Powering the seabed for a sustainable energy future
Race to the Subsea Facility
A pioneering heritage

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1980–present ESP
More than 200 electrical systems delivered

1998 Subsea transformer
World’s first commercial subsea transformer

2000 SEPDIS
World’s first subsea frequency converter

2000–2003 Topacio & Celba
First systems with subsea transformers

2005 DC link
First DC link from onshore to an offshore gas platform, reducing annual emissions by 230,000 tons of CO2 and 230 tons of NOX.

2006–2009 Tyrihans
31 km tie-back subsea electrical system

2007–2010 Ormen Lange
20 MVA subsea transformer - world’s most powerful subsea transformer

2008–2011 Åsgard/K-lab
Long step-out power qualification, 15 MVA, 47 km, 200 Hz

2011–2015 Åsgard
Long step-out 2x15 MVA, 4 7km, 200 Hz for subsea compression project

2012–2015 Gullfaks WGC
Long step-out, 2x9 MVA, 22 km, 200 Hz for multiphase compression project

2012–2019 Subsea power JIP
Subsea power distribution qualification

2013 JIP
JIP project officially launches

2016 Power switching cell
Key module of the variable speed drive, tested at 300-bar pressure at full load current

2016–2017 MV VSD
Manufacturing of first full-scale prototype

2017 Shallow water test
First full scale VSD prototype tested for 1,000 hours in shallow water

2017–2018 Power conversion cell test
3,000 hours test at 300 bar

2018–2019 MV VSD
Manufacturing of second full-scale prototype

2018–2019 MV switchgear
Manufacturing of full-scale prototype

2018–2019 LV control
Manufacturing of full-scale prototype
Distribution SCM Control Module for distribution

2019 Full system test
3,000 hrs full system test in shallow water - two full-scale VSDs in parallel, one four feeder switchgear, in addition to control and protection

2020 Completion
Technology Readiness Level 4 achieved. The subsea power distribution system is now ready for deployment
Offshore oil and gas operators have a clear vision for a safer, more energy efficient future for their mature basins through to the new remote deep-water frontiers. To achieve this vision the industry has set goals to:

- reduce emissions and environmental footprints
- improve health, safety and security of personnel
- increase productivity
- enhance asset cost efficiency

How it all started
As part of a Joint Industry Project (see below) ABB has pushed the boundaries in design, development and testing of subsea power distribution and conversion technology. The result is the world’s first fully qualified subsea medium voltage (MV) power distribution and conversion system. For the first time, the technology enables all production operations to be moved to the seabed, helping industry hit the goals outlined above, while realizing the dream of a Subsea Facility.

Operators no longer need to dream the extreme with subsea technology but can readily achieve it. The technology provides an environment that is completely free of surface infrastructure on the oceans. It truly paves the way for lower emissions, greater digitalization and control and remote operations, all while removing the human from harm’s way.

Collaboration:
$100 million Joint Industry Project between ABB, Equinor, Total and Chevron, supported by the Research Council of Norway.

Objective:
Power and control for large-scale subsea pumping and gas compression.

Challenge:
Transmission of electrical power, all with a single cable, maintenance-free, for up to 30 years:
- up to 100 megawatts (MW)
- up to 600 km distance
- up to 3,000 meters deep

Purpose:
Targeting greater recovery rates, reduced production costs and further development of deep-water production, especially in remote fields such as the Arctic.

Savings:
$500 million expected on capital expenditure.*

*In a case with eight consumers and a distance of 200 kilometres from infrastructure, the electrical power distribution solution would reduce capital expenditure by more than USD 100 million.

Foreword

Dr. Peter Terwiesch, President of ABB’s Industrial Automation business

“ABB is at the forefront of automation as we innovate and collaborate to deliver powerful solutions for tomorrow’s world. Our success in reaching this stage is a testament to the deep domain experience of our teams, with a passion and dedication to delivering a game-changer for the industry. Full subsea electrification has been a long-time coming. It’s not easy, but we’ve done it. Oil and gas companies now have access to technology that will completely transform how they operate.”

