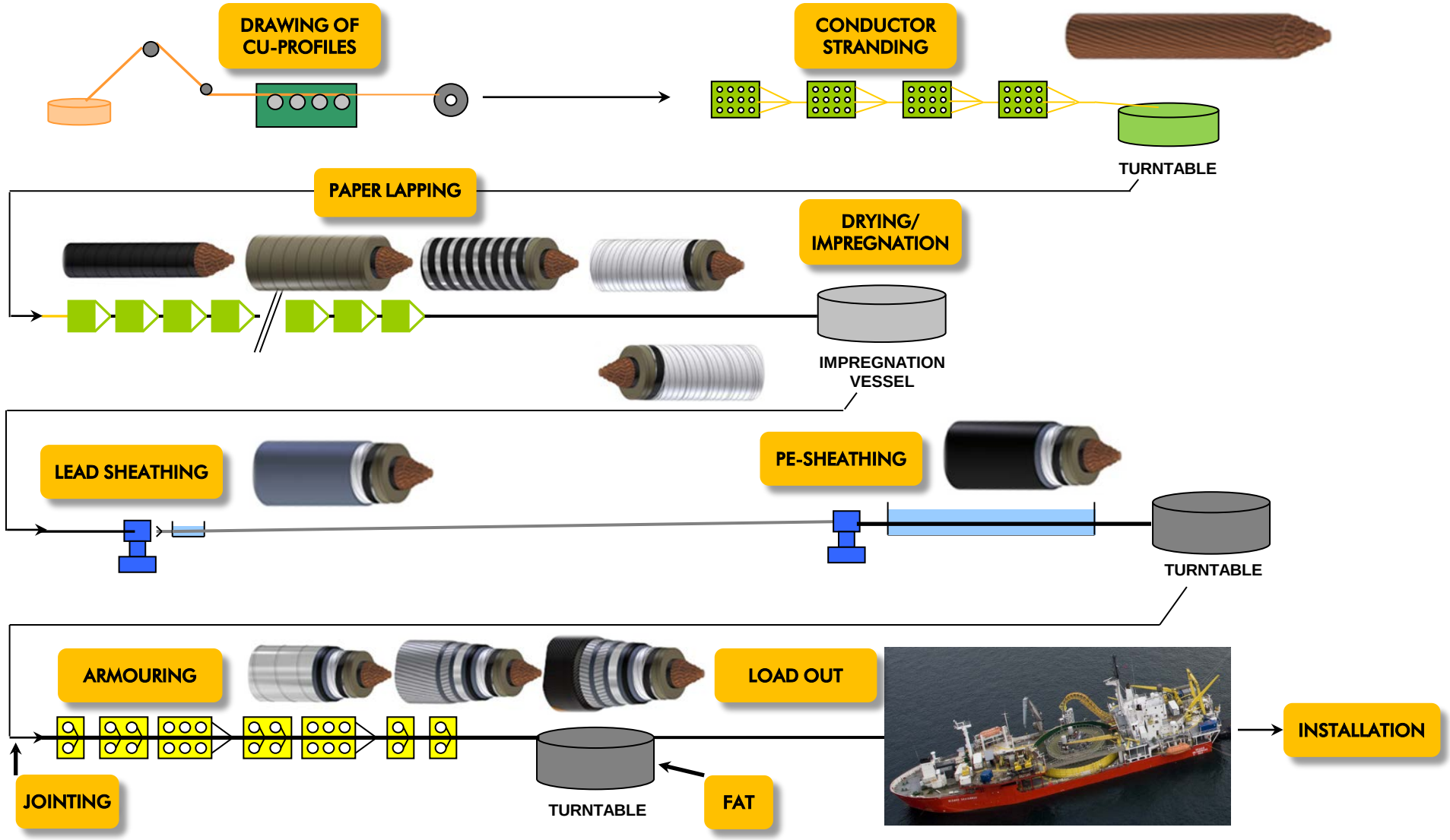
Polyethylene sheath

Transversal steel reinforcement

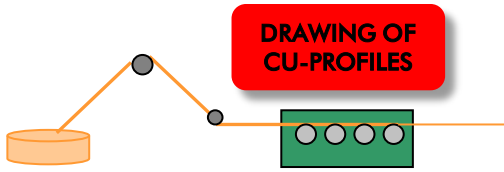
Steel wire armor

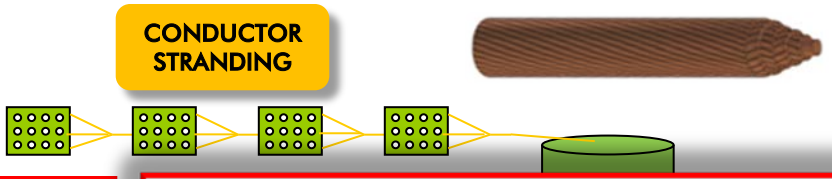
Corrosion protection and outer serving

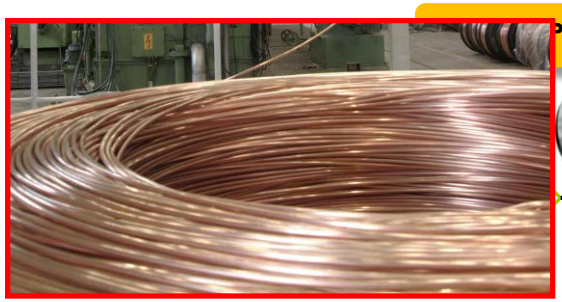
HVDC MI Cables
Manufacturing flow chart



