VALHALL RE-DEVELOPMENT PROJECT, POWER FROM SHORE

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ABSTRACT

A new platform will be built adjacent to the existing Valhall facilities in the North Sea between Norway and Scotland.

The new platform as well as all the existing equipment on the Valhall field will be supplied with electric power from shore, PFS, through a HVDC Light transmission. This is the first time HVDC is used to supply an entire offshore ac system.

This paper discuss the background for choosing HVDC Light, the features of the new system and the present design of the Power From Shore which is about to proceed into the detailed design phase.

1. INTRODUCTION

The existing Valhall complex consists of five bridge-linked platforms. In addition, three wellhead platforms, Hod, Valhall Flank South and North, have been installed about 6 km each, from the Valhall complex. The Valhall facilities are subject to reservoir compaction resulting in seabed subsidence (about 25 cm per year) and as a result the water depth at site has increased by about 5 meters. Based on wave consideration and impact on air gap and operation of the original facilities it has been recommended to replace the production and compression platform and the living quarter platform with a new facility in 2009.

Figure 1. The existing Valhall complex.

This new facility will be supplied with electric power from shore (PFS) through a High Voltage Direct Current (HVDC) Transmission utilizing the latest development in power electronics and computerized control and protection systems. The HVDC Light transmission system will include onshore and offshore converter stations joined by a 292 km cable. The transmission system will convert ac power from Elkem's 300 kV sub-station at Lista to dc power at 150 kV, transmit it through the sub-sea dc cable and convert it back to ac at 11 kV at the new platform to feed the entire Valhall field.

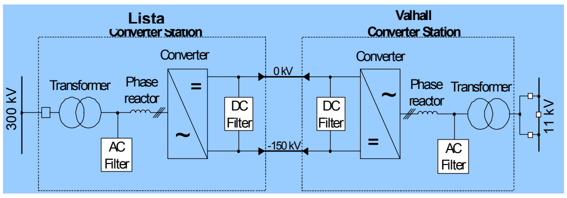

Figure 2 . Single Line Diagram of PFS with HVDC.

The system for Valhall will replace offshore gas turbines and deliver up to 78 Megawatt power to run the complete field. This will make Valhall one of the most environmental friendly fields off Norway´s shores. Following the final installation BP will also achieve a safer and more effective source of power supply, resulting in less maintenance and a lighter platform solution.

HVDC transmissions have been built for more than half a century with a capacity of a single converter up to about 1500 MW at a transmission voltage up to +-600 kV. Applications have normally been bulk transmissions from distant power generation, long underground or sub-sea cable transmissions or asynchronous ties between different power systems. Applications to feed power to or from offshore installations, using HVDC, have been discussed for many years. However, due to the nature of conventional HVDC which requires certain strength of ac system, to operate, this has not been feasible in the past. Not until the HVDC Light technology was developed by ABB about ten years ago. The new technology is based on transistors as opposed to the conventional HVDC, which use thyristors. This difference makes the new converters self commutated i.e. they do not require an existing ac voltage to operate but can feed into a completely passive load.

The first application of the HVDC Light technology was put into operation in 1997 and 2 years later the first commercial project was commissioned on the island of Gotland, Sweden. A total of 11 HVDC Light transmission systems are now in operation in different parts of the world.

The first offshore application was commissioned early 2005 to feed the new compressors on the Troll A platform outside Bergen, Norway. This is a double circuit, 2 x 40 MW sub-sea HVDC cable installation from Kollsnes to the Troll A platform 67 km offshore feeding two large compressors. The Valhall, Power From Shore project, is different from Troll in one very important aspect. This is the first time a complete offshore power system for an entire field will be fed with electric power from the mainland using HVDC.

2. REDUCING COSTS AND EMISSIONS WITH POWER FROM SHORE

Power from shore is cost efficient and have the advantages that it will save space and weight on the platform itself. This solution requires also less maintenance offshore than the conventional solution with gas turbines and last but not least it will contribute to a safer working environment on the platform as well as being more friendly to the environment by reducing emissions.