Kevin Kosisko, Senior Vice President and Head of Energy Industries, ABB

“This milestone marks an outstanding achievement and is the culmination point of an inspirational technology development achieved through tremendous dedication, expertise and perseverance. It is the result of intensive collaboration by over 200 scientists and engineers from ABB, Equinor, Total and Chevron in a multi-year, joint effort.

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.”

Kevin Kosisko, Senior Vice President and Head of Energy Industries, ABB

“We dreamed the extreme and we’ve made it a reality. Instead of having small cities on offshore platforms, with staff far from home, the entire production system can now be moved subsea. We can control it remotely using the power we supply from onshore or offshore renewable energies. We can halve the emissions and make our people safer. This is the field of the future – and it’s possible today.”

Asmund Maland, Group Vice President, Subsea and Offshore Power segment, Subsea, Oil & Gas, ABB

“Subsea power distribution is a critical component in our long distance tieback program. This technology will allow entry into new resources and will enable long-offset tiebacks to existing infrastructure, creating development opportunities that were not economically viable. ABB has been a collaborative partner who understands the importance of a rigorous qualification program for subsea equipment with high reliability target and long design life.”

Moises A. Abraham, Unit Manager – Subsea, Civil and Marine Engineering (SCME)
Chevron Energy Technology Company - ETC

Martin Grady, Vice President and Global Industry Manager, Oil & Gas, ABB
Since the first exploration wells were drilled in the shallow waters of the Gulf of Mexico in the early 20th century, many easy to access resources have been discovered and are being depleted. In many continents, the offshore industry is now a mature business.

Yet, the world’s hunger for energy continues. Feeding this hunger has driven operators into more challenging and remote deeper waters, while also seeking to maximize the economic recovery from their existing assets.

Tackling these new challenges means that operators need to find cost efficient, smarter and leaner production technologies that help:

- reduce emissions and their environmental footprints
- improve health, safety and security of personnel
- increase productivity
- enhance asset cost efficiency

For decades, many companies have attempted to locate production infrastructure on the seabed, where it is more efficient and has a far lower environmental impact. However, earlier subsea power distribution technology limits tieback distances under 150 km.

**Topside AC**

Consider today’s typical offshore hydrocarbon production systems, shown in Figure 1. Production equipment is housed on large, expensive to operate, manned floating or fixed structures. Power and control equipment must be housed on topsides structures, where space is often already constrained. Costly, dedicated power and electro-hydraulic umbilical cables are required for each power user on the seabed. This creates a topology which is expensive, hard to adapt to new configurations and restricted in its ability to support digitalization initiatives, due to limited bandwidth. Most structures use gas turbines for local power generation, the emissions from which impact on the environment. These structures expose humans to risk and require constant maintenance and logistics support. They are costly to build and to operate and energy inefficient.

**Subsea AC**

Now consider the subsea solution in Figure 1. Developments towards the electrification of subsea oil and gas production infrastructure has resulted in subsea components and systems from actuators to pumps and even compressors, increasingly being electrified.

Electrification helps to:

- increase system availability and control
- reduce component size and cost
- reduce energy intensity
- remove humans from a high-risk environment through remote and unmanned operations

By introducing technology that can distribute subsea power over long distances and down to great depths, to reach subsea production systems, the full possibilities of this technology can be realized.
Prior to the Joint Industry Project (JIP), only the transmission cable and subsea step-down transformer were existing and proven to operate underwater. Following the success of the JIP, ABB’s subsea power distribution and conversion system now comprises:

- Step-down transformer
- Medium voltage (MV) switchgear – see page 16
- Control and low voltage (LV) power distribution – see page 18
- Power electronics and control systems supported with 230/400 V

Expertise behind each of the component parts of the subsea power distribution and conversion system were drawn from ABB locations across the globe. See Figure 2.

Dream the extreme
Achieving the ultra-reliability required in the tough, operational conditions of the subsea environment means overcoming multiple and significant technical challenges. Nothing like this has ever been done before and, through the JIP, many new technical and commercial insights have been gained.

Early design considerations
A critical area of focus was ensuring the system would be modular, flexible and open. It also needed to meet reliability and availability targets that are even higher than for topside applications.

From the outset, the approach was to deploy solutions largely based on existing technologies. This way, reliability is proven, quality control and obsolescence strategies are well established and integration with existing topside hardware systems and software will be straightforward.