HVDC MI Cables
Manufacturing flow chart

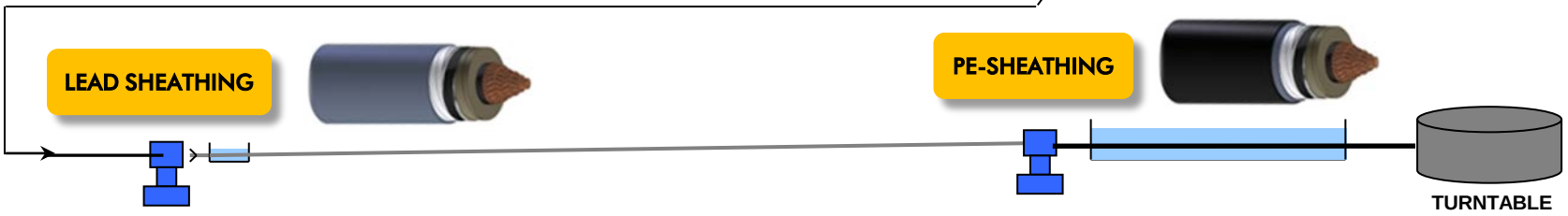


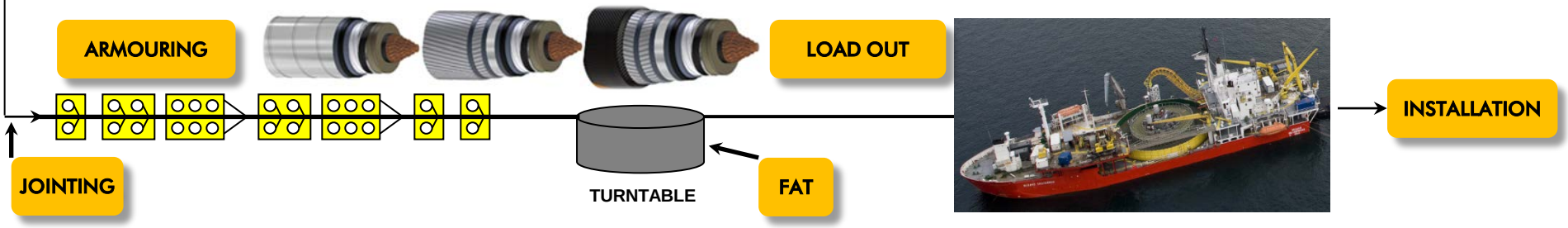




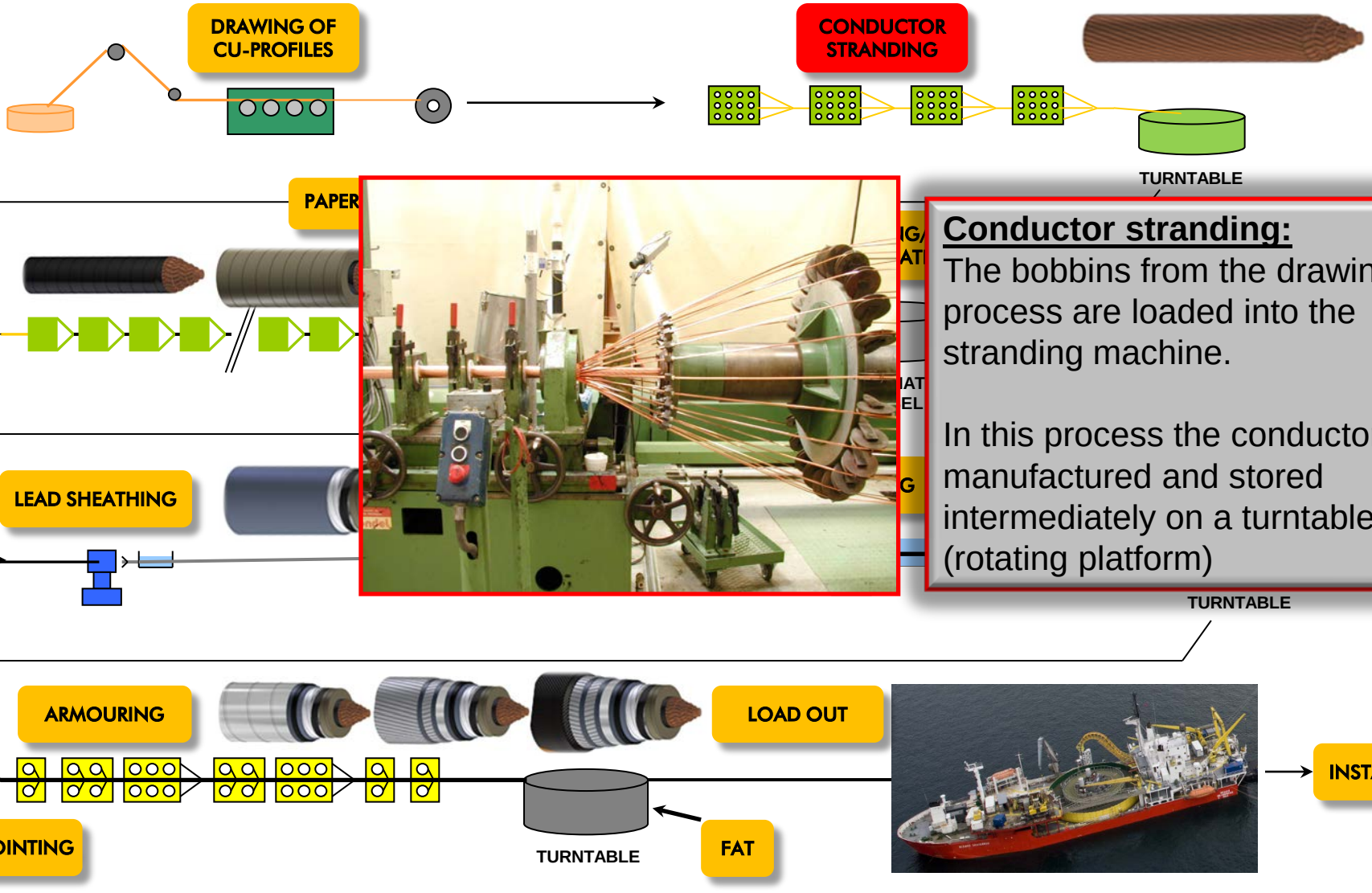
Drawing process:
Round wires are drawn to the desired shape and spooled to bobbins for use in the next process; the conductor stranding

