

Powering Troll

with new technology

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With its compressors, motors and electrical systems devouring many tens of megawatts, an offshore installation can be a power-hungry beast indeed. The onboard gas turbines or diesel generators that usually supply this power, however, manage no more than about 25% efficiency – way off the dazzling 75–80% efficiencies of, say, land-based combined cycle power plants. This inefficiency isn't just costly in terms of excessive fuel consumption, either; high emissions can rack up the cost still further, for example where CO₂ taxation applies.

Now, new technologies from ABB are making it easier than ever before to deliver electrical power to offshore installations, lowering operating costs and reducing environmental impact at the same time. Seventy kilometers off the Norwegian coast, two of these technologies – HVDC Light™ and Motorformer™ – are helping to power 40-MW compressor units on Statoil's Troll A platform without any local power generation.

Troll A platform (Photo: Øyvind Hagen, Statoil)

On most offshore installations, the power generators and large compressors are driven by onboard gas turbines or diesel engines with total efficiencies that can be as low as 20–25% even under ideal conditions. As a result, fuel consumption and CO₂ emissions are unnecessarily high. Ever since the Kyoto Protocol, which allows trading of greenhouse gas emissions, high CO₂ emissions

A conventional precompression project, with gas turbines, would have resulted in annual emissions of some 230,000 tons of CO₂ and 230 tons of NO_x.

have become a cost factor. On top of this, as on the Norwegian shelf, there may be CO₂ taxation, making emissions costly even without trading.

If the electrical power for all this equipment can be supplied from shore, the CO₂ emissions of offshore installations are eliminated, saving operators a con-

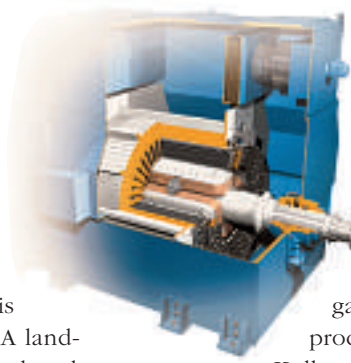
siderable sum of money. But that isn't all; transmitting electrical energy from shore is also more efficient in terms of equipment maintenance, lifetime and availability.

The overall environmental bonus of eliminating low-efficiency offshore power plants is considerable. A land-based combined cycle gas power plant, which utilizes the gas turbine's waste heat, can have an efficiency of as much as 75 to 80%. Even if high losses of 10% are assumed

for a long transmission line to an offshore installation, the saving will still be significant for most installations.

HVDC Light™ and Motorformer™ join the offshore club

Troll A is the largest gas production platform on the Norwegian shelf. Some 40% of Norway's total annual gas



production comes from Troll A, which can produce up to 100 million cubic meters of gas per day. Today, the reservoir pressure drives the gas to the onshore

processing plant at Kollsnes, where the condensate, water and gas are separated. The gas is then compressed and transported through pipelines to the European continent ■.

