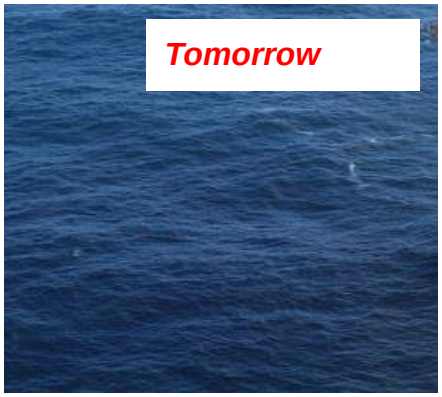
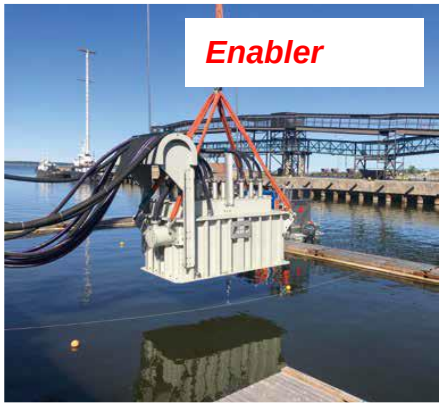
Subsea Technology *(3.000 m)*

All electric equipment on ocean floor



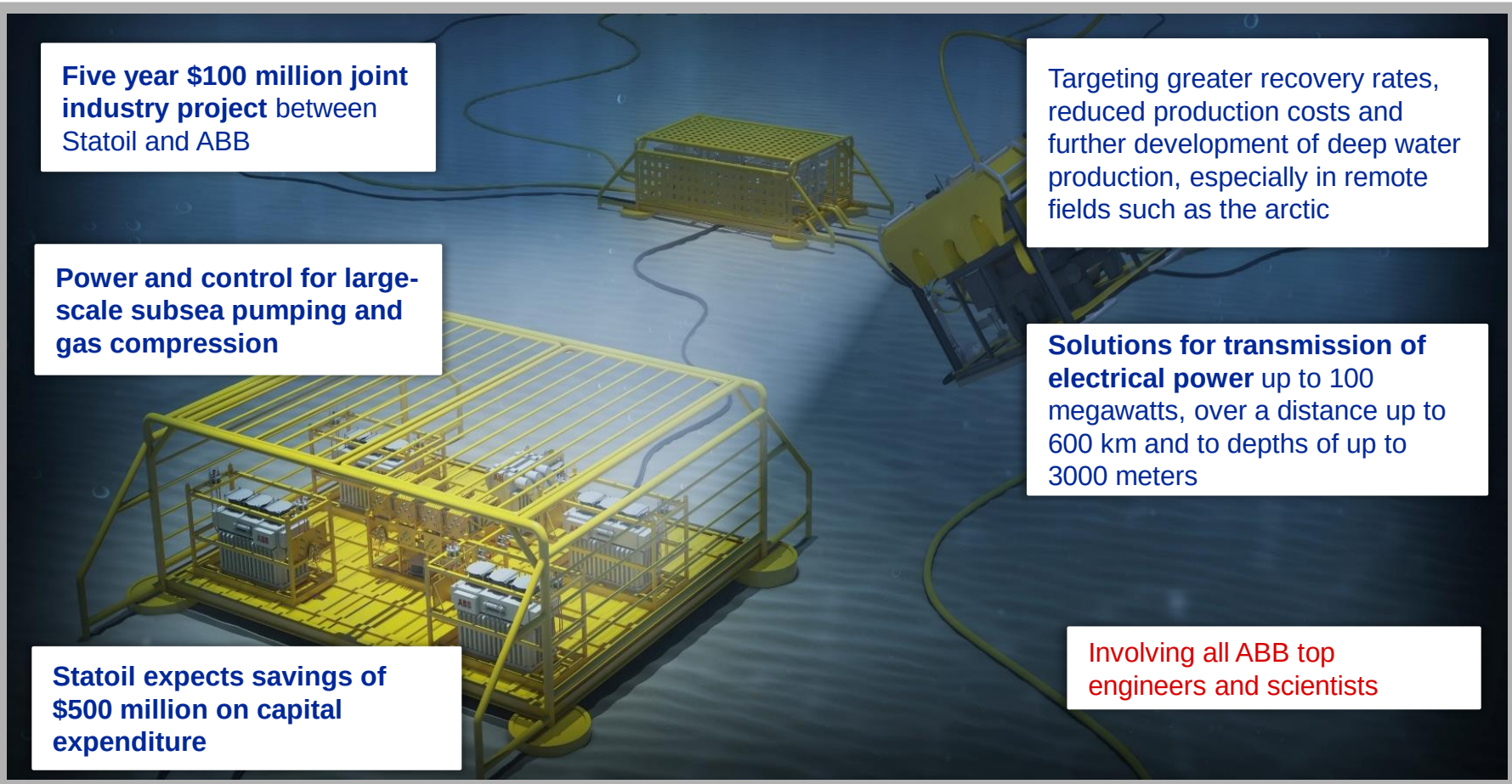


Presentation VBIK 2022-02-16

Birger Drugge

ABB and Statoil: enabling subsea factories of the future

Developing deep water subsea power and control technologies



Subsea power

Collaboration and benefits

Brown field

Extend existing infrastructure
- Tie-in of remote resource
- Increased production capacity
- Limited topside impact
- Pro-long life-cycle