IMPREGNATION
VESSEL





HVDC MI Cables
Manufacturing flow chart

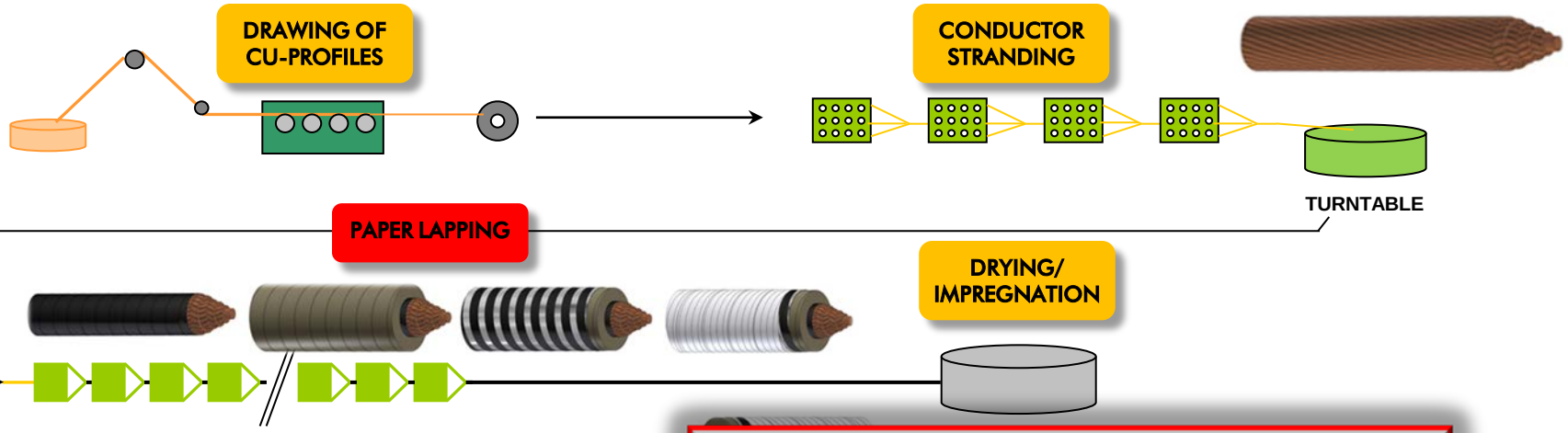


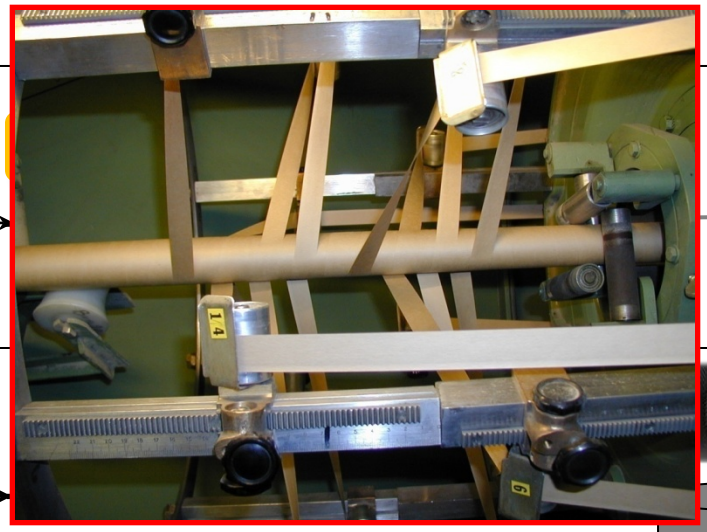
Conductor stranding:

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)

HVDC MI Cables
Manufacturing flow chart





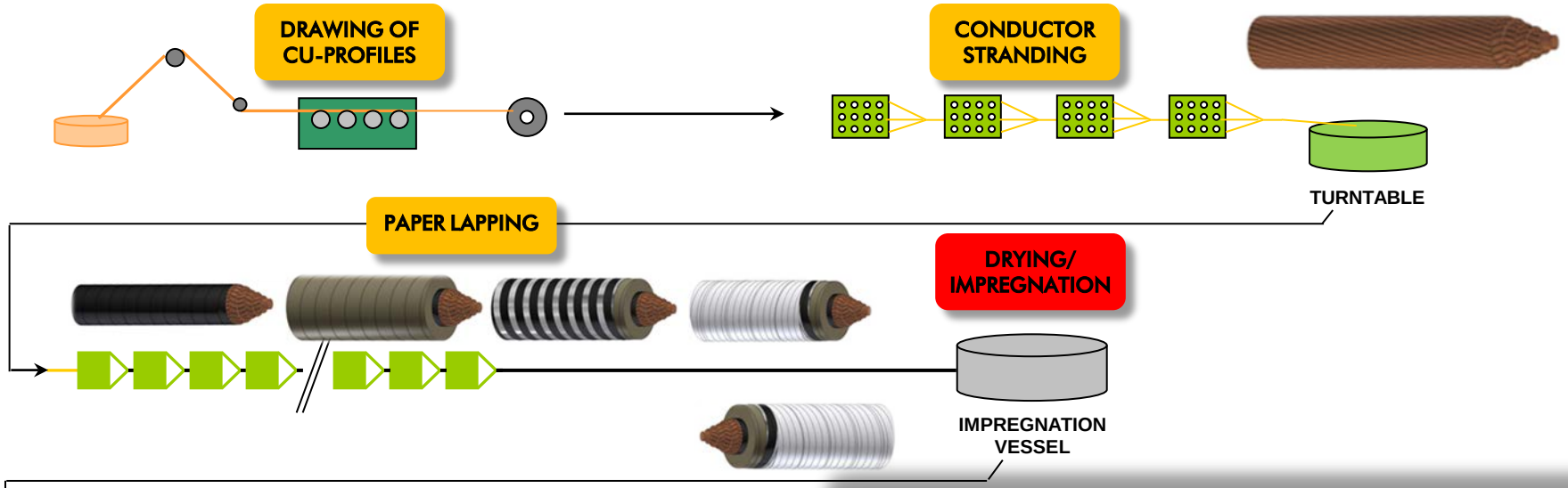
Paper lapping:

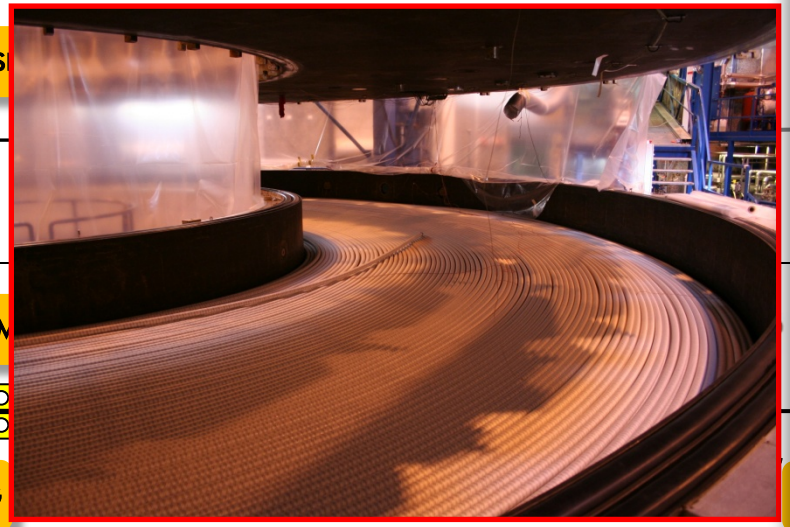
The finished conductor is guided from the turntable to the paper lapping line where the insulation system is applied.