The main factors for selection of Power From Shore with HVDC for the Valhall Re-Development project were;

- Reduce costs and improve operation efficiency of the field
- Minimize emission of climate gases
- Improve all HSE elements

On most offshore installations, power supply generators and large compressors are driven by onboard gas turbines or diesel engines. Many of these have total efficiencies as low as 20-25 % under the best of conditions. The result is emission of large amounts of CO_2 and unnecessary high fuel consumption. The Kyoto Protocol supports trading of greenhouse gas emissions. CO_2 emissions can therefore represent a cost. On the Norwegian shelf, CO_2 taxation already today in effect, makes emissions costly even without such trading.

If electrical power can be supplied from shore – for power supply as well as compressor drivers – CO_2 emissions from offshore installations are eliminated. This leads to a significant cost saving for oil companies. In addition, transmission of electrical energy from shore involves less maintenance, longer lifetime and higher availability than gas turbines and diesel engines. If the transmission equipment can be located on decommissioned installations offshore, the postponed removal cost for the installation can be an important factor as well.

In addition, the environment can no doubt be saved from considerable amounts of greenhouse gas emissions if the electrical energy can be produced on shore instead of in low-efficiency power stations offshore. A land based Combined Cycle gas power plant from which waste heat is utilized can have efficiency up to 75-80 %. Even with up to 10 % losses in a long transmission to an offshore installation, the savings will be significant for most installations.

It is estimated that for this project, annual emissions of some 300,000 tonnes of CO_2 and 250 tonnes of NO_x would result, compared with a combined cycle power plant with low NOx gas turbines. Avoidance of such emissions is a relief for the environment, and with the CO_2 taxation in effect on the Norwegian shelf, such emissions would also impose a significant operating cost.

To summarize, the Power From Shore system gives the following advantages:

High availability	98.5-99 %
Increased life length	40 years
Increased efficiency	
Reduction of CO_2, SO_X and NO_X	
Reduced maintenance	
Shorter maintenance shutdowns	

3 HVDC LIGHT – RECTIFYING, INVERTING AND CONTROLLING

With HVDC Light, the use of series-connected power transistors has allowed connecting voltage-source converters to networks – at voltage levels hitherto beyond reach. This can be used for power transmission, for reactive power compensation and for harmonic/flicker compensation. With fast "vector control", this converter offers the ability to control active and reactive power independently while imposing low levels of harmonics, even in weak grids. The powerful and robust HVDC control, MACH 2, proven in multiple HVDC and SVC installations to date, governs the converters.

In HVDC Light, Pulse Width Modulation, PWM is used for generation of the fundamental voltage.

Using PWM, the magnitude and phase of the voltage can be controlled freely and almost instantaneously within certain limits. This allows independent and very fast control of active and reactive power flows. PWM VSC (Voltage Source Converter) is therefore a close to ideal component in the transmission network. From a system point of view, it acts as a zero-inertia motor or generator that can control active and reactive power almost instantaneously. Furthermore, it gives only a limited contribution to the short-circuit power, as the ac current can be controlled.

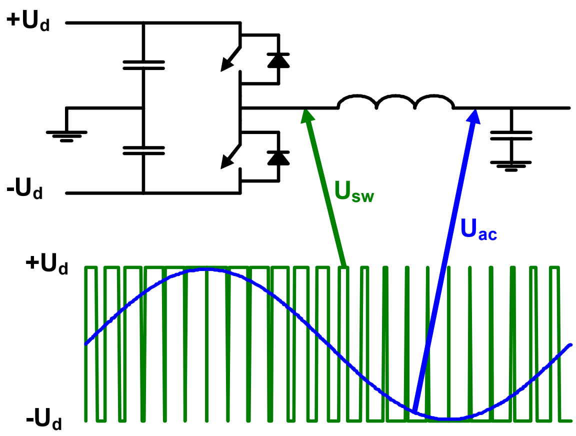

Figure 3. Principle of pulse width modulation, PWM.

