Kristian Gustafsson, Technology, 2015-10-15

Importance of testing and impact on cable system reliability

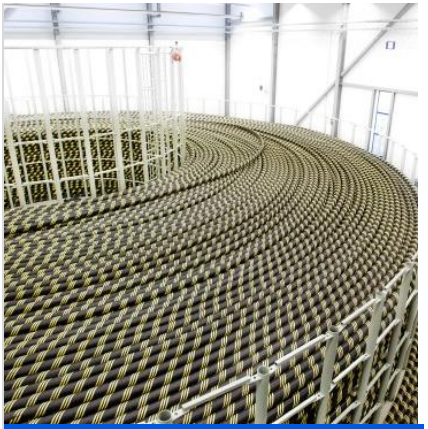
Transmission of electrical energy
What's available?

DC cables	AC cables

Technology	Al	Cu
AC XLPE 420 kV (MVAm/kg)	< 6	< 5
DC XLPE 320 kV (MWm/kg)	< 15	< 13
DC XLPE 525 kV (MWm/kg)	< 22	< 19

Sea cable system verification
The big picture

Technology qualification



Product verification

Installation verification

From idea to installed cable system
How to secure the quality?

1 Technology qualification

- Development tests
- Project specific qualification

2 Product verification

- Material tests at supplier
- Material tests at HVC
- Tests to verify production processes
- Routine test
- Sample tests
- Factory acceptance test

3 Installation verification

- Routine test of accessories
- Qualification of jointers
- Site acceptance test

Reliable cable system for the next 40 years

Cable system qualification and verification
Resources at HVC

- Mechanical laboratory
- High Voltage Laboratory
- Materials laboratory
- DC routine tests
- AC routine testing
- Routine test of land cables

Technology qualification
Type test and prequalification test of cable systems

Type test (≈3 months)

- Mechanical preconditioning
- Load cycle test
- Impulse test
- Dissection

Prequalification test (≈18 months)

- Mechanical preconditioning
- Load cycle test
- Impulse test
- Dissection

	Extruded DC	MI	AC
Standard or recommendation	Electra 171 Cigré TB 623 Cigré TB 496 Cigré TB 303	Electra 171 Cigré TB 623 Electra 189	IEC 60840 IEC 62067 Cigré TB 623 Cigré TB 490 Cigré TB 303

Technology qualification
Mechanical design

For sea cables the mechanical properties are very important

- Laying depth
- Minimum bending radius
- Ship parameters
- Wave height
- Protection requirements

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- Mechanical design

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- Global analysis
- Local analysis

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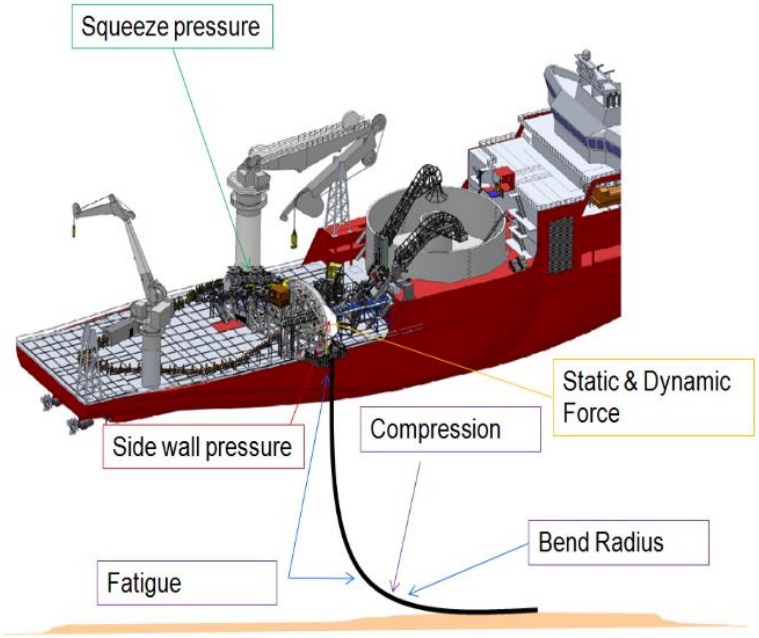
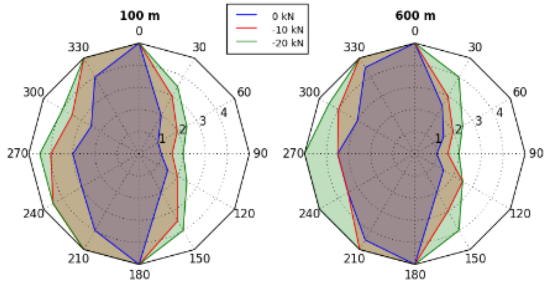




