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VALHALL POWER FROM SHORE AFTER FIVE YEARS OF OPERATION

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Harry Myklebust
AKER BP Engineering
Services Norway
harry.myklebust@akerbp.com

Kjell Eriksson
ABB AB, HVDC, Sweden
kjeller.eriksson@se.abb.com

Bo Westman,
ABB AB, HVDC, Sweden
bo.westman@se.abb.com

Gunnar Persson
ABB AB, HVDC, Sweden
gunnar.persson@se.abb.com

Abstract – Traditionally, electric power is generated on offshore platforms locally, using gas turbines. However, gas turbines have several disadvantages, including low efficiency (30 - 40 percent maximum), high carbon dioxide (CO_2) and nitrogen oxide (NOx) emissions, and high operating and maintenance costs. The possibility of conveying electrical power to offshore sites from more efficient and cleaner onshore generating facilities has been achieved with the invention and acceptance of voltage source converter (VSC) power transmissions as a competitive solution for long-distance shore-to-platform power delivery systems.

VSC links are increasingly being deployed to connect remote renewables to consumption centers, and to enable cross-border connections, power from shore links and city-center in-feeds where space is a constraint.

The compact and lightweight design of an offshore VSC converter enables it to be placed on an existing platform, changing the power source from gas turbines to onshore generation to meet existing or increased demand. It can also be fitted together with other equipment on new platforms. Power from shore improves safety for both personnel and equipment in a production and processing environment.

The VSC power from shore (PFS) concept has so far been used in the following installations: Troll A 1&2 for Statoil, delivered in 2005; Valhall for BP, delivered in 2011; and Troll A 3&4 for Statoil, delivered in 2015. A 100 MW transmission to the Johan Sverdrup offshore field will be operational in 2018.

The transmission to the Valhall field (78 megawatts (MW), 150 kilovolts (kV), was the first to provide general power from shore as the platform's only power source. It has been in operation for five years, and has delivered excellent performance. This paper will describe the experiences of these five years of operation and maintenance, and examine various aspects of the performance of power delivery to the platforms.

In addition, it will provide some perspective regarding influences on the sending end network, and its operation.

I. INTRODUCTION

The transmission to the Valhall field (78 MW, 150 kV) was the first to provide general power from shore as the platform's only power source. The Valhall transmission (see Figure 1) has been operating for five years, and has delivered excellent performance. This paper will describe the experiences of these five years of operation and maintenance, and examine various aspects of the performance of power delivery to the platforms.

Figure 1. Valhall transmission map

Applications to feed power to or from offshore installations using High Voltage Direct Current (HVDC) technology have been discussed for many years. However, because conventional HVDC technology requires an AC system of a certain strength to operate, this was not feasible in the past. The idea of providing offshore facilities with more efficient and cleaner power generation from shore was finally made possible by the invention of VSC technology for long-distance power transmissions. One specific advantage of PFS is the compact and lightweight design of the offshore converter, which can be placed on an existing platform to change the power source from gas turbines to power from shore to meet existing or increased demand, or fitted together with other equipment on new platforms. Power from shore improves safety for personnel and equipment in a production and processing environment.

II. HVDC AND PFS PROJECT EXPERIENCE AND EVOLUTION

The use of VSC converters for HVDC transmission began in 1997 with a test transmission rated for 3 MW and +/- 10 kV. The operational experiences of that transmission were sufficiently promising that a first commercial order was placed the same year, and went into operation two years later. This was a 50 MW, +/- 80 kV transmission infeed of land-based wind power to the small power network on the island of Gotland, in the Baltic Sea. Compared with the test link, this installation already represented a considerable increase in transmission capacity. Since then, another 30 transmission projects have been put into operation, or are under construction.