The philosophy ensured that all failures should be mitigated by design improvement or change rather than adding simple ruggedizing steps. All issues encountered during testing were shared and discussed with the project partners and sub-suppliers to draw on their field experience.

Highest overall reliability
To ensure compact and reliable solutions, ABB enclosed the VSDs and MV switchgear in oil-filled, pressure-compensated tanks. Throughout, each component has been iteratively honed, in a stepwise approach, optimizing product assemblies, and reducing the number of components and functions to ensure redundancy and high system reliability.

To ensure electronics and power components could operate in a pressure tolerant environment and within a dielectric oil, a key focus was placed on component screening and selection, material compatibility, material interface aspects and thermal performance.

Modular and flexible
Electronics and control modules are flexible and modular in design to allow for different sizes so that they can be accommodated within the system. Communications and control are Ethernet based, for ease of interfacing with the rest of the subsea system. High-speed fiber-optic communications enables responsive remote operations.

Realistic testing
With several hundred unique critical components and various stress conditions, a clear but pragmatic testing strategy was devised to learn the behaviors and limits of different designs. This helped mitigate the risk of failure before prequalifying for full-scale prototypes.

Starting with simulation and laboratory tests, materials, components, sub-assemblies and assemblies were all subjected to realistic stress levels in accordance with lifecycle profiles, before the final full system shallow water test.

All tests were carried out in adherence to API 17F Standard for Subsea Production Control Systems. Tests included temperature, vibration, pressure and accelerated lifetime. The project development followed the recommendations and technology readiness level (TRL) defined in DNV RP-A203, which provides a systematic approach to ensure the technology functions reliably and within the specified limits.
A new era in subsea operations

With ABB’s MV power distribution and conversion system operating down to 3,000 m, and therefore closer to the reservoir, subsea pumping and gas compression is more cost effective. This increases recovery rates while reducing energy losses.

Lifespan extended
The operating lifespan of an existing facility can be extended through more cost-efficient tie-ins, requiring minimal topside modifications. Future developments can be phased in and then easily adapted through an inherently more flexible system topology.

Reduced maintenance, manning and hardware
Cost savings are unlocked, and environmental footprints reduced, through less need for maintenance, manning and hardware, including hydraulic systems. This is particularly the case where full production systems are installed subsea and where long tiebacks no longer need multiple power cables or complex umbilicals.

Equinor estimates that for a 200 km step out with eight loads, the reduction in CAPEX cost by using subsea power distribution would be US$500 million.

ABB Ability™ digital solutions
Electrically powered solutions enable around the clock visibility of system performance. Using ABB Ability™ - the company’s digital platform - more precise control and advanced remote analytics can be performed. ABB Ability™ digital solutions deliver ABB’s deep domain expertise from device to edge to cloud, to help customers know more, do more, do better - together.

New life of field services
A subsea power distribution system can support new life of field services, such as advanced subsea resident drones, as they move around performing inspection and maintenance operations. It can also reduce chemical consumption for hydrate or wax formation mitigation in pipelines by providing the power needed for trace or direct heated pipeline systems, ensuring cost-effective flow assurance.
To access greater offshore wind resources, developers are moving into deeper waters, where floating offshore wind farms are the most technically viable solution. Floating offshore wind provides electricity for use onshore and for offshore platforms, replacing costly and locally produced gas-generated power and eliminating the need for long power export cables from shore. Emerging floating solar or ocean energy projects could also be used in the same way. For offshore oil and gas producers, these concepts reduce costs and emissions, allowing gas to be sold rather than burned.

For floating offshore wind farms, substations positioned on the seabed could be deployed. Studies have shown that collecting wind or solar power to feed maintenance-free subsea transformer stations could reduce costs by 30-40 percent, in water depths deeper than 60-70 meters. The cost saving could be even higher in water depths beyond 100 metres. Operators would reduce:

- Costly dynamic export cable requirements
- Maintenance needs and environmental footprint
- Human exposure to risk

In addition, floating offshore wind farms require less steel, with subsea cooling provided for free by the surrounding seawater. These new parks could also support next-generation, entirely unmanned, totally subsea offshore oil and gas production facilities with 80-110 MW of power, all via a single cable using ABB’s modular and scalable subsea power distribution solutions. Any excess power can still be exported to market, using the same system, and any future new power sources can easily be added – and be used by offshore power users.