Technology qualification
Mechanical tests

Test bays	
Tensile and bend	
Fatigue	
Bending stiffness	
Crush	
Longitudinal water	
Impact	
Squeeze	
Torsion	
J-tubes	

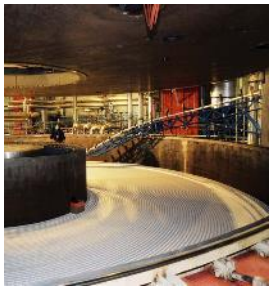
The mechanical complexity of cables depends on depth, diameter and application

Product verification
Extruded cables

Conductor Stranding

Extrusion

Degassing



Lead extrusion

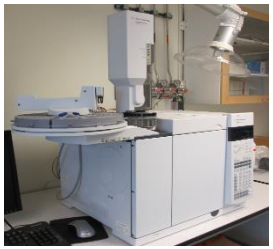
Armoring

Storage

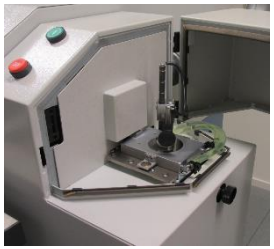
Resistance and longitudinal water barrier

Hot set

Gas measurement



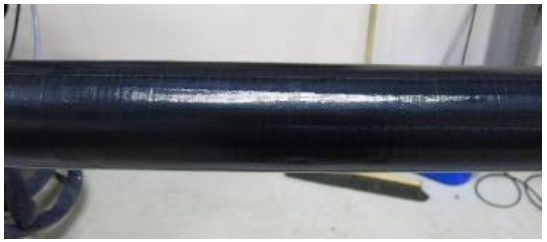
Alloy content



Routine test

Product verification
Extruded cables, factory joint

Factory joint

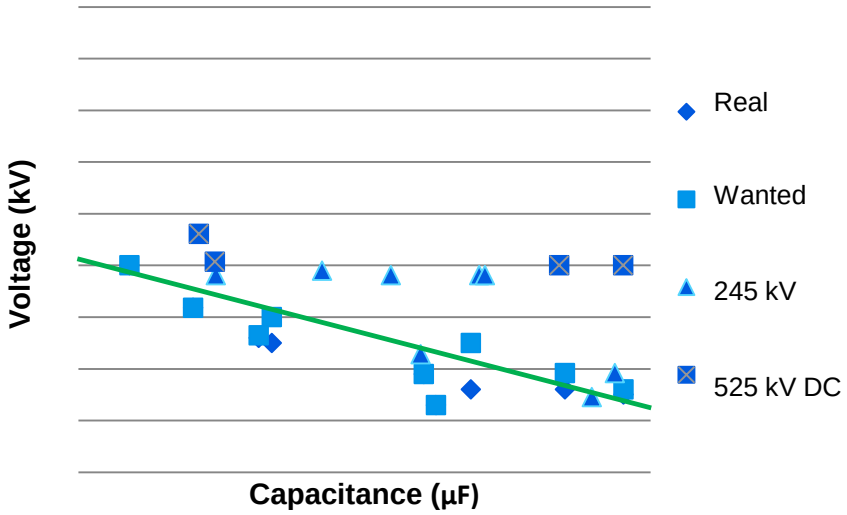


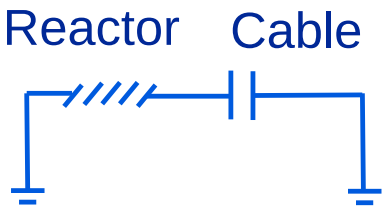
- Factory joints are the most important product for a sea cable factory
- Factory joints enables rational installation of sea cables