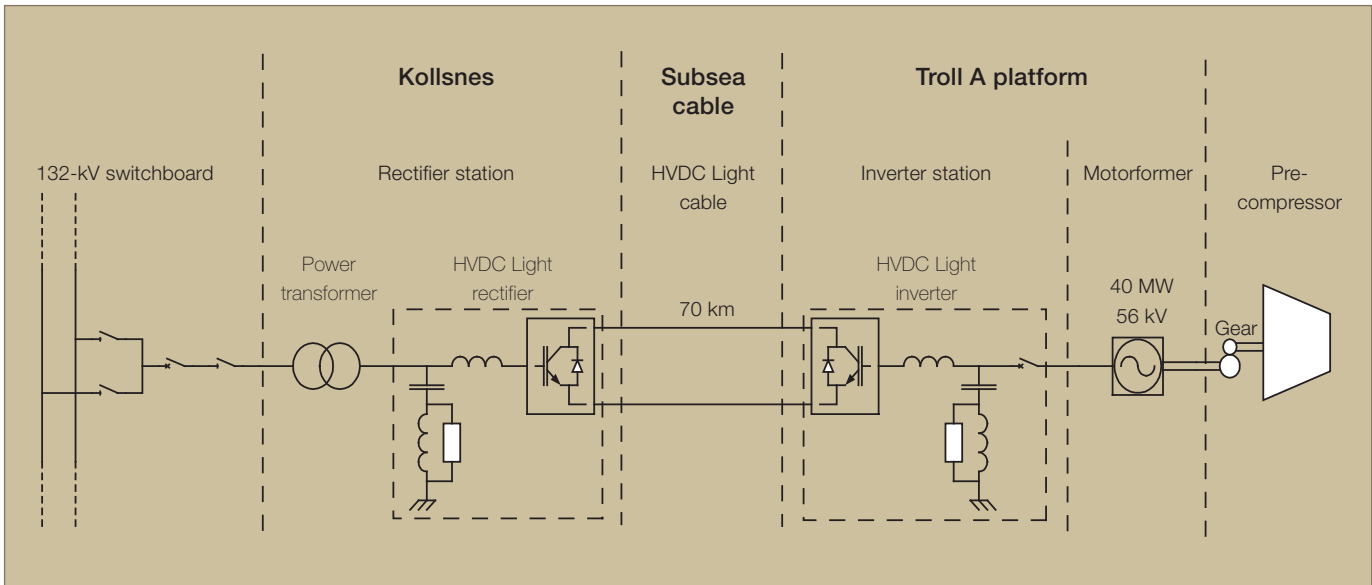
As the gas is taken out of the reservoir, the pressure inevitably decreases. This means that to maintain production capacity, offshore precompression of the gas will eventually become necessary. ABB has been awarded two contracts as part of Statoil's Troll A Pre-compression Project: a US\$ 185 million contract for the compression equipment and a US\$ 85 million contract for the electric drive systems for compressors.

1

Gas from Troll A is processed at Kollsnes before being transported to the European continent.



From the rectifier station at Kollsnes, subsea HVDC cables transmit power to the Troll A Platform, where the inverter station and Motorformer™ are located. Two identical systems are to be installed.



The new installation is due to go into commercial operation in the fall of 2005 as part of a program introduced to maintain and expand the platform's production capacity.

Choosing conventional systems for this project would have meant that gas turbines would drive the compressors. In that case, it is estimated, annual emissions of some 230,000 tons of CO₂ and

230 tons of NO_x would result. Besides their impact on the environment, the CO₂ taxation in effect on the Norwegian shelf means that such emissions would also be a significant cost factor. Working with Statoil, ABB developed an alternative system **2** based on two innovative ABB technologies – HVDC Light™ and Motorformer™. These have been successfully employed on shore since 1997 and 1998, respectively, but never before on an offshore installation or together as an electric drive system. The system uses power from the on-shore electrical grid to drive the compressors on Troll A, thus eliminating greenhouse gas emissions from the platform.

HVDC Light – rectifying, inverting and controlling

HVDC Light [1], by using series-connected power transistors, enables voltage source converters to be connected to networks, at voltage levels higher than ever before, for power transmission, reactive power compensation and harmonic/flicker compensation.

On Troll A, an HVDC Light converter (inverter) feeds the variable-speed synchronous machine driving each com-

pressor with AC power obtained by converting the incoming DC, which is transmitted from shore over submarine cables. As their speed is variable, the compressors are supplied with power at variable frequency and voltage, right through from zero to maximum speed (at 63 Hz) and from zero to maximum voltage (56 kV), including starting, acceleration and braking. The drive systems perform equally well at each end

HVDC Light

In the past, high-voltage DC links have been used almost exclusively to transmit very high powers over long distances. HVDC Light [1] is a new transmission technology based on voltage source converters that extends the economical power range of HVDC transmission down to just a few megawatts.

HVDC Light also offers power quality improvements, for example reactive power compensation and harmonic/flicker compensation. Thanks to fast vector control, active and reactive power can be controlled independently, with harmonics kept low, even in weak grids.

Motorformer

Motorformer [2] features conventional rotor, exciter, control and protection technologies. Most of the stator technology is also conventional – the exception is the winding, which is made of XLPE-insulated cable. The stator's cable slots are designed for low electrical losses, high-strength cable clamping, efficient cooling and simple installation.

The first Motorformer to go into commercial operation, at the AGA plant in Sweden, has verified the many benefits of using HV cable technology in large electric motors. Motorformer is suitable for most applications where conventional technology is used today.