Green field

Subsea factory
- Enabling subsea production
- Lower CAPEX & OPEX, increase recovery rate
- Flexibility
- Pioneer technology

Joint feasibility study

Subsea Power for optimized field development
- Enabling subsea production
- Case/ FEED studies
- Explore options for power from shore
- Evaluate options – select optimal choice

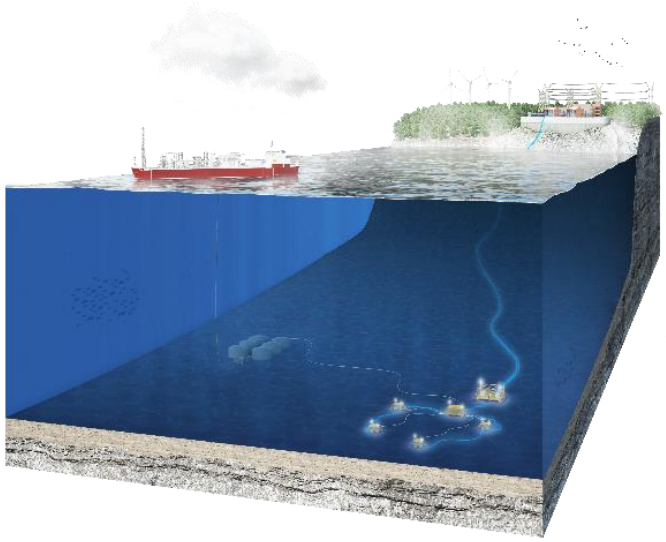


ABB collaborates with customers to find the best subsea power solution for different fields

Business cases

Overview

Subsea Gas Compression	Multiple subsea gas compressor trains with subsea compressors and supporting pumps Typical motor loads 2-18 MVA Total power up to 100 MW
Subsea Oil Boosting	Multiple pumps – boosting, ESP, … Typical motor loads 2-6 MVA Multiple auxiliary loads 400/230/24 V AC&DC
Existing assets	Extend life and recovery of existing assets Adding subsea processing equipment with minimal changes to existing topsides Optional Power from shore Tying in new/smaller assets to existing infrastructure

Modular subsea power system improves subsea production

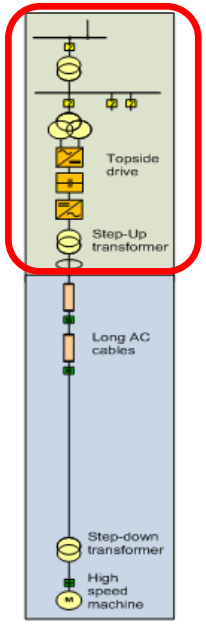
Reliable subsea power

Roadmap

Today

Topside AC

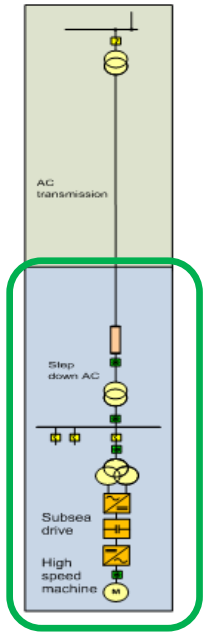
+ Subsea O&G processing
– Platforms/floaters needed
– Many cables needed
– High OPEX, CAPEX
– People safety procedures
– Environmental impact
– Limited step-out distance



Subsea Joint Industrial Project

Subsea AC

+ Subsea O&G processing
+ No platforms/floaters
+ One cable over many
+ Longer step out distance



ABB's leading subsea power & automation solutions enabling future subsea processing