Product verification
Why AC testing of extruded cables

- AC voltage testing is more effective than DC testing for detecting insulation defects
- Higher power means longer cable core lengths can be tested with AC voltage
- Higher power means an increased number of factory joints are tested with AC voltage and PD measured
- Higher power may eliminate need of ridged sea joint if all factory joints can be tested before delivery

Product verification
Routine tests, what's the challenge?



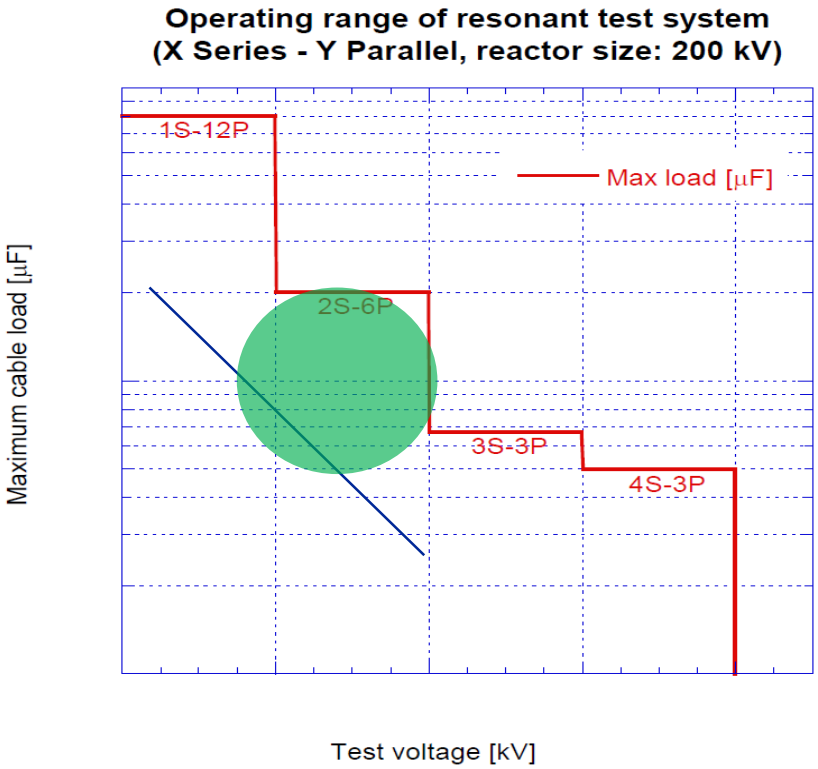


W= CxU^2

What to do?

- Shorter delivery lengths
- Reduced voltage
- Inverse AC testing
- **Increase capability**

Product verification
Operating range



1S12P ≈ 400 km

2S6P ≈ 100 km

3S3P ≈ 30 km

4S3P ≈ 25 km

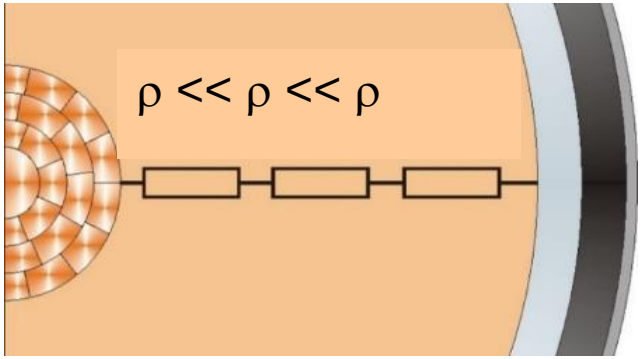
Ongoing and future projects

Ultra long delivery AC and extruded DC lengths tested according to standard or internal requirements to improve quality and reduces the number joints in field

Cable system verification
How to test factory joints?