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).

HVDC MI Cables
Manufacturing flow chart





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.

HVDC MI Cables
Manufacturing flow chart

Lead sheathing:
After the drying and impregnation process the moisture proof lead sheath is applied.

OF
LES

CONDUCTOR STRANDING

TURNTABLE

PAPER LAPPING

DRYING/
NATION

GNATION
SSEL

LEAD SHEATHING

PE-SHEATHING

TURNTABLE

ARMOURING

LOAD OUT

INSTALLATION

JOINTING

TURNTABLE

FAT

HVDC MI Cables
Manufacturing flow chart

DRAWING OF CU-PROFILES

PE-sheathing:
The PE-sheath is applied directly above the lead sheath.
This sheath acts as mechanical and corrosion protection of the lead sheath.

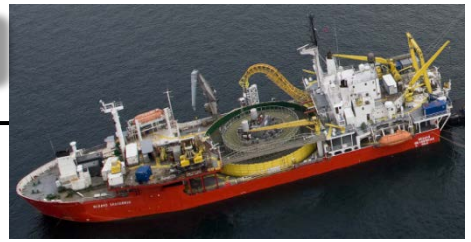
LEAD SHEATHING

PE-SHEATHING

TURNTABLE

ARMOURING

LOAD OUT



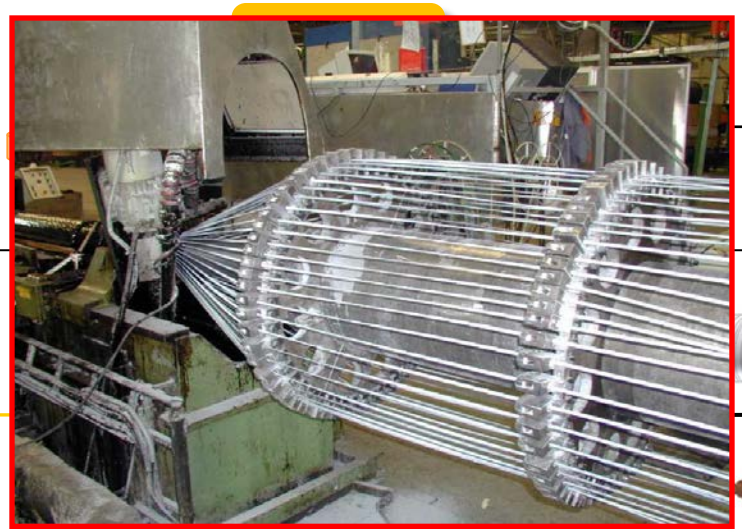
INSTALLATION

JOINTING

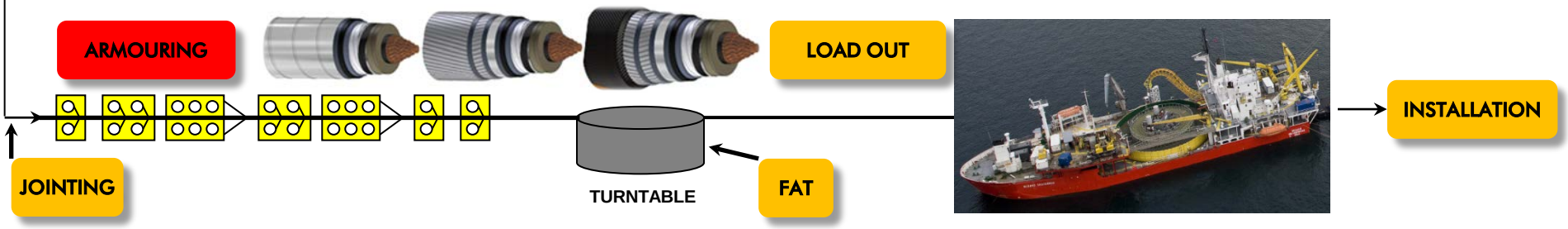
TURNTABLE

FAT

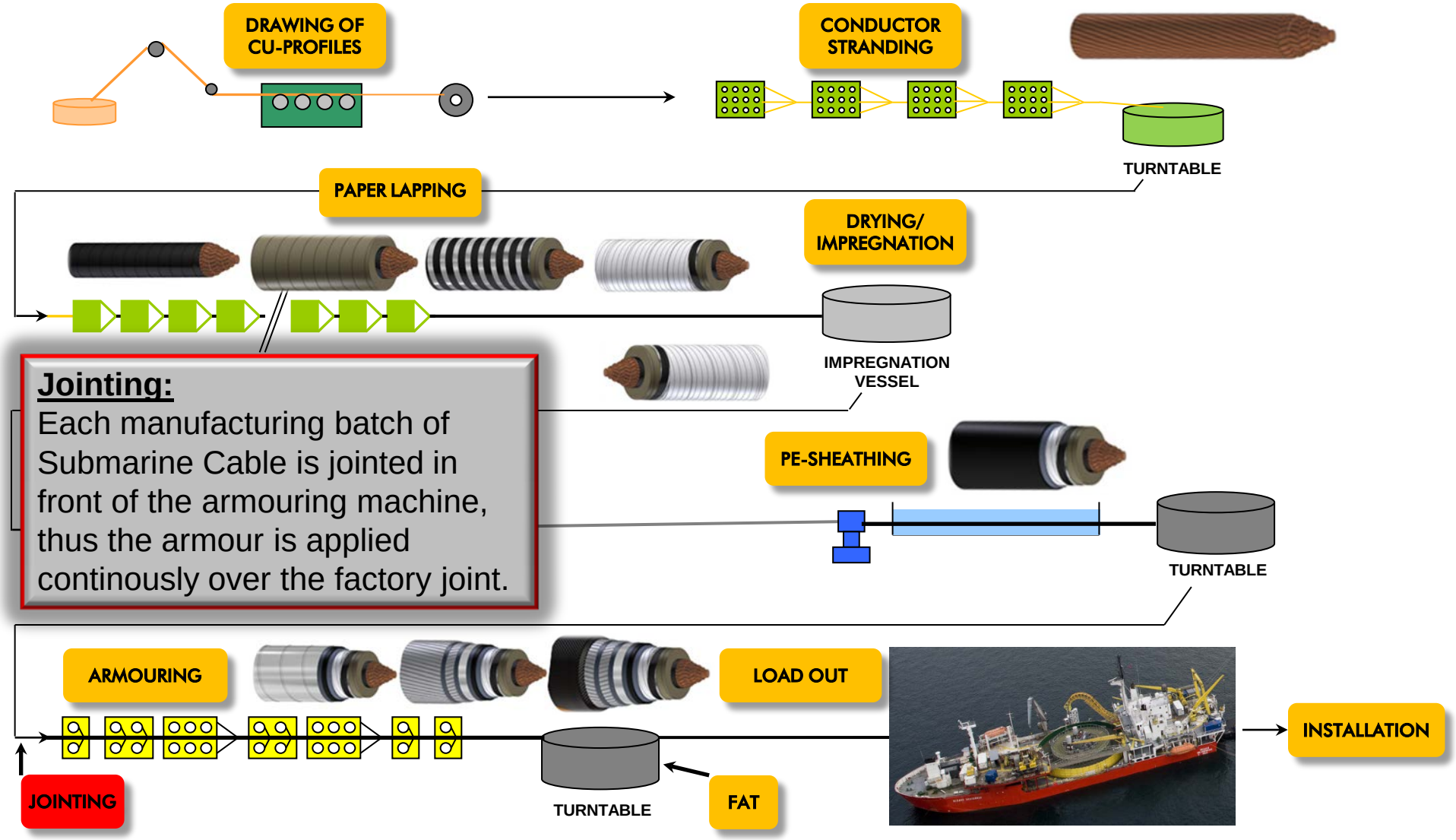
HVDC MI Cables
Manufacturing flow chart



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.



HVDC MI Cables
Manufacturing flow chart



Jointing:
Each manufacturing batch of Submarine Cable is jointed in front of the armouring machine, thus the armour is applied continously over the factory joint.

HVDC MI Cables
Manufacturing flow chart

CONDUCTOR STRANDING

TURNTABLE

DRYING/ IMPREGNATION

IMPREGNATION VESSEL

LEAD SHEATHING

PE-SHEATHING

TURNTABLE

FAT:
Factory Acceptance Test is performed to verify the integrity of the insulation system.
A 525 kV cable is tested at 945 kV.

ARMOURING

JOINTING

TURNTABLE

FAT

INSTALLATION

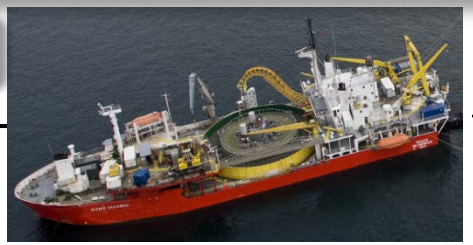
HVDC MI Cables
Manufacturing flow chart

DRAWING OF CU-PROFILES

Load out:
After the Factory Acceptance Test is performed the submarine cable is ready for load out to the cable laying ship.

