Powering platforms

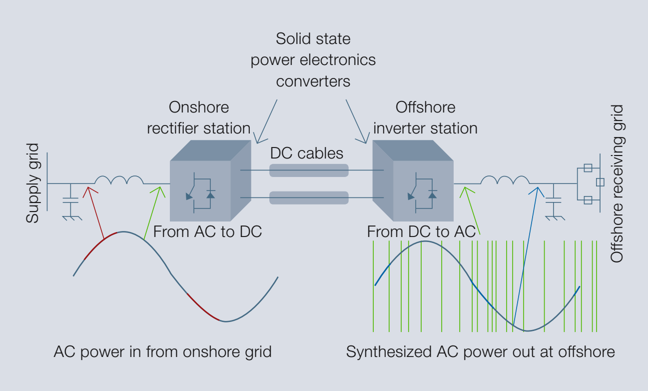
Connecting oil and gas platforms to mainland power grids

Rahul Chokhawala

Provision of electrical power and other forms of consumable energy start with the exploration of primary energy. These primary sources are often located in remote places and their operation poses significant challenges for exploration companies. Oil and gas platforms far offshore are a prominent example of these sites, at which safety, environmental constraints and life-cycle economy are high on the agenda. With HVDC Light®, ABB offers the most economic solution with the smallest environmental footprint to power the operation of such platforms.

The operator of a platform has two different options to power all the local machinery: generate electricity on site with gas turbines that drive generators or get electricity from shore via subsea cables. While it seems natural to use the gas produced at the platform to run local gas turbines, in the majority of cases this is not the most economic solution.

1 Key components of a VSC-based HVDC system



Gas turbines (GTs) are essentially jet engines that extract energy from a flow of hot gas produced by the combustion of gas or fuel oil. Shaft power generated in this way drives generators to produce electricity. The process of producing electricity involves combustion, compression, heat transfer and spinning, resulting in the need for equipment that, besides consuming a great deal of fuel, requires considerable operation and maintenance (O&M) efforts.

A platform with a generating capacity of 100 MW would typically release over 500,000 tons of CO_2 per year.

GTs deployed offshore are mostly simple-cycle types due to weight and space constraints on platforms. Simple-cycle GTs have remarkably low energy conversion efficiencies, particularly when operated at less than full capacity, as is often the case. Best operating efficiency of GT generation is in the range of only 25 to 30 percent. Considering the ideal fuel to electrical energy conversion ratio for standard natural gas of 10.8 kWh/m^3, burning one standard cubic meter of natural gas produces just about 3 kWh of electricity and at the same time releases about 2 kg of CO_2. A platform with a generating capacity of 100 MW would typically release over 500,000 tons of CO_2 per year, combined with the emission of about 300 tons of nitrogen oxide (NO_x), a gas corrosive to both the environment and to people's health.

O&M work is proportional to the number of GTs onboard. It is not uncommon that a platform consuming 100 MW would have five or six GTs onboard given the redundancy requirement and individual applications involving direct GT drives.

AC cables transmitting power to offshore installations are a proven technology, typically supplying to platforms at distances of tens of kilometers. For longer distances, AC cable transmission poses challenges as a number of issues inherent to AC systems become important. Coaxial cables form distributed capacitance increasing with cable length. In AC systems, cable capacitance generates reactive power, which should be compensated by midpoint reactive power compensators or Static Var Compensators (SVCs), for example.

Dynamic issues associated with long-distance AC cables need to be evaluated and mitigated as well. For example, the presence of large cable capacitance in series with transformer magnetization reactance could lead to ferroresonance during line energizing and to possible failure. Also, momentary voltage dips due to onshore grid disturbances amplify while propagating along long cables, possibly tripping sensitive offshore equipment.

DC cable transmission fits best to connect offshore platforms.