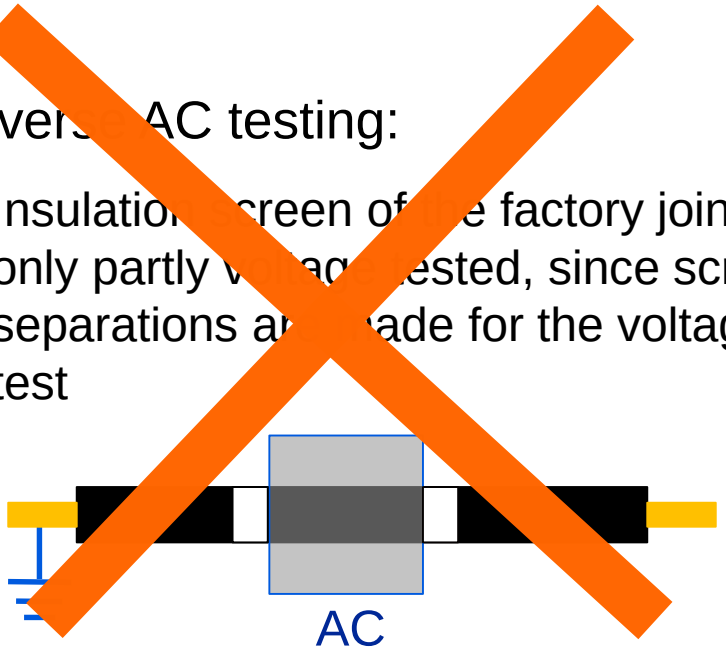
AC testing

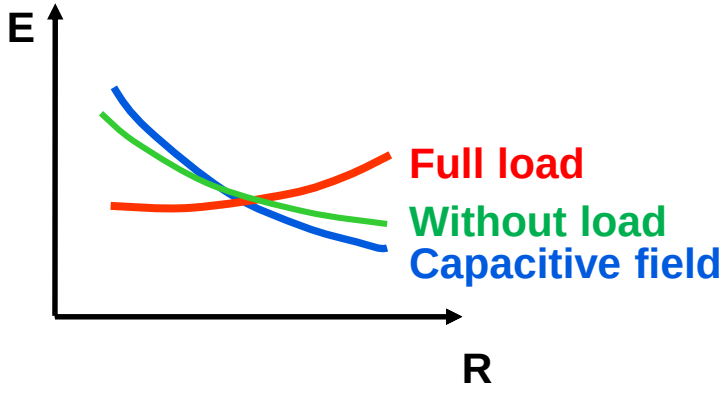
- All insulation layers of the factory joint are fully voltage tested: conductor screen, main insulation, and insulation screen



Inverse AC testing:

- Insulation screen of the factory joint is only partly voltage tested, since screen separations are made for the voltage test

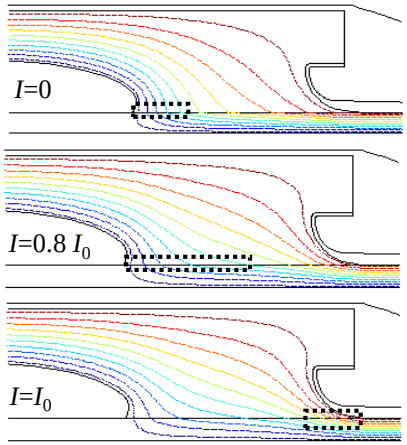




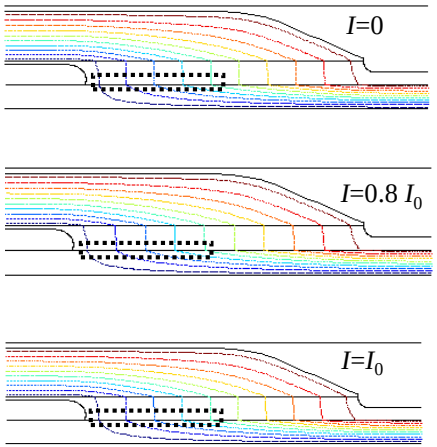
Cable system verification
Premolded joints