ARMOURING

LOAD OUT



INSTALLATION

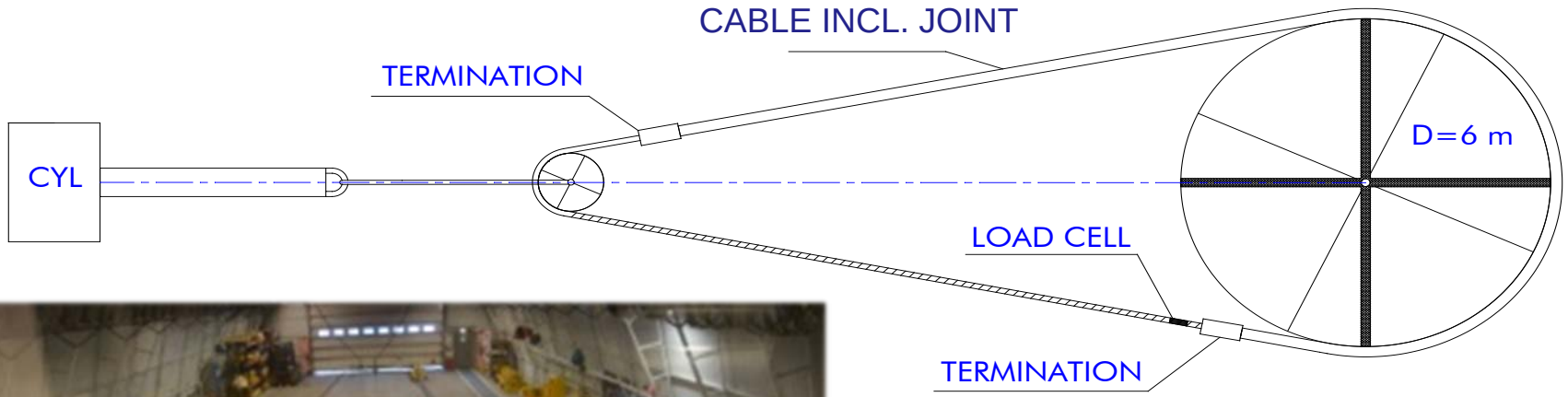
JOINTING

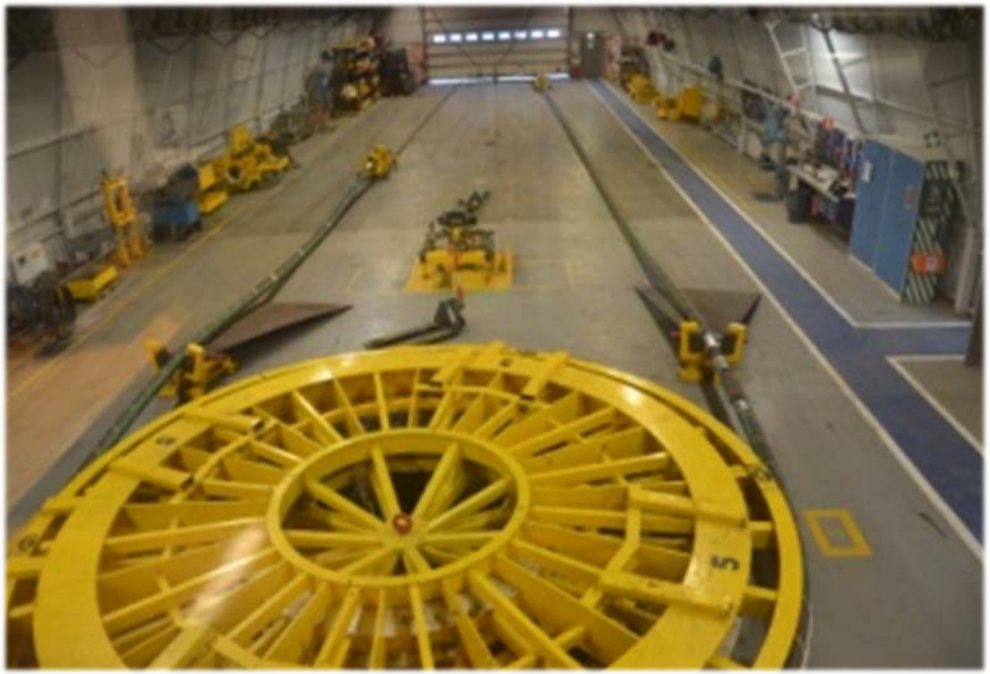
TURNTABLE

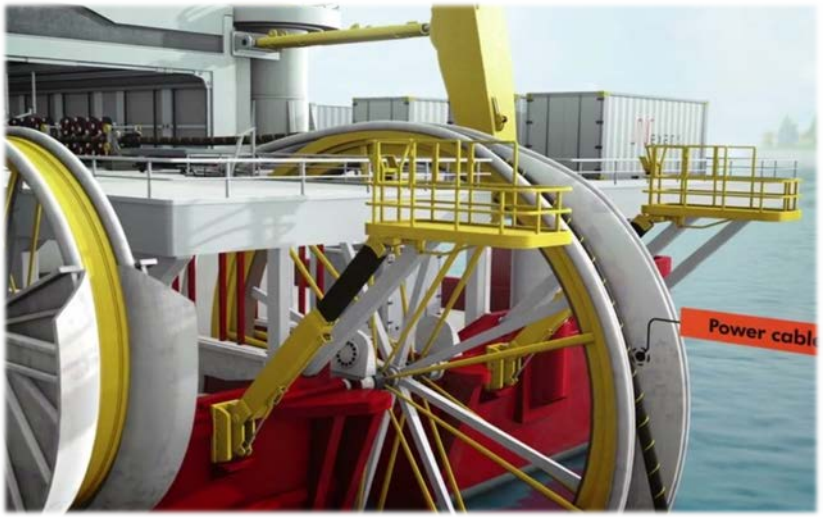
FAT

Type Testing Mechanical

- 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







Type Testing Electrical