There is no need for communication between the rectifier control on land and the inverter control on the platform – the only quantity that needs to be detected in both ends of the transmission is the dc-link voltage.

The HVDC Light converter design for Valhall is based on the two-level bridge but with the midpoint of the capacitor floating. The switching of the bridge between 0 kV and -150 kV makes optimal use of the coaxial HVDC cable design with the center conductor at high voltage and the return conductor close to the grounded screen. The design philosophy enables operation both steady state and dynamic, with extremely low levels of induced ground currents. This feature is one of the critical factors for implementing an HVDC system in an offshore environment. There is no need for any cathode protection in conjunction with the installation.

Operation with fixed 60 Hz frequency in the offshore end and fixed 50 Hz grid frequency in the onshore end does not require main circuit equipment that differs from the normal design. The design principles adopted for normal transmission system applications can also be used to feed a local offshore ac network such as the Valhall complex.

Some of the more important benefits with an HVDC transmission feeding a platform are;

- Control of AC voltage and frequency
- Direct On Line start of large asynchronous machines
- Ride through of mainland ac system disturbances

The performance of the HVDC transmission system together with the platform ac system has been verified in simulations using EMTDC, an Electro Magnetic Transient Stability Program for simulation of e.g. power transmission systems. The simulation set-up includes an equivalent of the mainland AC network, a detailed model of the HVDC main circuits including e.g. a switching converter bridge, filters and a dc cable model and extensive representation of the Valhall platform ac network.

The 11 kV distributions on the new Production and Hotel platform is divided into two busses with major compressors and pumps split between them and connected directly on the 11 kV level. Two 11 kV feeders, one from each side connects to the existing Water Injection Platform. From this platform the electric power is distributed to the rest of the complex at 4 kV and/or 690 V.

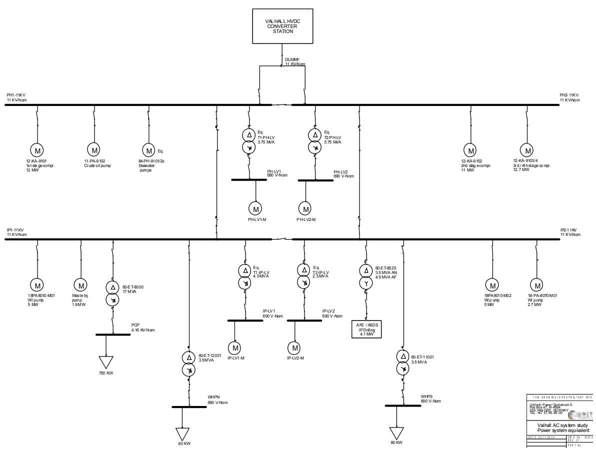

Figure 4. Single line diagram of the AC system on Valhall fed by Power From Shore.

The control and protection software included in the Dynamic Performance Study is the same as will be delivered to the plant. The set up of the control functions uses Hidraw, which is ABB's graphical programming tool for the software in the control system.

The performance has been verified by investigating a variety of faults and disturbances in the AC systems as well as Direct On Line starts of large motors (12.5 and 15 MW).

The results of the Dynamic Performance Study verify a safe and stable operation of the Valhall HVDC Light transmission. The ac voltage and the frequency on the Valhall platform are well controlled. The recovery times after disturbances are within the target values. Figure 5 below illustrates a Direct On Line start of a 15 MW motor.