3

HVDC Light™ extruded submarine cable, with double armoring (80 kV rating)



of the frequency spectrum. Small filters at the converters' outputs keep the motor winding stress at a safe level.

The inverter control software is adapted for both motor speed and torque control. The motor currents and voltages and the rotor position are measured and used together with an advanced model of the machine's electromagnetic parameters to calculate converter switching pulses in much the same way as for smaller industrial variable-speed drives (ACS 600/ACS 1000/ACS 6000). Unity power factor and low harmonics are assured, along with a sufficiently high dynamic response, over the motor's entire operating range. Protection and monitoring of the converters and synchronous machines, as well as control of the excitation converter feeding the latter's field winding, are handled by ABB's well-proven Industrial™ HVDC Control, MACH 2.

Overall control of the rectifier station at Kollsnes is also handled by the MACH 2.


There is no need for communication between the rectifier control system on

land and the motor control system on the platform; the only quantity that can be detected at each end of the transmission system is the DC link voltage. As the DC link cannot store much energy, the motor control system is designed to follow even rapid changes in power flow at the opposite end without disturbing motor operation. Nuisance tripping is generally kept to a minimum.

The HVDC Light converter for Troll is based on a two-level bridge with grounded midpoint. Only extremely low ground currents are induced during steady state and dynamic operation, this feature being one of the main reasons for using HVDC for the power supply. No cathode protection of any kind has to be provided for this installation.

HVDC Light cable – the power carrier

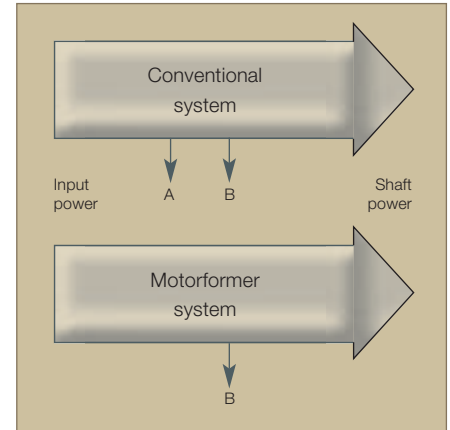
The HVDC Light concept includes a further innovation: the HVDC Light extruded polymer cable. The shift in high-voltage AC technology from paper-insulated to extruded polymer cable was the incentive for ABB to develop and produce an extruded cable offering the same benefits – flexibility and cost-effectiveness – for HVDC transmission.

Troll A's importance as a major gas producer called for an extremely reliable transmission link. The actual cable has a 300-mm² copper conductor surrounded by a very strong and robust polymeric insulating material . Water ingress is prevented by a seamless layer of extruded lead, over which there are two layers of armor – steel wire woven in counter helix – to provide the required mechanical properties. This design ensures that the cable has the strength and flexibility necessary for laying in the North Sea. The two electric drive systems require an HVDC Light cable system with two cable pairs (one for each drive), physically separated from each other on the sea floor. The two cables in each pair are operated in bipolar mode, one having a positive and the other a negative polarity.

To make sure that the cables will not be damaged by anchors or trawling, they are laid in trenches on the sea bed

4

Use of Motorformer™ eliminates transformer losses (A). Only motor losses (B) remain.



formed by water jetting, or covered with rocks where this is not practicable.

Motorformer™ drives the compressors

Following the introduction in 1998 of new, innovative cable winding technology, ABB's engineers soon began to consider the possibility of using HV cable windings in place of conventional windings in electrical motors in order to radically increase the motors' voltage ratings. Such a motor can then be connected directly to the HV grid, doing away with the need for a costly step-down transformer.

The first product to be based on this principle was an HV cable-wound generator. Shortly afterwards, the same concept was applied to motors, resulting



in the development of a synchronous machine, dubbed Motorformer™ (see panel on page 17). The first unit was installed in 2001 at an air separation plant in Sweden, where it drives a compressor. This motor is directly connected to a 42-kV bus. In the meantime, ABB offers HV motors of this kind for voltages up to 70 kV. Work is currently under way to develop units rated at 150 kV.

Apart from eliminating the step-down transformer and related switchgear, Motorformer reduces the total system losses by as much as 25% [4]. Being epoxy-free, it also has important environmental benefits, including easy recyclability. And fewer components mean higher system reliability and availability, plus reduced costs for service, maintenance and spares.