DC cable transmission systems, on the other hand, are generally immune from the drawbacks associated with long-distance AC cables. In fact, voltage source converter (VSC)-based high-voltage direct current (HVDC) systems are designed to transmit large amounts of power over long cable distances. A major cable distance limitation was thus lifted upon the arrival

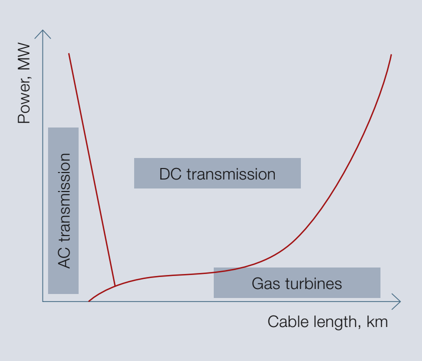
2 HVDC Light module on Statoil's Troll-A platform

of VSC-based HVDC transmission to offshore applications [1, 2].

The main difference between DC and AC transmission is the presence of an AC-to-DC converter that rectifies onshore grid AC power to DC power for the purpose of transmission and the presence of a DC-to-AC converter at the consumer end that synthesizes DC power back into AC power 1. While the converters increase the cost of the DC system, the number of required cables is reduced from three for the AC system to two for the DC system. This reduction, combined with the reduced DC cable size due to inherently higher utilization efficiency, results in cable cost savings that could more than compensate for the converter cost as the cable distances increase.

HVDC Light® is a cable transmission system based on ABB's VSC-based HVDC technology. The system, initially developed for land-based applications, went into operation in 1997 on the island of Gotland in Sweden, connecting wind generators in the south to the island's grid in the north. Since then, eight such systems have been installed worldwide for land-based applications, totaling almost 1,200 MW and 500 km. The first offshore version of HVDC Light® went into operation in the North Sea in 2005 at Statoil's giant Troll-A gas platform 2. The next HVDC Light® footprint is scheduled to take place at BP's Valhall field, also in the North Sea, with operation scheduled for 2009.

3 CAPEX – "Windows of opportunity"



DC transmission offers a broad "window of opportunities" for CAPEX savings.

HVDC Light® electrical converters are based on Insulated Gate Bipolar Transistor (IGBT) power semiconductors with switching frequencies of up to 2,000 Hz in synthesizing the sinusoidal AC output. The maintenance requirement is small compared with a single GT, as it is determined by conventional equipment such as AC breakers and cooling systems.

The optimal solution

When selecting the energy supply for a platform the operator has to evaluate a number of different criteria:

- Greenfield or brownfield upgrade or extension
- Application of the energy on the platform
- Local regulations
- Installation cost
- Operational cost

Field development

A new field development allows for a fresh approach with little or no demolition or removal expenditures for existing equipment. Troll-A HVDC Light® is an excellent example where the need for pre-compression of gas for pipeline transportation arose due to a drop in reservoir pressure over past production years [3].

A field redevelopment may as well necessitate additional power and may or may not require demolition work to remove existing generation equipment. Valhall HVDC Light® was part of a redevelopment project where the field operator, BP, decided to remove the existing GT and rely solely on power from shore (PFS) with the power supply capacity increased to the required value [4].

A third type of field development involves electrification of an existing platform or of a cluster of fields.

Applications

If a compressor is driven by a variable-speed drive to achieve targeted process performance, an HVDC energy supply, together with a high-voltage motor, would be the preferred solution, as was the case for the Troll-A pre-compression project [5].