The vision was that power from shore should be one of the interesting applications of VSC technology. Preparatory studies for such projects began early, and in 2002 Statoil ordered PFS transmissions for compressors 1&2 (45 MW each) on the Troll A platform, to be operational in 2005. This was followed by a PFS transmission to BP's Valhall field, which was delivered in 2011 and which provides complete electrification of the field (78 MW and 150 kV). The compressors for Troll A were a first stage, and from the beginning it was understood that more compressors would eventually be needed as the natural pressure of the field decreased. Two more compressors were installed, and HVDC VSC transmissions Troll 3&4 were deployed to power them in 2015. Johan Sverdrup is now the fourth VSC-HVDC power from shore system to be installed in the North Sea. In this case, the application is similar to the Valhall scheme.

Today, the development of VSC converters has enabled installations to operate at +/- 320 kV and around 1,000 MW, and projects with +/- 500 kV are now under construction. For PFS projects a voltage of +/- 80 kV provides advantages for transmissions up to approximately 200 MW, because it enables a small converter footprint on an offshore platform.

Today there are five VSC-HVDC power from shore transmissions in operation, and one under construction (see Table 1).

Transmission	Distance km	Power MW	In operation
Troll A 1&2	70	2x44	2006
Valhall	292	78	2011
Troll A 3&4	70	2x50	2015
Johan Sverdrup PFS	200	100	2018

Table 1. VSC PFS transmissions in operation or under installation

III. HEALTH, SAFETY AND ENVIRONMENTAL ASPECTS OF POWER FROM SHORE

A power from shore solution is cost efficient, saving space and weight on the platform itself, and requires less offshore maintenance than a conventional gas turbine solution. It contributes to a safer platform work environment, and by reducing or almost eliminating emissions of CO_2 and NOx is more environmentally friendly.

Some of the main reasons for choosing a VSC-HVDC power from shore system for Valhall include:

- reduced costs and improved operational efficiency of the field
- minimal offshore platform emissions by substituting smaller gas turbines for more efficient and environmentally friendly generation onshore; atmospheric emissions are close to zero for the energy used at the Valhall field, and estimated reductions are 300,000 metric tons of CO_2 and 250 metric tons of NOx annually.
- Improved platform HSE by enhancing the safety and work environment, with fewer offshore lifts, decreased boat and helicopter traffic, reduced noise, etc.
- Electric and magnetic fields were measured at the Valhall PFS module, offices and electrical rooms to evaluate electromagnetic properties, with reference to the EC directive and guidelines for field exposure.

Normal operating values were recorded while the PFS transmission was loaded at 41 MW. Field values in the Valhall PFS module were moderate or below the limits set out by the directive for occupational exposure.

IV. DESCRIPTION OF VALHALL REDEVELOPMENT PROJECT

The Valhall complex has been in operation since 1982, and consists of five bridge-linked platforms. The Valhall facilities were subject to reservoir compaction resulting in seabed subsidence (about 25 cm per year) and as a result the water depth on site had increased by about 5 meters. Increasing water depth and wave considerations resulted in a recommendation to replace the production and compression platform and the living quarter platform with a new facility.

It was decided to supply the new facility with electric power from shore via a VSC-HVDC transmission, utilizing the latest developments in power electronics and computerized control and protection systems. This replaced offshore gas turbines and provides power to the entire field, which makes Valhall one of Norway's most environmentally friendly offshore fields. The user desired a safer, more effective power source, and a lighter, smaller platform solution requiring less maintenance.

The transmission system (see Figure 2) based on VSC technology includes onshore and offshore converter stations joined by a 292-km long subsea DC power transmission cable. AC power is converted to DC power at 150 kV in the 300-kV substation at Lista, Norway. The power is transmitted by DC cable to the field and converted back to AC at 11 kV on the new platform, powering the entire Valhall field.