Subsea power

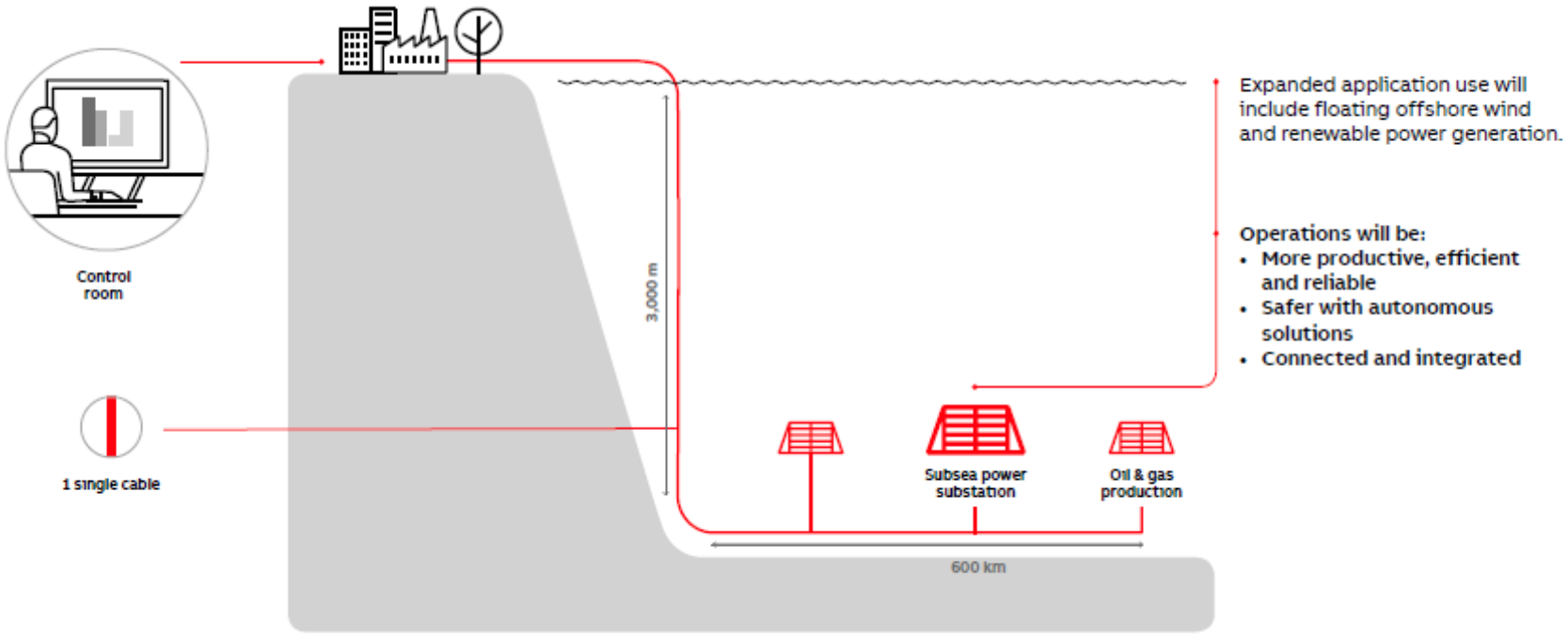
The key challenges that you are facing

Cost Efficiency	Reduce CAPEX and OPEX Improve recovery rates Extend the life of aging assets
Flexibility & Reliability	Subsea power solution can meet different type of offshore oil & gas field development and needs.
Sustainability & Risk	Sustainable subsea solution for minimize environmental impact and improve safety.