4 Life-cycle OPEX parameters

OPEX parameters	NCS	Average	
Electricity wholesale price	46.7	66.7	$/MWh
Fuel sales value	0.24	0.24	$\$/\text{Sm}^3$
HVDC Light converter losses	4 %	4 %	
HVDC Light cable losses	4–6 %	4–6 %	
Fuel to electricity conversion at 100% efficiency	10.8	10.8	KWh/Sm^3
GT turbine efficiency	40 %	30 %	
Released CO$_2$ at 100 % efficiency	0.21	0.21	
CO$_2$ tax or trade value	56.3	16.7	$/ton
Released rate of NO$_x$	0.4	0.4	kg/kWh
NO$_x$ tax (over 20 year horizon)	7.5	2.5	$/kg
GT O&M costs/yr per 25 MW unit (+ WHR + ST in NCS)	2.5	1.7	M $/year
HVDC light system O&M (all sizes)	0.7	0.7	M $/year
Analysis period	20	20	years
Interest rates – net present value	7 %	7 %	

An application may require the direct online start of motors (eg, BP's Valhall). This can be simply factored into the design of a VSC-based HVDC system. However, for GT and AC PFS solutions, devices such as soft-starters would be needed on the platform.

Local regulations

Regulations play an important role in the deployment of efficient, environmentally friendly and safe equipment offshore. In Norway, efficiency-boosting equipment such as waste heat recovery (WHR) units and steam turbine generators (ST) are mandatory in new GT capacities offshore. The required efficiency improvement for simple-cycle GTs from typically 25 to 30 percent to around 40 percent reduces fuel consumption and taxable greenhouse gas (GHG) emissions while adding to O&M costs. WHR and ST would also add to initial capital expenditures and to space and weight requirements on a platform. Such regulations clearly have a favorable influence in consideration of PFS.

Initial investment CAPEX

With a given set of development, application and local regulations, the estimation of initial investment depends on the primary system factors, meaning rated MW and installed kilometers of cable. Together they form a pattern for the so-called "windows of opportunity" 3.

For a given transmission distance, the capital expenditure (CAPEX) transition between DC PFS and GT is governed largely by the MW power capacity to be installed. With increasing power requirements, the DC PFS option becomes more favorable. While HVDC Light® is simply sized up to cover just about any given megawatts (up to 1,000 MW), GT units multiply in number to achieve the required level. In addition, the gas turbine's O&M expenditures increase with the number of GTs but remain at about the same low level for HVDC Light® [6, 7].

Life-cycle OPEX savings are significant with power from shore.

Longer distances favor the DC solution when additional converter costs can be balanced by lower cable costs.

Economic evaluation of competing power supply solutions requires intimate knowledge of the capital and other initial expenditures and of the parameters influencing life-cycle operating expenditures (LC OPEX) specific to a given project. These costs have to be analyzed on a case-by-case basis.

Unlike CAPEX data, which is strictly proprietary in nature, OPEX data are widely available in public data sources. Based on this large set of published data, a comparison of LC OPEX can be made for GT- and PFS-based solutions. The comparison is made along three sets of parameters: 25 MW/50 km, 100 MW/100 km and 250 MW/300 km. Each of these cases is analyzed for Norway and "Average"; Average refers to regions such as the European Union where GHG emissions or efficiency-related regulations are more moderate and the cost of electricity is higher than in Norway.

The major components of LC OPEX are costs of fuel and offshore O&M manpower. Additional costs related to GHG, in form of either local taxation as in Norway or trading value as in the European Union. LC OPEX forms a substantial part of the total cost and has to be included in any life-cycle cost calculations for power systems that are under consideration.

4 lists key published OPEX parameter values, associated with the two regional scenarios for GT- and PFS-based solutions. Since differences between AC and DC cable systems are minor from an OPEX point of view, the following calculations use HVDC Light® solutions to represent AC and DC PFS-based options. The indicated electricity prices are expected wholesale prices, and the CO$_2$ trade value