Today, equipment ranging from multi-megawatt seafloor compressors to subsea resident vehicles or offshore fish farm operations can tap into this new power source. The possibilities are wide open.

Tomorrow’s world – leaner, cleaner and smarter

With ABB’s fully qualified subsea MV power distribution and conversion system, most of the world’s known offshore hydrocarbon resources are now within reach for electrification. These subsea production systems can be remotely operated from onshore control rooms, with greater control and reliability than previously achievable. It is now possible to synchronize with renewable energy resources and other ocean users.

Operators would reduce:

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Variable speed drive

A significant focus of the JIP is the 9 Mega Volt Amp (MVA) variable speed drive (VSD), used to control the motor torque and speed of a subsea pump or compressor. The VSD typically controls a subsea compressor’s motor with 6 to 7 kV. Subject to water temperature and application requirements even higher output voltages may be needed. The modular VSD ensures that two units in parallel can run a load of at least 18 MVA. Mounted on a common subsea frame, multiple VSDs can be combined, thereby avoiding any increase in the number of wet-mate connectors needed.

Diagnostics
The VSD is packed with diagnostic sensors which track the performance of the driven load as well as the on-going performance of the drive itself. This ensures the highest system resilience by helping operators to predict behavior, optimize operations and track key performance indicators.

Thermal challenges
VSDs generate much heat which can degrade system and component life. It is essential that the VSD has a suitable temperature environment for each component and that heat generated by losses are efficiently dispersed to the surrounding seawater. For these reasons, VSDs are housed in oil-filled pressure compensated units. This avoids the need for a large pressure tolerant housing while benefitting from the natural convection (or passive) cooling of the VSDs.

To increase the VSD’s cooling surface, external coolers were considered. However, potential complications with this technique changed the focus on improving heat transfer on the VSD’s inside housing. By increasing the wall surface area, engineers gained more in temperature reduction than they lost from not using external coolers.

Testing concept
Two prototypes were built to test the concept: one with external cooling and one without, in different seawater temperatures. Without external coolers the entire power range could be covered when situated in most seawater temperatures, including warmer waters. The option remains to increase the cooling ratings by using additional heat exchangers.

Component tolerance
The VSDs electrical and mechanical components, including capacitors, semiconductors, local electronics and wiring, had to withstand the full environmental pressure down to 3,000 m and be chemically compatible with the dielectric liquid. For example, novel design solutions for packaging existing insulated-gate bipolar transistor (IGBT) and rectifier chips were developed in order to obtain compatibility with the pressure and oil environment.

“A lot of the engineering and new technology lies around allowing non-failure modes to happen without having to stop the operation,” says Heinz Lendenmann, VSD Project Manager, Subsea Technology Program. “This is down to building-in redundancy in various ways, including making the system modular.”

Long term availability and reliability
To ensure long-term availability and reliability, the subsea VSD is built on a robust power cell-based topology with long-established power semiconductors using overrating design margins. This was a change from the initial drive topology, which was not as modular and required more complicated control systems.

ABB’s cell-based design enables redundancies to be built into both the control and power circuits. Any power cell failure is prevented from migrating to neighbouring cells, because they can work in series or parallel. Thus, the faulty cell can be bypassed with the use of integrated disconnectors. This means the VSD will provide full nominal power even with the loss of one cell per phase (typically there are 12 power cells, with four cells per phase).

While similar systems are used topside, to enable this concept subsea, the cells must be disconnected locally and remotely, which ABB has achieved. The drive’s fault management system has redundancy at several levels, including in the communications to the cells and over several layers of control.

Components with a higher electrical rating than the application would need are also being used. These include the overrated semiconductors. This means that components can be operated further from their rated values and therefore operate for longer. However, some application may choose to run with lower margin and higher total power output to be more in line with the lifetime of other production equipment.

Verification tests
Through the program, extensive subsea-specific verification tests were carried out to prove robustness of the materials in the new environment, including power cycling and thermal cycling, from small components to full assemblies. The full power cell has been operating over more than 5,000 hours, under pressure. All components, including the optical fibers and their connectors, have performed flawlessly.