- Performed subsequent to the tensile bending test
- Performed acc. to Cigré Electra 189

10 positive load cycles
+945 kV (+1,8·U_0)

↓

10 negative load cycles
-945 kV (-1,8·U_0)

↓

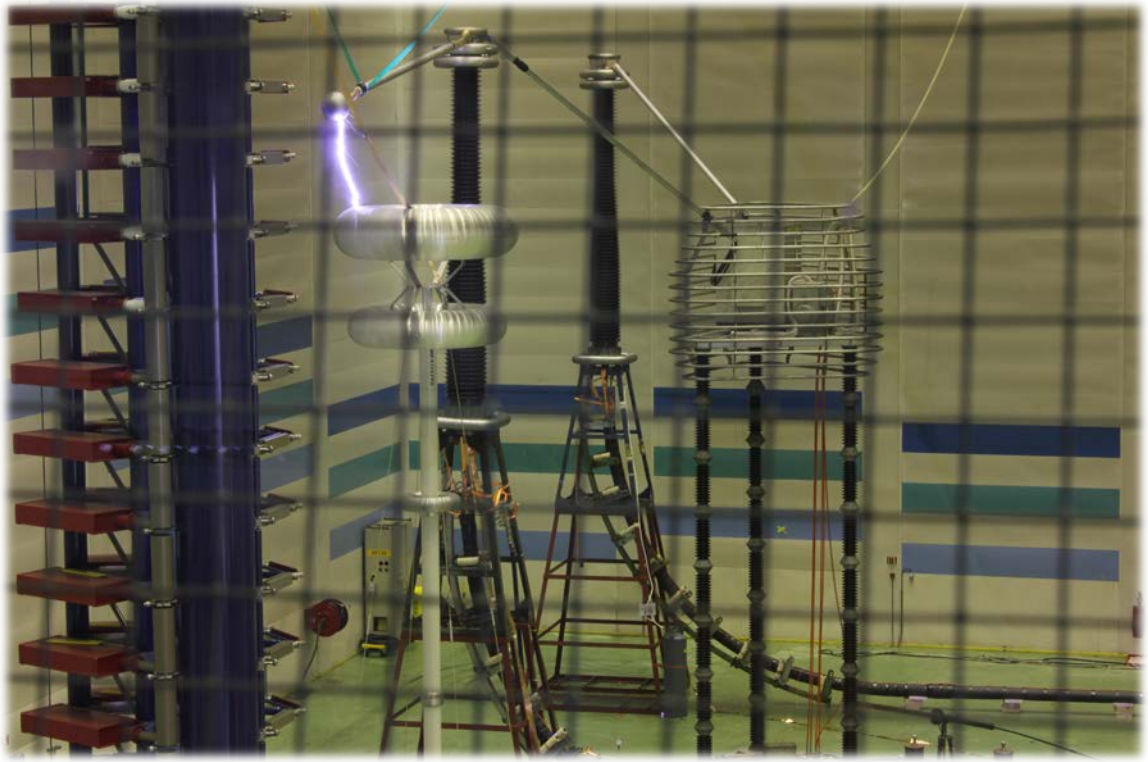
10 load cycles with polarity reversals
±735 kV (±1,4·U_0)