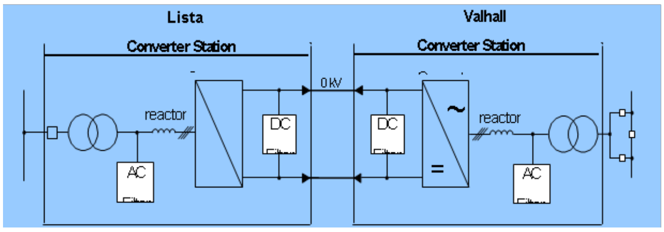

Figure 2. PFS transmission for Valhall

High-voltage equipment is installed in a module offshore, and inside a building onshore. The ventilation system in the module and building is designed to protect high-voltage equipment and electronics from salt and humid air. There are no special requirements regarding main circuit equipment installed in an offshore environment.

The HVDC module comprises two floors (see Figure 3). AC filters and phase reactors are on the top floor; the converter valves and DC equipment are installed below. This is also where the 150 kV HVDC cable terminates. The converter transformers are located in a separate room, and the bushings penetrate 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 minimize harmonics to the platform AC system.

The HVDC module (see Figure 4) is 17 x 30 x 13.6 meters (WxLxH). In this space, there is not only enough room for high-voltage equipment but also auxiliary systems, mainly the valve cooling system, ventilation system and auxiliary power system. HVDC control and protection equipment and communication with the platform control system are installed in two separate electrical rooms.

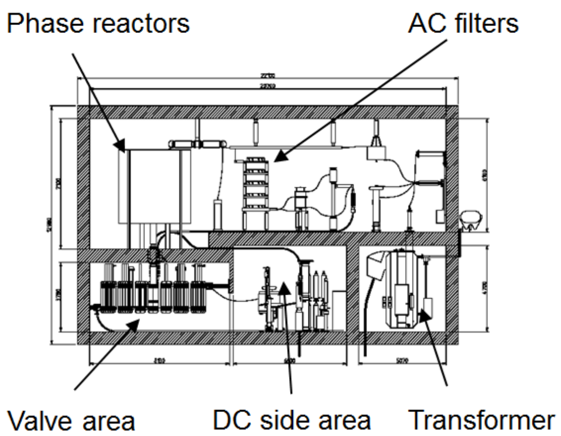

Figure 3. Layout of offshore converter

Figure 4. HVDC module lifted to platform

V. EXPERIENCES FROM FIVE YEARS OPERATION OF THE VALHALL PROJECT

The Lista substation on the mainland was commissioned in 2009, two years ahead of the platform station, and was initially operated as a Static Var Compensator (SVC). The platform station was commissioned from February to May, 2011. During this time only limited utility power was transmitted to the platform. Full operation commenced in June 2013.

A power from shore solution comprises a simplified offshore installation, reduced maintenance, offshore manning and operation costs. In addition, PFS provides technical advantages for the direct on-line starting of large motors.

Much of the scheduled maintenance has been outsourced to the supplier, who provided the necessary specialists. For example, in October 2016 maintenance was performed at the Lista mainland station over the course of six days (taking 283 man-hours), and at the Valhall offshore station over the course of eight days (taking 426 man-hours), which is well within the total time allotted for production stoppage and maintenance. During commissioning and testing, a few trips occurred and the system was properly debugged.

Since 2013, events and availability have been followed up (see Table 2).

Year	Unavailability, forced	Unavailability, scheduled	Overall availability
	%	%	%
2013	0.29	2.16	97.55
2014	0.02	0.81	99.17
2015	0.05	1.18	98.77
2016	0.09 (4 months)	2.24 (Oct. maintenance)	-

Table 2. Availability records

One reason for the difference in scheduled unavailability from year to year is that complete scheduled maintenance is only done every third year. In this context it is important to mention the following events, which occurred in the period from 2013-2016:

- one trip due to a faulty control card, which was exchanged
- SF6 pressure alarms in a leaking circuit breaker, which was exchanged
- alarms from an HMI computer card, which was exchanged
- alarms from a faulty IGBT, which was exchanged during the 2016 maintenance
- installation errors in the HVAC system resulting in instability were duly corrected

On the whole, the Valhall VSC-HVDC power from shore system is considered to have turned in an excellent performance over its time of operation.