Figure 4: Variable speed drives are an instrumental part of the subsea concept, controlling the speed and torque of subsea motors for seawater injection.
Medium voltage switchgear

ABB’s medium voltage (MV) subsea switchgear distributes 11-33 kV to the motors driving the compressors and pumps, via the VSDs. The switchgear supports up to six feeders, or a tie breaker to support cascading of two switchgear assemblies. The unit connects to a subsea step-down transformer, or directly to a subsea power cable from topside to shore.

The switchgear that has now been developed is sufficiently powerful to supply a small town. The rated voltage is 36 kV and the main busbar current is 1600 A. A range of variants exist to support conventional 50 and 60 Hz frequency as well as 16 2/3 Hz, which is used in very long transmission distances.

The MV subsea switchgear is based on ABB’s widely used vacuum breaker technologies, which have a long record of reliable operation and established quality control and obsolescence strategies. The bespoke breakers are manufactured in Germany by world-renowned engineers who have applied their expertise to ensure that the switchgear technology is equally reliable underwater.

All components are designed to operate at 300 bar. The enclosures are oil filled and pressure compensated, with the hydrostatic pressure of the seawater acting on the oil to maintain ambient pressure inside the enclosure.

“We know there is a lot of potential to develop fields in very deep waters, up to 3,000 meters,” says Vitor Moritsugu, R&D engineer at ABB who has been leading the work on the subsea switchgear. “Our aim has been to build devices that can withstand the harsh environment caused by extreme pressure.”

Simply using a reinforced enclosure to protect the equipment was not an option. The dimensions, weight and the costs involved would have made such a project impracticable. 300 bar is equivalent to 3000 tonnes per square metre of the enclosure surface.

A pressure compensated enclosure, by contrast, is filled with oil, which does not compress under pressure. The pressure at depth is transferred to the interior of the enclosure via external bellows that enable the water pressure to act on the oil. This way, the oil exerts the same pressure on the inside walls of the structure as that of the water on the outside. With the pressure on both sides equalised, the enclosure stays intact and the structure can be made lighter. The strength of the enclosure is further enhanced by optimising its dimensions and shape.

Powerful switchgear

The extreme requirements for reliability has increased the amount of testing required, as well as the number of operational scenarios that have had to be foreseen and prevented. For instance, redundancy is provided by two independent control modules, each one with independent power source. Each side has a full set of sensors and actuators. During a energy shut down, all breakers open automatically.

Two auxiliary step-down transformers are used to power a redundant auxiliary distribution system. The system also includes low-voltage circuit breakers to enable de-energizing and independent retrieval of the connected auxiliary load; protection from faults in the auxiliary system, as well as external power input for system status monitoring.

Oil for insulation and more

The components inside the enclosure are submerged in the oil that is used for pressure compensation. The oil also acts as a coolant fluid. However, the heat dissipation from the switchgear is only moderate. Cooling is a far smaller issue here than in the enclosures for subsea transformers and variable speed drives, where it poses a much greater challenge.

A third purpose for the oil is to act as electrical insulation. The oil allows a reduction on the clearance between live parts and surrounding metal surfaces to avoid partial discharges.

Testing times

The testing procedure for the equipment forced some novel thinking. All the subsea equipment that is being developed already exists for topside applications, so there are established testing procedures in place. However, these are not always practical to use, as all the sealing joints of the equipment are welded.

Instead, testing has been incorporated into the manufacturing process. Each time a sub-assembly is incorporated into a larger assembly, the whole structure is tested again, and so the system is built step by step.

“It has been a great feeling of achievement on the occasion that we completed the field tests,” says Moritsugu.

“Of course, we knew all along this would be achievable, we had the best resources for this challenge. With a lot of hard work, the team was able to finish the test at the manufacturing site and get the unit ready for its 3000 hour shallow water test.

“To get to this point, a multidisciplinary approach was needed, starting with electrical studies and planning. The work then moved to chemical analysis of materials, mechanical design and simulations. This combined with many hours of testing and a very talented team were the foundations to developing the product,” says Moritsugu.