Cost efficiency and Power productity in the new subsea frontier

ABB’s pioneering subsea power distribution and conversion technology

Enabling a new era in offshore oil and gas

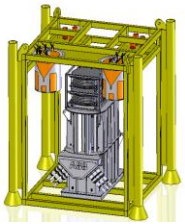


Subsea technology program

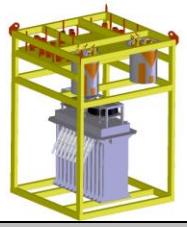
Supported by a comprehensive portfolio

Subsea Modules

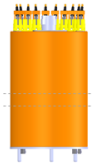
Power conversion module



Power distribution module



Control module



Products

Power Cell

Circuit breaker

Controller

Subsea Transformer

Power cable

Components

Power Semiconductors

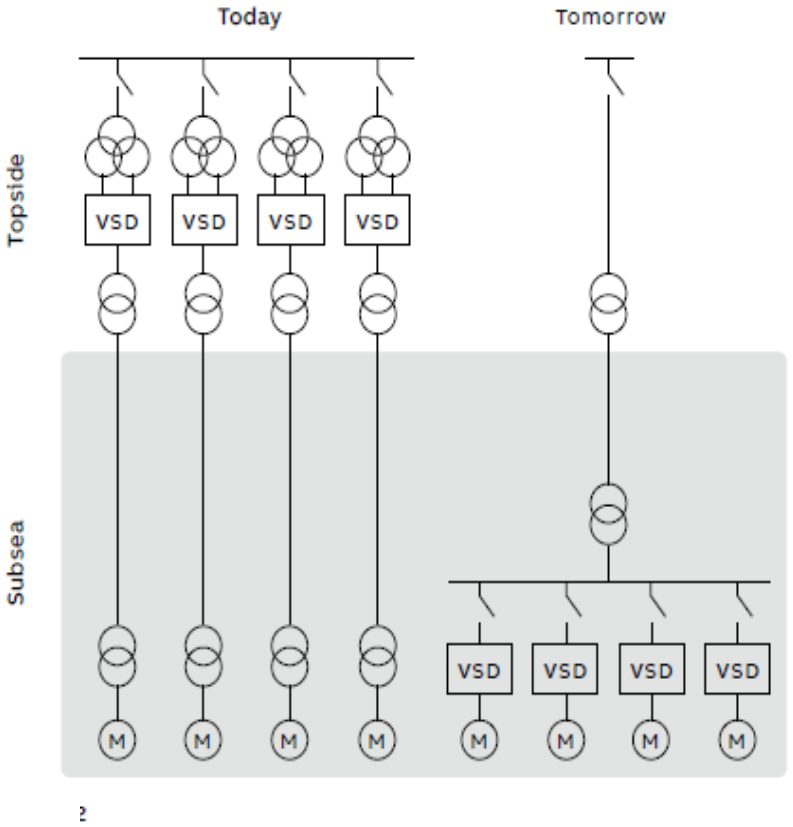
Circuit Boards

Power Capacitors

ABB’s pioneering subsea power distribution and conversion technology

Enabling a new era in offshore oil and gas

- Modular in design.
- The VSDs can operate motors, from 0.5 to 18 MVA.
- Voltages from 2.0 kV to 7.2 kV.
- Capability to drive conventional speed pumps and wet gas compressors rated at 50 – 120Hz, high-speed gas compressors up to 18,000 rpm directly
- Step-out distances from a few km to over 600 km.



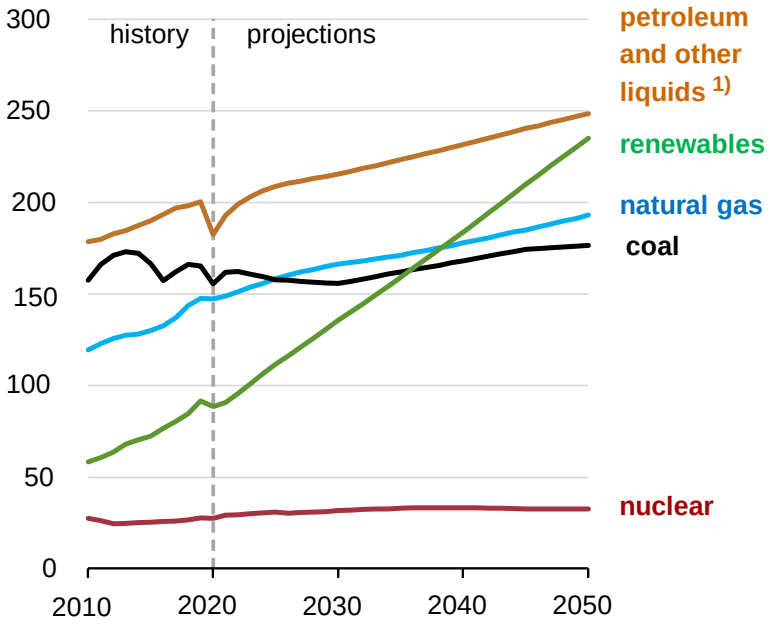
Source: ABB Review, 1, 2020, p. 52.

Subsea Technology *(3.000 m)*

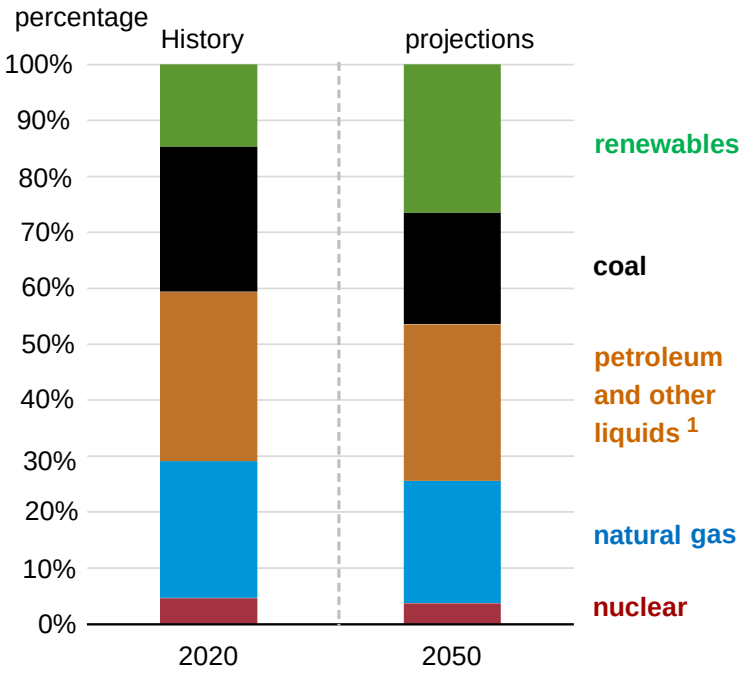
Primary energy consumption by energy source

