Statoil

Johan Sverdrup Field Power solutions

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Johan Sverdrup Field Power solutions		
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Innhold

1 Introduction

The purpose of this report is to document the work and assessments made related to power from shore (PFS) to the Johan Sverdrup field.

[redacted]

Due to the uncertain situation, an alternative power solution based on dedicated power from shore for Johan Sverdrup has been evaluated in parallel. This evaluation includes an area solution as one of three scenarios to supply power for future phases on Johan Sverdrup; dedicated power from shore to Johan Sverdrup, power from shore to as an area solution and offshore power generation (turbines).

Alternative scenarios to supply power to future development phases will be assessed further.

The government issued an official statement on the 23. January 2014 saying that there has been a consensus in the parliament (Stortinget) that;

"Hovedvirkemidlet for å begrense CO2-utslippene fra sokkelen er den høye utslippskostnaden selskapene står overfor gjennom det europeiske kvotesystemet og CO2-avgiften; samlet på om lag 450 kr/tonn CO2."

Furthermore, the statement says that; *"Basert på de rammebetingelser som er gitt, må selskapene på forretningsmessig grunnlag blant annet etablere en utbyggingsløsning, herunder vurdere hvilken kraftløsning som er best for den enkelte utbygging".*

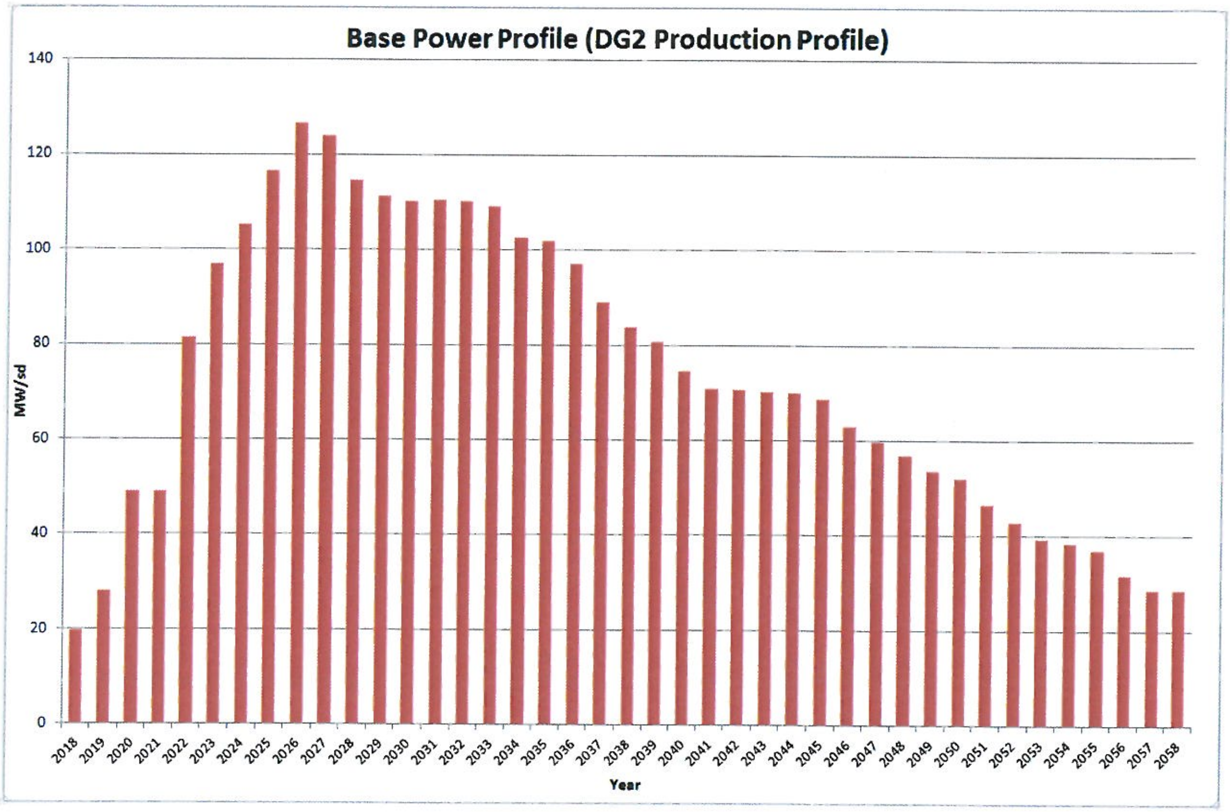
2 Power demand

The analysis is based on the latest power requirement for the Johan Sverdrup field. Power profiles from other fields are based on license-approved data.

A sensitivity calculation is done based on an alternative Statoil assessment of future power requirements taking into account IOR options.