An oil-filled pressure tolerant remote operated vehicle (ROV)-installable subsea control module (SCM) houses the switchgear’s one atmosphere nitrogen filled subsea electronic modules (SEM). The SCM contains capacitors that are used as a backup power for the electronics, if needed. Voltage and current sensors within the switchgear and its communications systems are all redundant. During development of the switchgear, no major technical obstacles or design iterations arose and the system is now fully qualified for operation on the ocean floor.
The subsea power distribution and conversion system consists of main assemblies for power distribution, conversion, auxiliary supply and control. The equipment has been specially developed to operate with high reliability in deep waters.

The subsea control module (SCM) is the brain of the overall system. It provides the power delivery system with an advanced automation and communications network backbone for monitoring and overall control, along with good protection of the entire system.

The SCM includes the ABB’s high performance PEC controller, which has been substantially redesigned for subsea use. In addition, the SCM contains capacitors that store energy so that the system can run long enough for safe shutdown in the case of an emergency. It also has a unit with electronics specifically for the driven device, such as control for a variable speed drive.

The SCM houses four subsea electronic modules (SEMs). The SCM is an oil filled structure operating at ambient pressure, like all the other main units in the system. The sea water acts on bellows and transfers the external pressure to the oil on the inside. The oil will then exert an equal pressure to the sides of the structure from the inside, as that of the sea water on the outside, keeping the structure intact.

The SEMs are filled with nitrogen and operate at atmospheric pressure. To withstand the high pressure at depth, they have very thick steel walls. The electronics are mounted on metal beams. Heat does not travel well in nitrogen, so the heat needs to be dissipated through the metal and via the enclosure walls into the surrounding oil of the subsea control unit. Power enters the units via penetrators and metal pins surrounded by a glass disc which acts as insulation against the metal enclosure.

Optical cables are used extensively for communication. This eliminates the risk of high voltage on the communications network in case of a fault. It ensures fast communications over long distances without the use of amplifiers. The optical cables also enter the enclosure via penetrators.

Figure 6: With thorough testing and design work, the autonomous subsea processing plant of the future is coming together, piece by piece.

The guidelines break new ground in several important aspects and in many cases go against conventional wisdom. For instance, while a symmetrical circuit board layout may look neat and professionally designed, this does nothing to dampen vibrations. Vibrations are more effectively mitigated by an asymmetrical board layout.

The remoteness of the equipment, and the difficulty of retrieving and servicing parts, makes reliability a key concern. A significant amount of time has been invested in calculating the lifetime of components and optimising their thermal characteristics.

Accelerated lifetime testing has been carried out on samples of components. The idea is for components to be operated for over one year at elevated temperatures and without failures. Based on this, a statistical model shows that it is highly likely that the components will outlive the production life of the field itself.

Such testing is far more stringent than what would be required for normal industrial products and more in line with what would be appropriate for aerospace or military use.

Granular knowledge

When working on the design for the controller, the ABB team went back all the way to the single component level. The team created new design guidelines with a library of subsea approved components that can be used in electronic design by ABB and its suppliers.

The guidelines break new ground in several important aspects and in many cases go against conventional wisdom. For instance, while a symmetrical circuit board layout may look neat and professionally designed, this does nothing to dampen vibrations. Vibrations are more effectively mitigated by an asymmetrical board layout.

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Finding the culprit

Most standard products that have been used have been completely taken apart and re-engineered from the ground up. The design team has looked at every component and its functionality in detail, its physical characteristics and how it is affected by the environmental conditions.

A significant challenge was to capture the precise conditions leading to a test deviation or a change in device behaviour or component value. This was particularly frustrating and difficult where the deviations were intermittent and only apparent under the harshest of test conditions.

Vibration tests for frequencies below 2000 Hz were particularly challenging. These frequencies can cause movements of objects, but when the vibration stops, the object can go back to its normal state. For instance, vibrations can cause the plates inside a capacitor to move. This changes the value of the component and such changes can be very difficult to trace.

Root cause analysis

A key point throughout the testing was that all faults that occurred had to be analysed in detail and future faults mitigated by design improvements. For instance, a common way to improve the reliability of products used under harsh conditions is to add glue to components or encapsulate boards into epoxy. However, this leads to poor thermal characteristics and higher weight. The requirements are more effectively met by designing a complete new product that achieves the same functionality.