VI. INFLUENCES ON END NETWORK DELIVERY

The converter station equipment was ready at the same time for both the offshore module and the onshore substation. Even so, the Lista onshore station was immediately installed and commissioned in 2009, two years ahead of the platform commissioning and start up. In the meantime, BP had to either preserve an inactive station, or run it in SVC mode. The second option had two advantages: it provided an opportunity for station operators to test and experience the system's SVC function. During that time, reactive power capability was increased from +/- 10 megavolts ampere reactive (Mvar) to +/-50 Mvar, as there were no active power transmission operations to the platform.

Figure 5 demonstrates how the converter station supports the AC grid with reactive power over the course of one day.

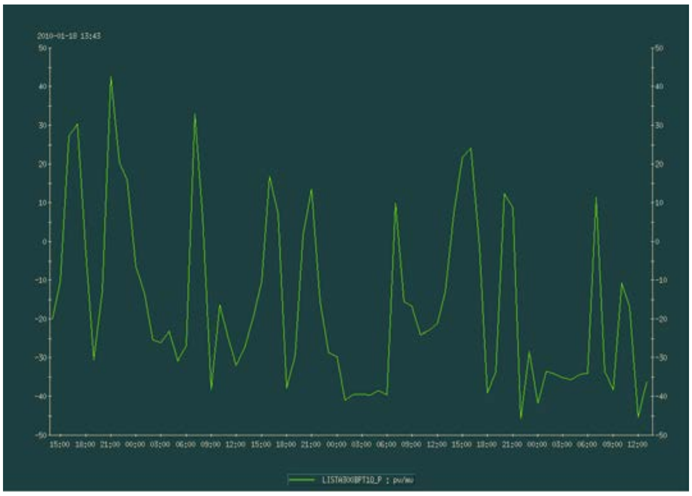

Figure 5. Daily variation of Mvar support from converter station

During this time there was one converter outage due to a faulty control card.

At a later stage the system was improved by increasing reactive power support capacity by +/- 20-50 MVAr (dependent on AC voltage), also when transmitting full power to the platform.

VII. CONCLUSIONS

The VSC-HVDC power from shore transmission solution supplying power to the Valhall platform has delivered an excellent performance. Power has been provided securely and well within expected availability, and expected functionality for operations and maintenance. Greenhouse gas (GHG) emissions have been drastically reduced, compared with generating power locally on the platform. In summary, the Valhall installation demonstrates that power from shore technology is a secure, reliable and practical alternative for platform electrification.

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IX. VITAE

Bo Westman graduated from the Chalmers University of Technology, Gothenburg in 1980 with an MSc in Electrical Engineering. He has been in various manager positions in ABB since 1984. He have since then worked with a number of HVDC projects and since 2005 with a focus on HVDC VSC technology. Bo is a member of Cigre.
bo.westman@se.abb.com

Harry Myklebust graduated from the department of Electrical Engineering, Technical Collage in Telemark with a BSc. degree in 1984. In the past thirteen years he held position as Technical Authority working with design and construction of electrical system for major offshore installation for BP in Norway.
harry.myklebust@akerbp.com

Kjell Eriksson graduated from the Royal Institute of Technology, Stockholm in 1964 with an MSc in Electrical and Electronics Engineering. He has been working within ABB HVDC since 1965 and has been in various manager positions. Since 2004 he is a consultant within ABB HVDC. He is a member of the Cigré and was convener of working group WG14(B4).33.
kjeller.eriksson@se.abb.com

Gunnar Persson graduated from the Chalmers University of Technology, Gothenburg in 1977 with an MSc in Electrical Engineering. He has been in various manager positions in ABB since 1986.Since 2008 he is working for the HVDC unit in Sweden. He is a member of the Cigré and also member of working group WGB2.62.
gunnar.persson@se.abb.com