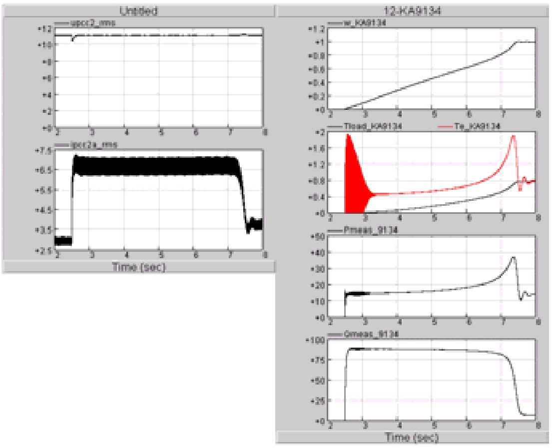

Figure 5. Illustration of DOL motor start

Figure 5 above, shows from upper left to lower right; ac bus voltage in kV, total current infeed to the platform in kA, motor speed in p.u., motor and load torque, active and reactive power drawn by the starting motor. The figure illustrates that the HVDC Light converter compensates almost momentarily for the active and reactive power needed by the accelerating motor. The bus voltage is therefore almost unaffected. It is only in the very first moments that a small dip can be seen.

4. DEMANDS ON HVDC OFFSHORE

Space and weight are scarce resources on offshore installations. Particularly in the light of these constraints, the HVDC Light concept offers important advantages. Since the filters are small, HVDC Light can be made compact and lightweight compared to other solutions.

Apart from the obvious needs to make the converter station compact and lightweight, the offshore environment places a number of other demands on the converter station and equipment. Examples include:

- Safety for personnel as well as for equipment in a production and processing environment.
- Reliability and Availability is of utmost importance since a shutdown means shut down of the whole production at Valhall.
- The offshore environment is very tough with salt and humid air which imposes severe requirements on the choice of materials and surface treatment.
- Integration of the control system towards the process control and shut down systems on the platform.

Figure 6. The new Valhall, Production and Hotel platform with the HVDC module on top.

The high voltage equipment has been installed inside a module offshore and indoor a building onshore. The ventilation system in the module/building will be designed to protect the high-voltage equipment and the electronics from salt and humid air. The main circuit equipment is therefore exposed to lower environmental requirements than a normal outdoor installation, which allows for a more compact design.

The ventilation also has to take care of the airborne losses. An advantage of being offshore in the North Sea is that cold (5-11 °C) water for cooling is readily available. Another requirement on the ventilation system comes from possible presence of gas in the area. The installation offshore will be over pressurized to ensure that no gas can enter high voltage areas. In case gas is detected, the system is tripped and deenergized directly. A conclusion is that there are no additional requirements on main circuit equipment when installed in an offshore environment.

The HVDC module will be built in two stores with the ac filters and phase reactors on the top floor and the converter valves and the dc equipment below. This is also where the 150 kV HVDC cable is terminated. The converter transformers will be located in a separate room with the bushings penetrating through the walls to the phase reactors and to the 11 kV ac side respectively. AC filters are located on both sides of the transformer to reduce harmonics to the platform ac system to a minimum.

The size of the HVDC module as shown in Figure 7 below is:

17 x 30 x 13.6 m   (W x L x H)

In this volume there is not only room for the high voltage equipment but also the auxiliary systems, mainly the valve cooling system, the ventilation system and the auxiliary power system. There are also two electrical rooms for the HVDC control and protection equipment and for communication with the platform SAS system.

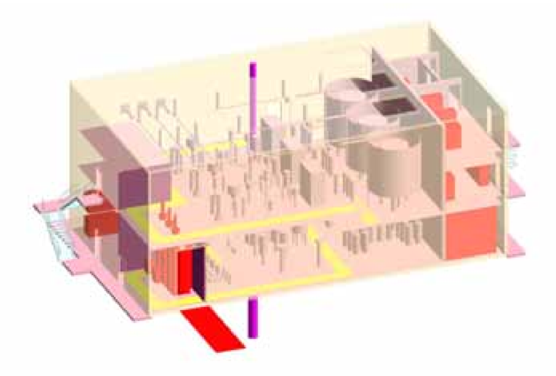

Figure 7. A closer look into the HVDC module

The onshore converter station is located at Lista and connected to the Norweigan 300 kV power grid through a double circuit line to Feda. The principal layout for the converter at Lista is essentially the same as on the Valhall platform with two major exceptions. The ac voltage at Valhall is 11 kV while it is 300 kV at Lista. The ac switchyard is therefore built as a conventional outdoor installation with one ac breaker but with two disconnects which makes it possible to connect Valhall to either of the two busses in the existing switchyard. The other major difference is the cooling system for the valves. At the platform seawater is the final media for cooling. At Lista dry cooling towers are used to cool against the outdoor air.