Primary energy consumption by energy source, world

quadrillion British thermal units



Share of primary energy consumption by source, world



1) *includes biofuels*

Source: U.S. Energy Information Administration, International Energy Outlook 2021 (IEO2021) Reference case

Subsea Power – system features

Modular pressure compensated design

Input frequency 16/50/60 Hz

Transmission voltage 36 – 145 kV (typical)

Transmission distance up to 600 km (16 Hz)

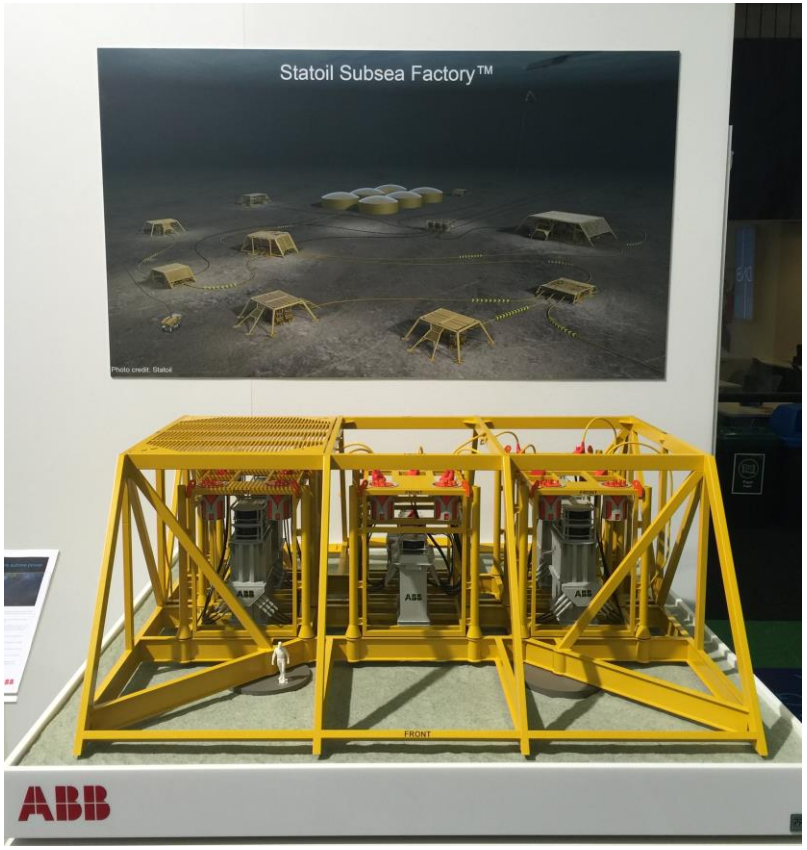
Water depth up to 3000 m

Design life 30 years

High availability with built-in redundancy

Retrievable modules

System concepts verified in shallow water system test



Subsea Technology *(3.000 m)*

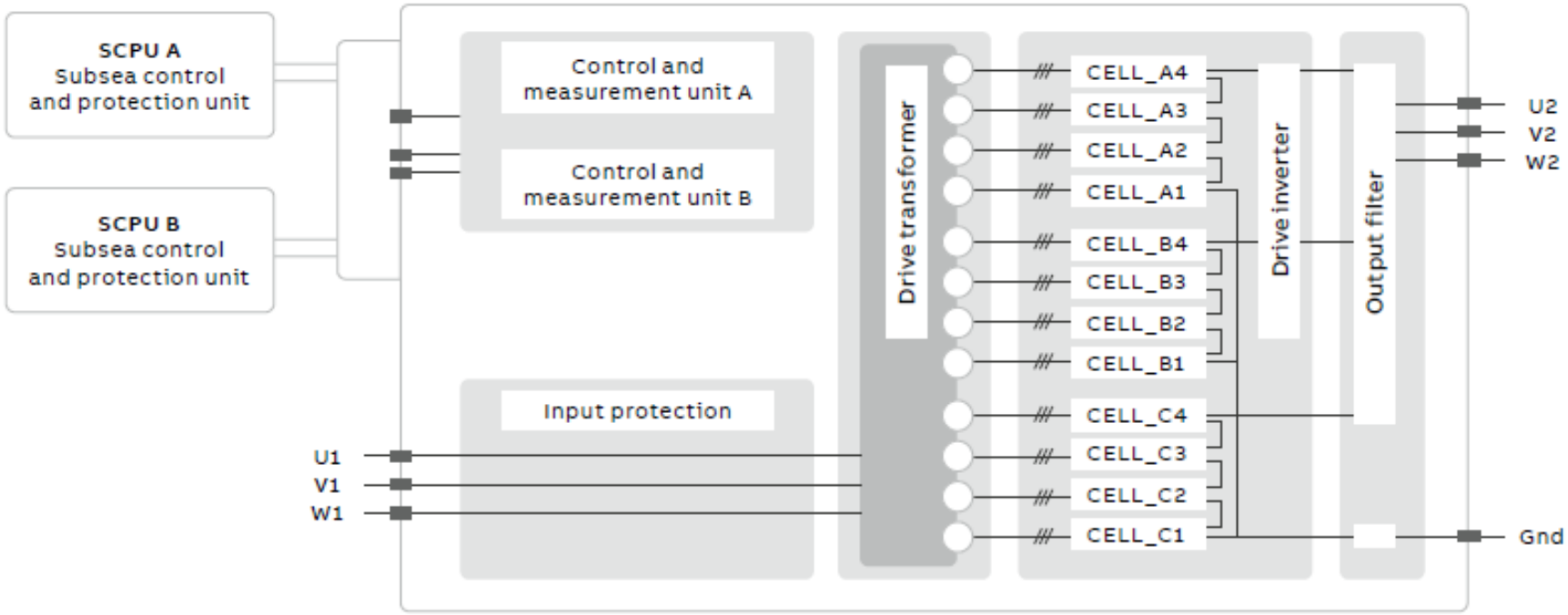
Presentation VBIK 2022-02-16 – Technical challenges