↓

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

↓

Superimposed lightning impulse test
±525 kVDC, ±1050 kV impulse

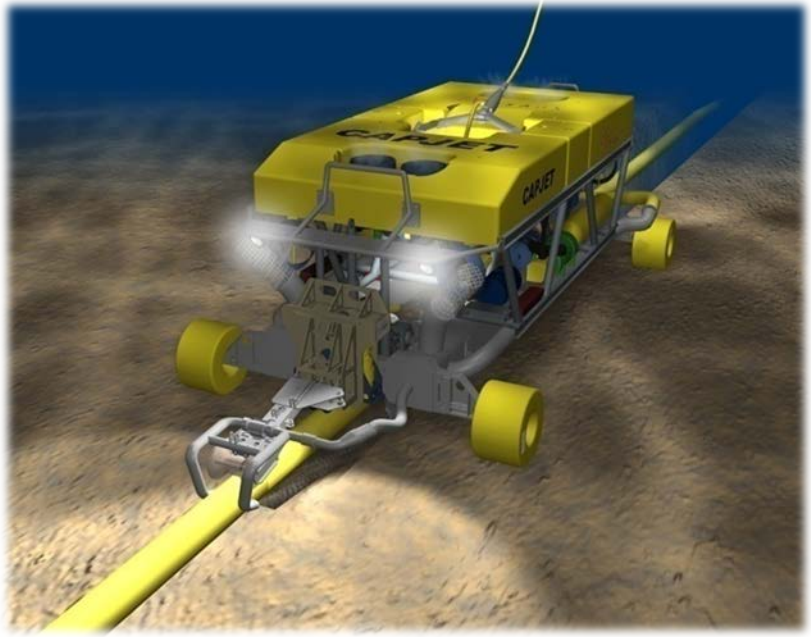


Submarine Cable Installation

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



Underground Cable Installation

- 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

Drum loaded onboard a transport ship

Cable pulled from the drum on site

Underground Cable Installation

- 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

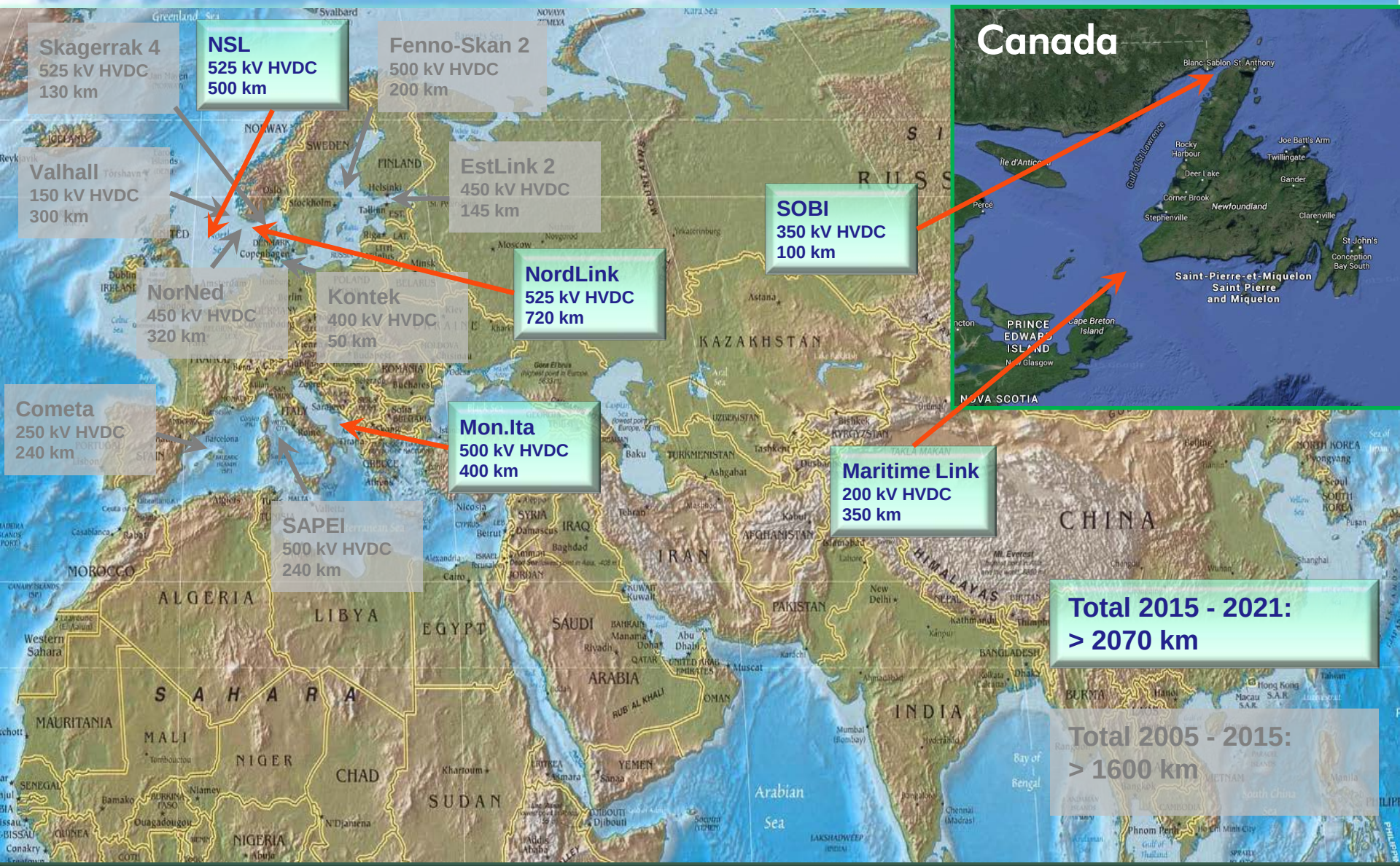
On-site preparations of the jointing pit

Cable termination

- 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

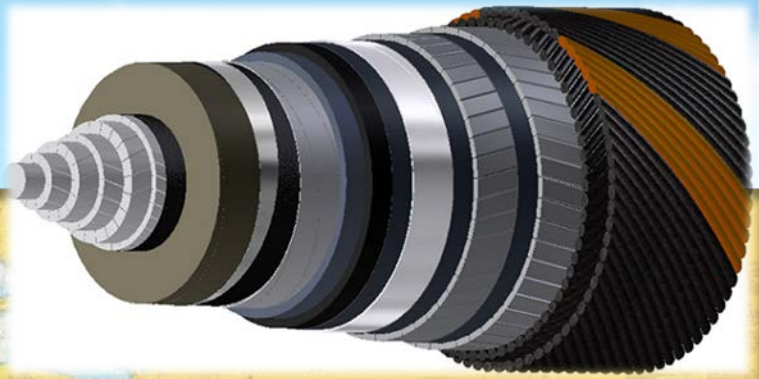
Nexans HVDC MI Cable Projects (2005 - 2015)