Adaptation of the control system towards the platform process control introduces another dimension in reliability compared to normal transmission systems. In an area exposed to gas, safe and guaranteed tripping is more important than continuous operation. The control system has therefore been complemented with circuits for external tripping from emergency shut down (gas and fire detection) systems. Tripping in this case also include opening the ac breaker onshore at Lista together with a sequence for automatic grounding of the dc cable to remove the energy in-feed.

The inverter control software is adapted to perform voltage and frequency control – while the control hardware is identical for rectifier and inverter converters. Protection and monitoring of the converter is also included in the same controller.

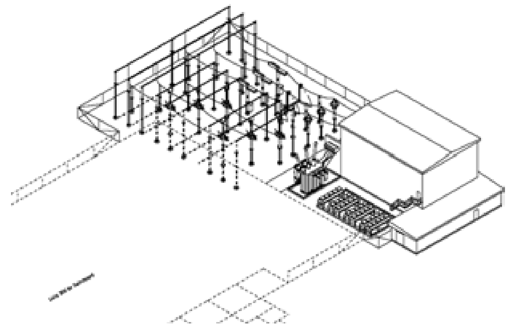

Figure 8. HVDC converter station at Lista

One important design aspect is to keep the dc voltage at a constant value since this is essential for controllability as well as ensuring that there is no unnecessary over-voltage stress on the dc system. This is however identical to the design of a transmission system where one station, in this case the onshore, controls the dc voltage while the offshore controls the active power. The control coordination of the stations is made without the use of telecommunication system.

One of the important issues during the design has been the harmonics ranging from low order harmonics up to very high frequency. The desire to have low weight on an offshore platform gives the optimum solution that the platform should not be designed for excessive harmonics. The design philosophy has therefore been to install filters with the same filtering capacity that is normally required in a high voltage installation and not allow for large harmonics. The harmonic generation from a HVDC Light converter is primarily at the switching frequency (1620 Hz) and above while there is almost no generation of harmonics in the low frequency range (5, 7, 11 and 13:th harmonic), which is common in a classic HVDC converter.

5. CONCLUSIONS

In most cases, power supply to offshore installations from shore has been difficult or even impossible as long as the alternatives have been ac cables or classic line-commutated HVDC systems. VSC technology has enabled development of HVDC systems with converter stations that require smaller filters and no local generation or synchronous condensers, and with control properties far superior to those of classic HVDC. The technology using HVDC Light now makes it possible to supply electric power from shore to offshore installations.

Placing high voltage equipment on offshore installations poses some challenges, size and weight constraints are important. The module can handle the special safety considerations and the harsh offshore environment, therefore standard, or even lower rated, electrical high voltage components can be used. The same design can also be used to feed local ac network offshore.

The benefits with Power From Shore for Valhall can be summarized as follows;

- Simplified offshore installation, lower offshore manning and reduced operation costs
- Improved safety and working environment
- Emission to air offshore close to zero for energy supply to the complete Valhall field
- Fewer offshore lifts give HSE benefits
- Less boats, less helicopters
- Technical advantages regarding Direct On Line start of large motors and electrical system fault level in the offshore grid

Power from shore is cost efficient, save space and weight on the platform itself, requires less maintenance offshore than the conventional solution with gas turbines. It will also contribute to a safer working environment on the platform as well as being friendlier to the environment by reducing emissions. All these aspects have been very important for BP, which is the operator of the Valhall field, and their partners Amerada Hess, Total and Shell.

6. REFERENCES

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