- Pressure 300 bar at 3000 m depth *(1 bar = 100.000 Pa = 100.000 N/m^2)*
  - Tank / pressure vessel design ?
  - High pressure knowledge and impact on design stresses and lifetime not solid.
  - Contacts' / material / components' performance not known and not tested at 345 bar
  - Compatibility test results not available.
  - Temperature distribution inside tank not verified.

  - Relevant test procedures
    - *Testing, testing, testing, ……*

Subsea Technology *(3.000 m)*

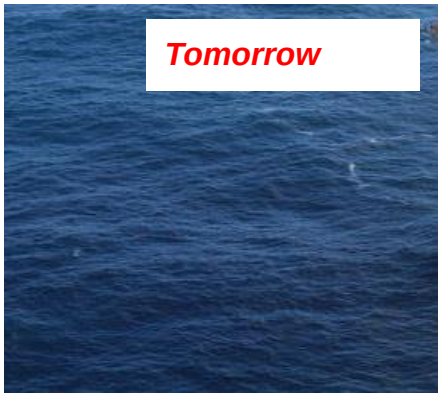
Main building blocks, configuration, and single line schematic of a prototype subsea power converter.

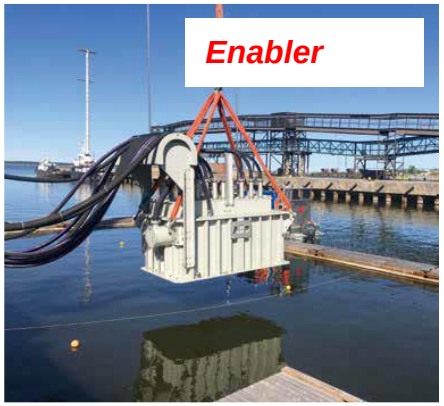


Source: ABB Review, 1, 2020, p. 55.

Subsea Technology *(3.000 m)*

All electric equipment on ocean floor





Subsea DC Link Capacitors, an example

Subsea Capacitors Development Project

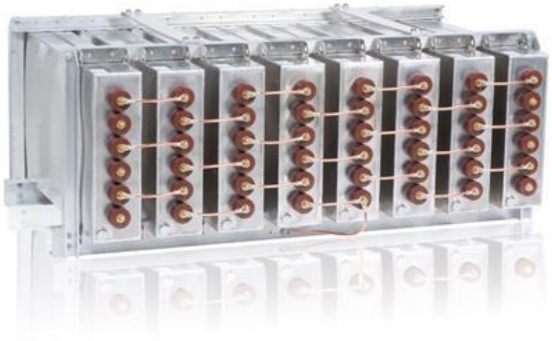
Background

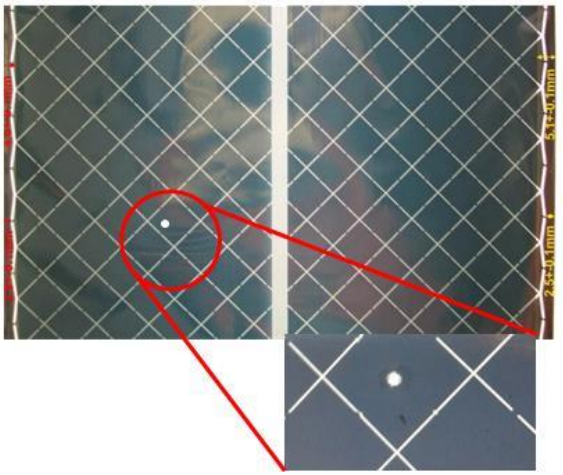
Activities started in a Technology Development Project with active participation of SECAP