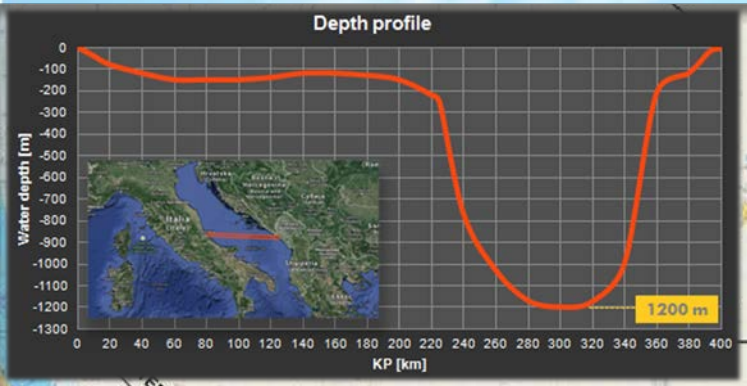
Nexans HVDC MI Cable Projects (2015 - 2021)



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 3: 87 km cable from KP 232 to KP 148

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

EL

Pescara

ITALIA

MONTENEGRO

EL Jaz

TRACCIATO DEI CAVI SOTTOMARINI

CAVO ADRIA-1

LIMITI ACQUE TERRITORIALI

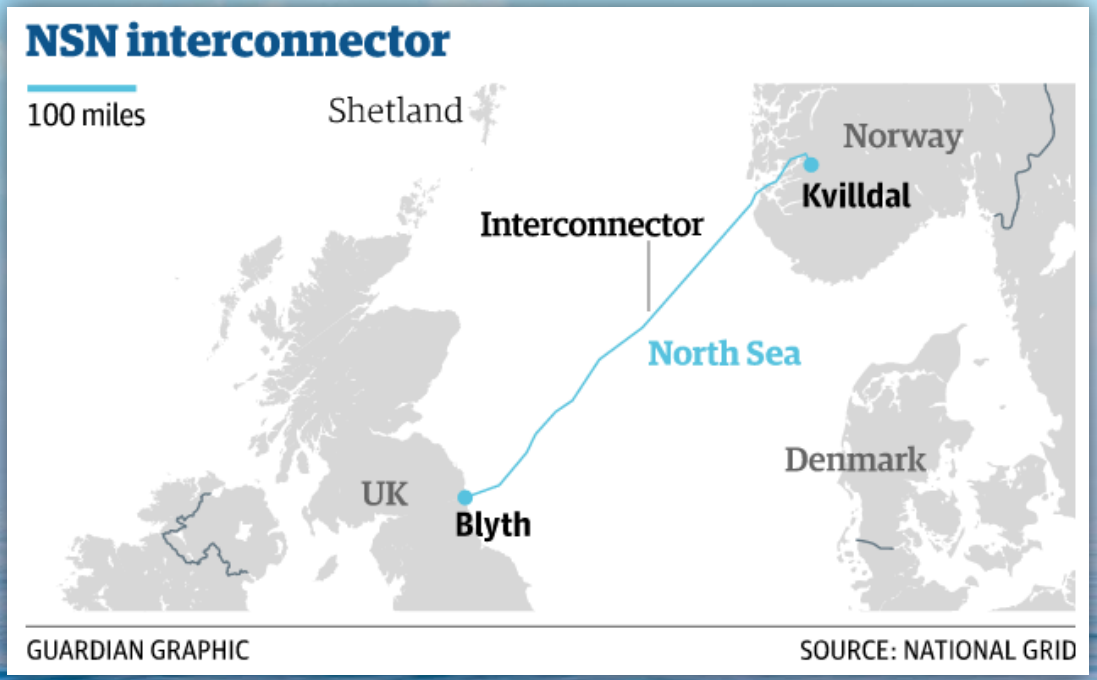
Examples of Nexans projects – Nord.Link

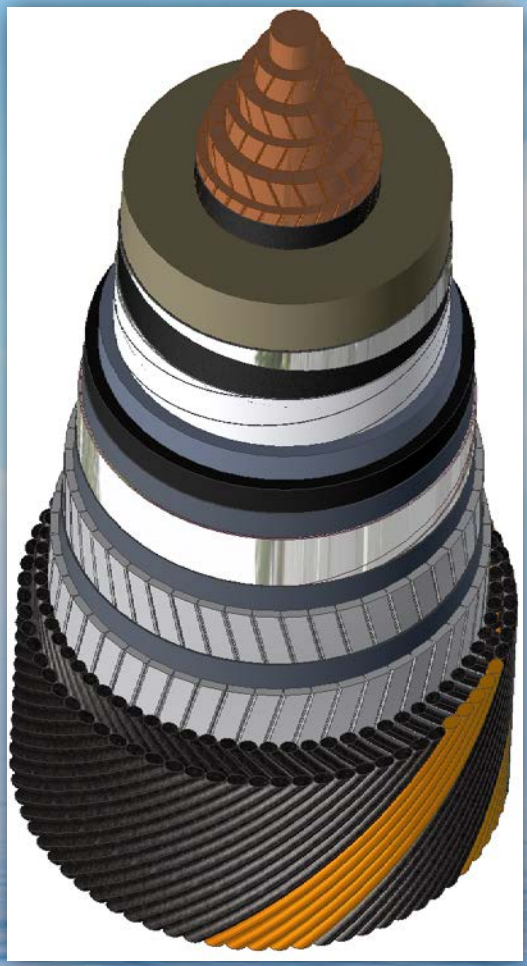
- HVDC Interconnection between Norway and Germany
- Contract value: 500 M€
- 724 km 525 kV HVDC MI Cable
- Type Testing ongoing in Halden
- Commercial operation in 2020

Statnett TenneT Taking power further kfw BANKENGRUPPE Nexans

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





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Many thanks for your attention!