- The quality of every joint is verified with an AC voltage test and Pd measurement

Geometric



ABB, Non-Linear Resistive



The resistive field grading material gives low electric field strength throughout the insulation system

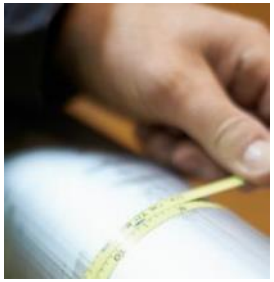
Cable system verification
MI cables

Conductor Stranding

Paper lapping

Drying and Impregnation

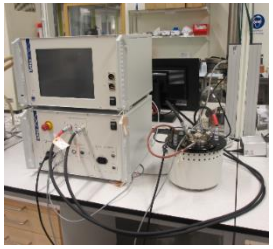
Lead extrusion



Armoring

Storage

Permeance Thickness



Loss factor

Dielectric response

High Voltage test

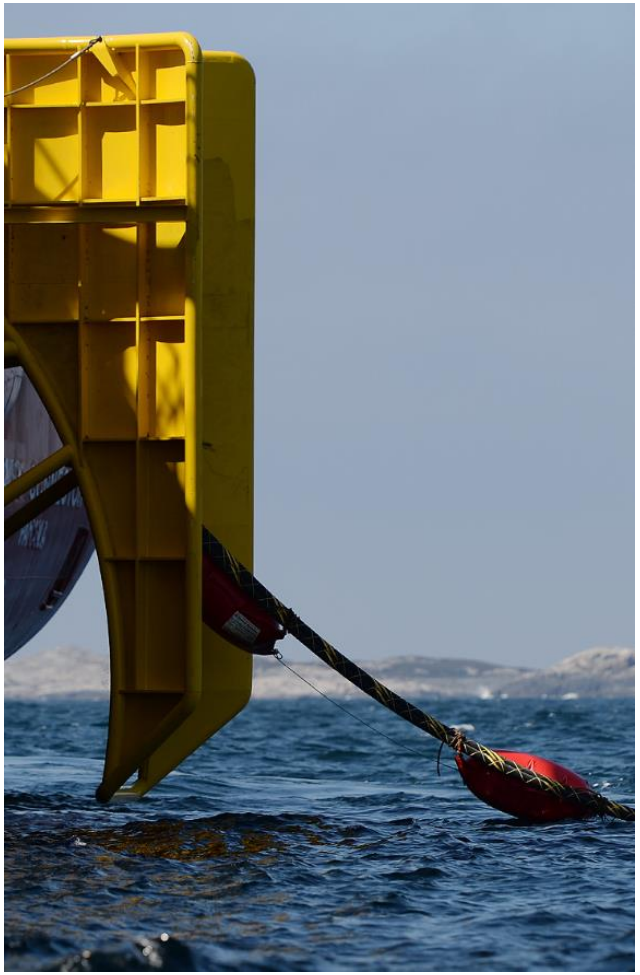
Conductor resistance

Capacitance

Power factor test

Factory acceptance test

Installation verification
How to ensure a successful test?



Installation verification
Some of ABB recent experience

Extruded DC 300/320 kV

- ABB have installed and successfully commissioned 2000 km cable and >1000 joints without any failure

AC cables

- **Martin Linge** 132 kV
  163 km
  1 rigid sea joint
- **Troll** 66 kV
  70 km
- **Lillebält** 420 kV
  15 km

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