First approach was to use a DryDCap solution

Testing at high pressure revealed technology barriers that would require extensive basic development work with unwanted risk and time constraints

Wet capacitor technology was concluded the technology to go for





Subsea Capacitors Development Project

Base case design DC link capacitor Durus-01

Well proven ABB basic wet capacitor technology

- Nominal voltage U_{NDC}=1.98 kV
- Capacitance= 1.25 mF, tolerance 0...+10% (at delivery)
- 2 standard soldered porcelain bushings and 2 terminal studs
- Fluid-impregnated polypropylene film dielectrics
- Stainless steel container
- >40 capacitor elements in parallel, each of them individually fused

Electrical and mechanical specific deep sea imposed design aspects and risks are solved (verified with tests and simulations)

4 Capacitor units per cell

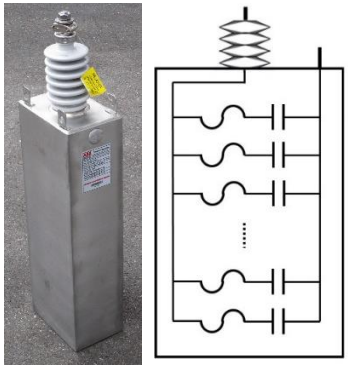
Capacitor Test Objects and Measurement Method

Pressure test infrastructure

Capacitor unit pressure test

Medium voltage drive cell pressure test

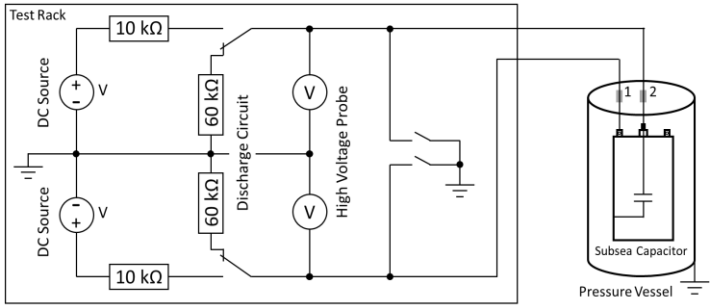
Test object



Pressure tolerant oil filled power capacitor. Internally fused capacitor elements

Standard fuse design for 1 bar applications

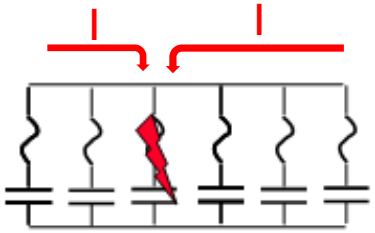
Testing circuit



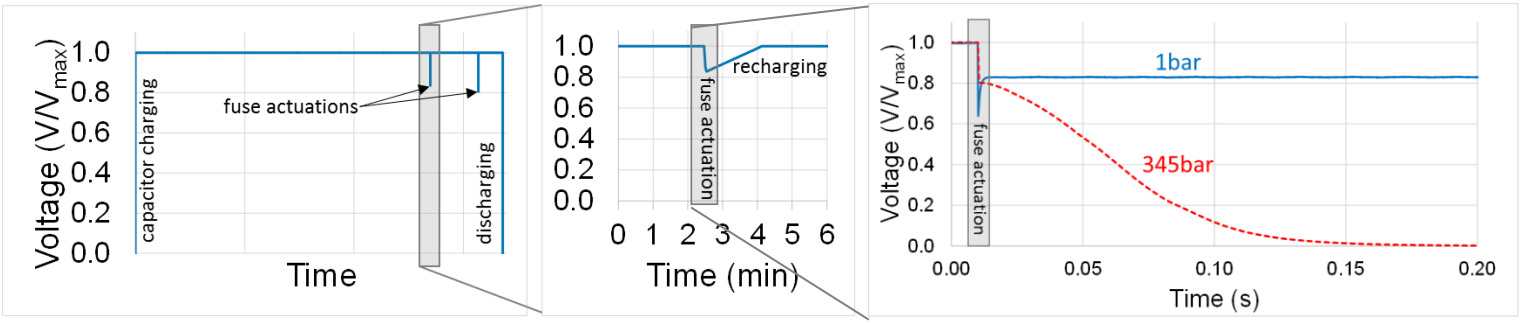
- Capacitor charging and discharging
- Real time capacitor voltage monitoring
- Real time capacitor leakage current monitoring