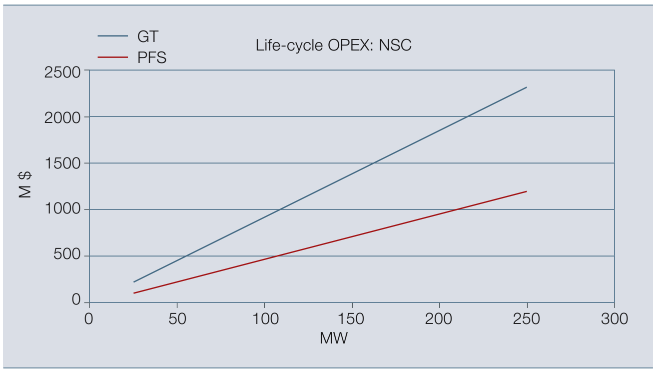
5 Life-cycle OPEX costs: 100 MW, 100 km, Norway

Life-cycle OPEX costs – NCS 100MW, 100km:	GT	PFS
	M $	M $
NG fuel or electricity costs	552	505
CO$_2$ taxation	294	0
NO$_X$ taxation	30	0
O & M costs	113	8
Total life-cycle OPEX	988	513

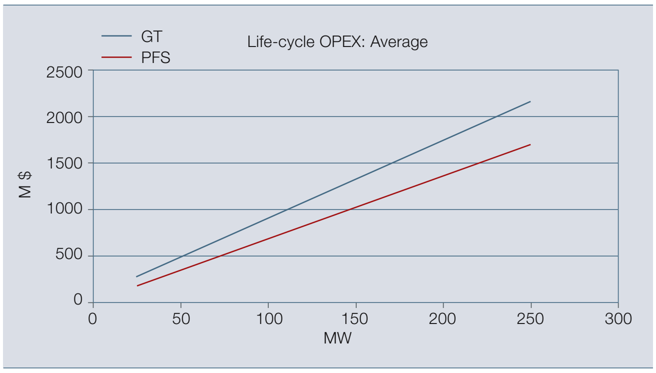
6 Life-cycle OPEX costs: 100 MW, 100 km, "Average"

Life-cycle OPEX costs – Average, 100MW, 100km:	GT	PFS
	M $	M $
NG fuel or electricity costs	736	722
CO$_2$ taxation	116	0
NO$_X$ taxation	10	0
O & M costs	76	8
Total life-cycle OPEX	937	729

7 Life-cycle OPEX for Norway: GT versus PFS



8 Life-cycle OPEX for "Average" regions: GT versus PFS



for Average regions is based on a 20-year horizon.

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5 and 6 provide estimated net present values of life-cycle OPEX for Norway (NCS) and Average for 100 MW and 100 km. LC-OPEX amounts are large and clearly form the dominant quotient of total life cycle cost (CAPEX + OPEX), particularly for new development or redevelopment projects.

9 Live-cycle OPEX savings with PFS for all six cases

Live-cycle OPEX savings with PFS	NCS M M $	Average M $
250 MW, 50 km	114	48
100 MW, 100 km	476	208
250 MW, 300 km	1189	514

10 Annual CO$_2$ reduction on platform with PFS

Yearly CO$_2$ reduction on platform	NCS ton	Average ton
250 MW, 50 km	114,975	153,300
100 MW, 100 km	459,900	613,200
250 MW, 300 km	1,149,750	1,533,000

11 Annual NO$_x$ reduction on platform with PFS

Yearly NO$_x$ reduction on platform	NCS ton	Average ton
250 MW, 50 km	88	88
100 MW, 100 km	350	350
250 MW, 300 km	876	876

LC OPEX as a function of power for Norway and Average regions is presented in 7 and 8.

The savings in LC OPEX when using PFS instead of GT is significant for all considered cases 9. The savings in offshore emissions of greenhouse gases associated with GT-based generation are also remarkable when using PFS solutions 10 11.

PFS: an attractive alternative

The examples given clearly show that a power supply to platforms from mainland via cables offers highly economic and environmentally friendly solutions that increase operational safety at the same time. While individual evaluations are needed for each project, the typical cases presented here give enough indication to seriously consider PFS solutions for greenfield and brownfield installations. ABB's HVDC Light® systems have demonstrated the advantages, and it can be expected that more platforms will be equipped with PFS solutions in the future.

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