Figure 7: The success of the Subsea facility is a result of collaboration between ABB and its partners, together with the individual talents of ABB’s subsea engineers.
Achieving results

In 2019, the subsea power distribution system was brought together for the final 3,000-hour shallow seawater test, in a sheltered harbor.

A complete system was put through its paces as one unit, comprising:

- MV switchgear
- Control and low voltage distribution equipment
- Two parallel 9 MVA VSDs

**Test program**
The ABB Ability™ System 800xA was used to control the tests, which included:

- System tests
- Thermal run stability at nominal power to overload conditions
- Long period testing
- Power loop

**Lessons learned**
Throughout the development process much has been learned about how power electronics behave subsea, all of which have then been applied to create a reliable, robust and flexible technology for today’s offshore oil and gas operators.

The project has taken a structured, yet pragmatic design philosophy approach, based on the use of known established components, but a willingness to change these when they were being either not suitable or reliable enough for the harsh subsea environment over periods of up to 30 years.

For the choice of materials, for example, a standard protection sleeve for a cable connection within an oil filled container had to be changed so it was compatible with the oil. Changing the material meant repeating much of the qualification and testing, but it ensured that a weak point was removed.

ABB’s engineering team benefited from the regular and deep partner involvement at multiple levels, from bi-weekly project meetings and monthly progress reports to three-day intensive face-to-face workshops. These allowed in-depth discussion covering topics such as failure mode, effects and criticality analysis (FMECA) of the specific products under development.

This is the way the design of the controller was approached. Originally a standard high performance industrial controller, this went all the way back to the drawing board. Several different prototypes were designed. The result was a product with very impressive characteristics that performed far beyond expectations.

“At one point we came to an impasse in the design work. I spent over a year testing but failing to find a fault. In the end, through detailed root cause analysis of components, I was able to find and fix the problem,” says Henning Nesheim, R&D principal engineer for subsea technology at ABB.

“Of course, this is difficult. This has never been done before. But it is a fantastic sense of achievement knowing that you have overcome the obstacle and created something that will last.”

Controllers and electronics for subsea use have to meet far more stringent requirements than units on the topside and in standard industrial applications. Once the PEC controller and the other control boards had been designed, tested and formally passed, they were assembled into a complete unit, the SEM. The same testing procedure was then applied again, but now with the complete unit.

It was by no means certain from the outset that existing technology should be the starting point for the new technology – this was only concluded after extensive lab tests. The test results showed this to be a good starting point, but that the physical layout and function needed to be optimised for the harsh subsea environment and high emphasis placed on reliability. Now, through extensive testing, design modifications, re-testing and validation the control system is fully qualified and ready for operation. This applies to all parts of the system, down to the fundamental building blocks and components.
Based on knowledge, experience, thorough qualification and testing processes, ABB is extending the limits of what is possible in subsea. It is achieving this by enabling the full electrification of all infrastructure, increasing automation, process capability and safety, while bringing the lowest possible footprint production facilities.

With subsea power distribution, a remote operated and even autonomous Subsea facility is now possible, helping to reduce CAPEX and OPEX, while improving production efficiency and increasing recovery rates.

ABB’s subsea HV power transmission and MV distribution infrastructure provides today’s operators with a viable, clean, minimal footprint solution for tiebacks out to 600 km and down to 3,000 m water depth, taking humans out of harm’s way, reducing emissions and minimizing environmental impact.

New, unmanned, remote operated production operations in the deepest waters are unlocked.

But, this is just the beginning. Just like onshore power grids transformed the world in the late 19th century, subsea power distribution offers a transformation for how we operate safely and cleanly across the ocean space from today for decades to come.

The future with ABB will be even more autonomous, as we help enable safe, secure and sustainable operations. We believe in the power that electrification can bring to the offshore industry. We also believe it has potential that stretches far beyond oil and gas. Join us as we listen, collaborate, learn and adapt in continuing to #DreamtheExtreme. Building the future takes vision, and with subsea technology, the possibilities are limitless. Let’s embrace, connect, and deliver for tomorrow’s energy future.

2 As above.