Fuse Testing at 1bar and 345bar: Standard Fuse Design

Process of fuse operation



Monitoring of fuse operation and element failures



1 bar

- Reliable fuse operation (blue curve)
- Current limiting fuse behavior
- Full voltage withstand with high open fuse resistance

345 bar

- Standard fuse design current limiting
- But low open fuse resistance of ~100 Ω
- Voltage withstand no longer guaranteed after fuse actuation

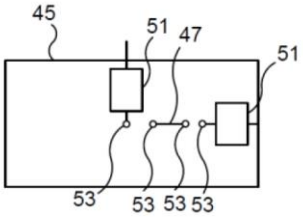
Fuse Testing at 1bar and 345bar: Fuse Modification

Standard fuse design

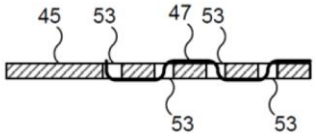
- Open circuit after fuse operation
- No residual soot formation

- Fuse wire completely evaporated
- Black conductive soot track formation with a resistance of few 100 Ohms

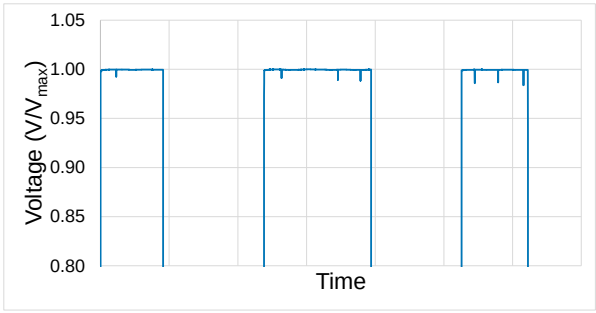
Fuse design for high pressure applications



EP 3,179,495 (B1)



- Extensively tested at 1bar and 345bar
- Excellent current limiting function
- Extremely high open fuse resistance of >10MΩ
- Long term stability verrified over several 100 hours after inital fuse actuation by continuous leakage current measurements.



Reliable fuse actuations at 345bar

Subsea Capacitors PD Gate 4

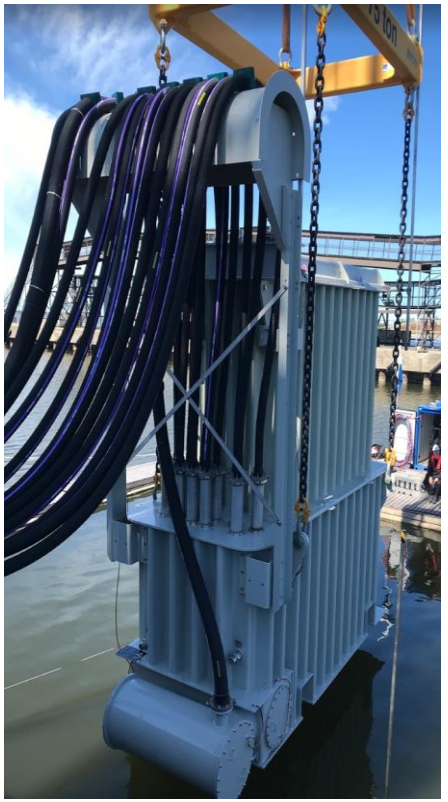
PD Project Status – Executive Summary

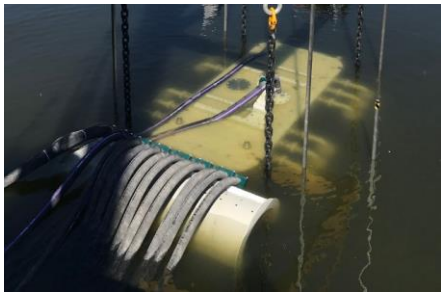
- We have successfully manufactured Subsea capacitor units at ABB Xi'an Power Capacitor manufacturing plant, China, using material from the approved/designated suppliers.
- We have successfully passed all the Qualification tests, including re-done relevant tests on Xi’an, China made model and full-size units.
- The Subsea Shallow Water Test I and II, a full-scale operating pilot test in the harbor in Vaasa, Finland, is completed with very good results.
- QA system specifics for Subsea completed

- Product Development Gate 5, DC Link capacitors, has been passed and the product is commercially available

Subsea Variable Speed Drive

Both old and new DURUS submerged on June 30th, 2019





Subsea Technology *(3.000 m)*

All electric equipment on ocean floor

“Moving the entire oil and gas production facility to the seabed is no longer a dream. Remotely operated, increasingly autonomous, subsea facilities powered by lower carbon energy are more likely to become a reality as we transition towards a new energy future,” *(Dr. PeterTerwiesch, ABB).*

The deep subsea technology with all electric equipment on ocean floor is enabling new innovative products and opportunities, e.g. subsea maintenance robots, subsea drones, seabed mining and much, much more *(see oil and gas company websites and videos).*

Power and productivity
for a better world™