A challenging environment for high-voltage equipment

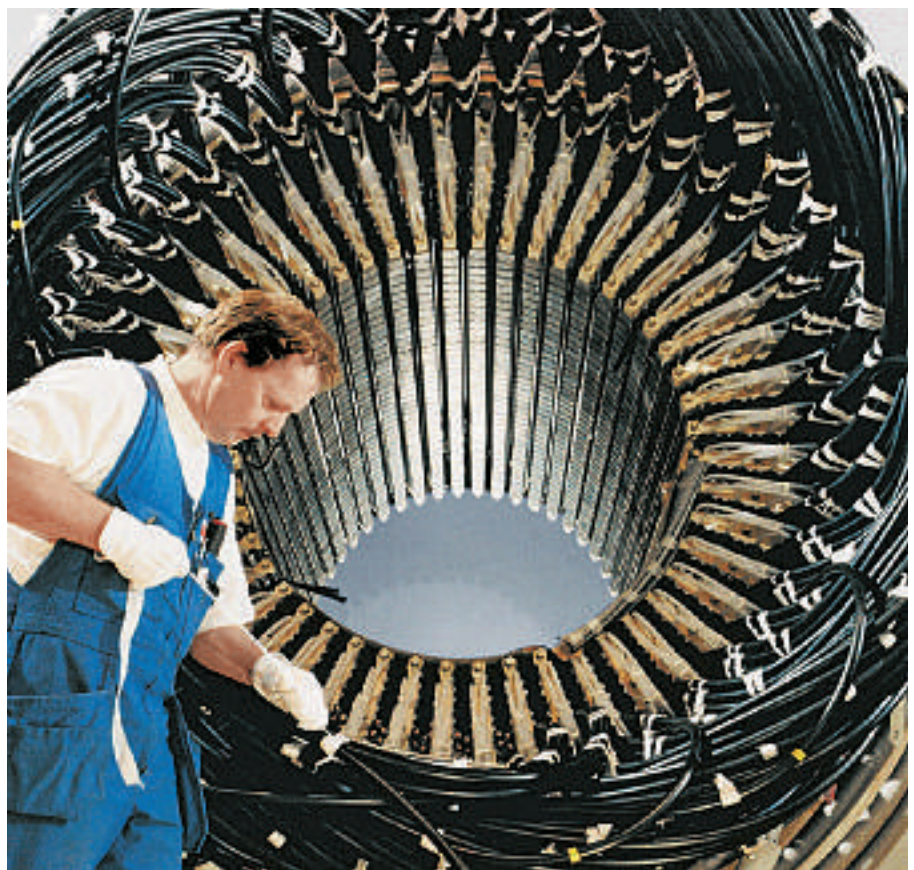
Offshore equipment design is constrained by the need to keep both footprint and weight to a minimum. HVDC Light and Motorformer offer important advantages in precisely these areas:

- Smaller filters and the absence of synchronous condensers make HVDC Light more compact and lighter than traditional HVDC systems.
- No large, heavy transformer is required to connect the Motorformer to the HVDC Light converter.

Other design considerations in connection with this project were:

- Safety: Troll A produces large quantities of hydrocarbon gas, which is not allowed to come into contact with high-voltage equipment.
- Environment: The high-voltage equipment must be protected from the damp, salt-laden sea air.

HVDC Light™ and Motorformer™ ensure a small footprint and low weight – two essential characteristics for offshore equipment.



- Availability: Given the daily production of gas worth US\$ 10-15 million, high equipment availability is essential.

HVDC Light and Motorformer are innovative technologies with all the qualities needed to power offshore platforms from shore for maximum economical and environmental benefit. Troll A is the first such platform anywhere to be powered in this way, the electric drive

system being part of a program to maintain and expand production capacity. The elimination of

CO₂ emissions and a smaller equipment footprint are just two of the benefits enjoyed by Statoil as a result.

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[1] G. Asplund, K. Eriksson, K. Svensson: HVDC Light – DC transmission based on voltage sourced converters. ABB Review 1/1998, 4–9.
[2] G. L. Eriksson: Motorformer – A new motor for direct HV connection. ABB Review 1/2001, 22–25.