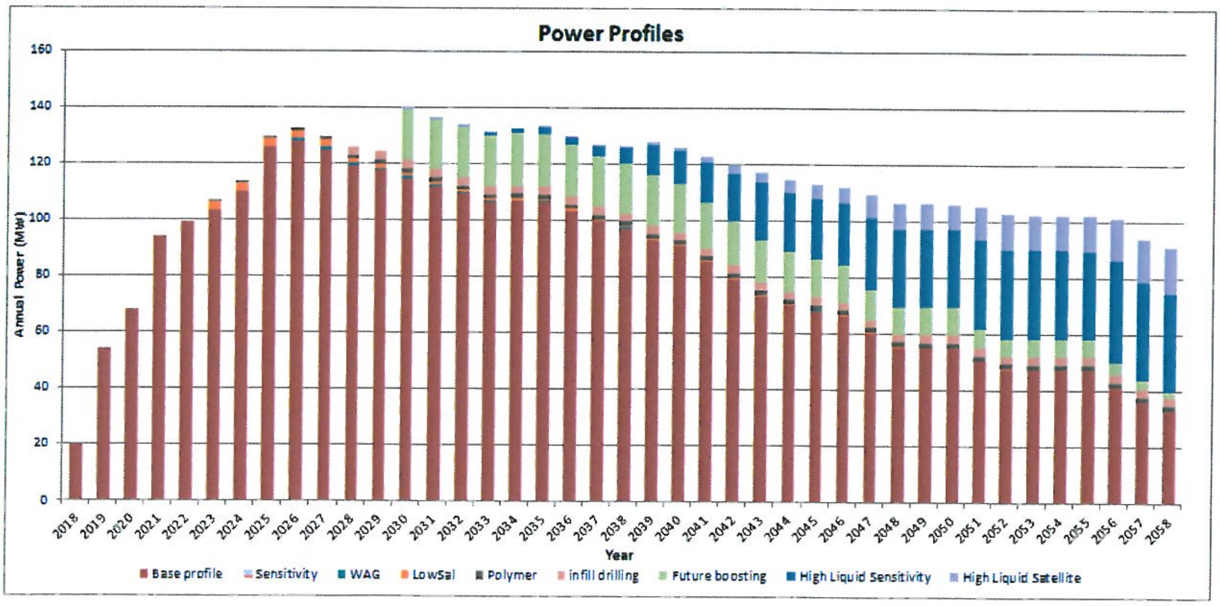
2.1 Johan Sverdrup power requirement

Below is the expected power requirement for the Johan Sverdrup full field based on the DG2 production profile. Future IOR (Increased Oil Recovery) and power requirements at the satellite production facilities are not included. The maximum power requirement is estimated to be 127 MW (in the year 2026).



Below is a power profile with following sensitivities

a. High liquid production profile
b. WAG – IOR functionality
c. Polymer – IOR functionality



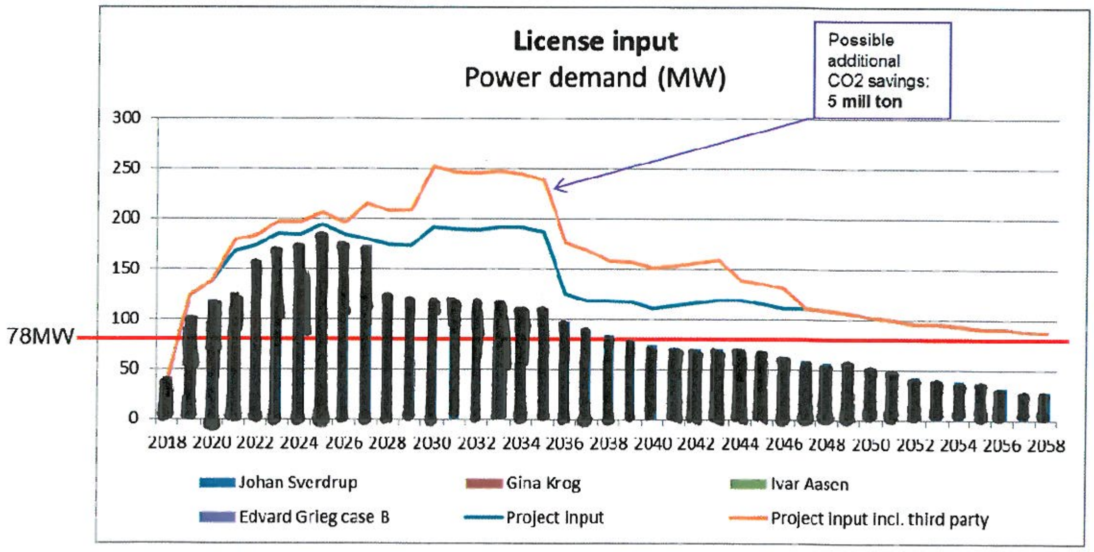
In addition to the uncertainties for IOR functionality that will be implemented and configuration of the satellite processing facilities, there is an uncertainty in the total liquid production and required gas lift rates in the base case production profile. The consequence of higher liquid production (compared to base case production) on power profile has been shown. The figure also illustrates the power consumption for IOR functionalities factored in based on probability.

[redacted]

[redacted]

2.2 Power demand from Johan Sverdrup, Edvard Grieg, Ivar Aasen and Gina Krog

[redacted]



3 Power from shore – alternative technical solution

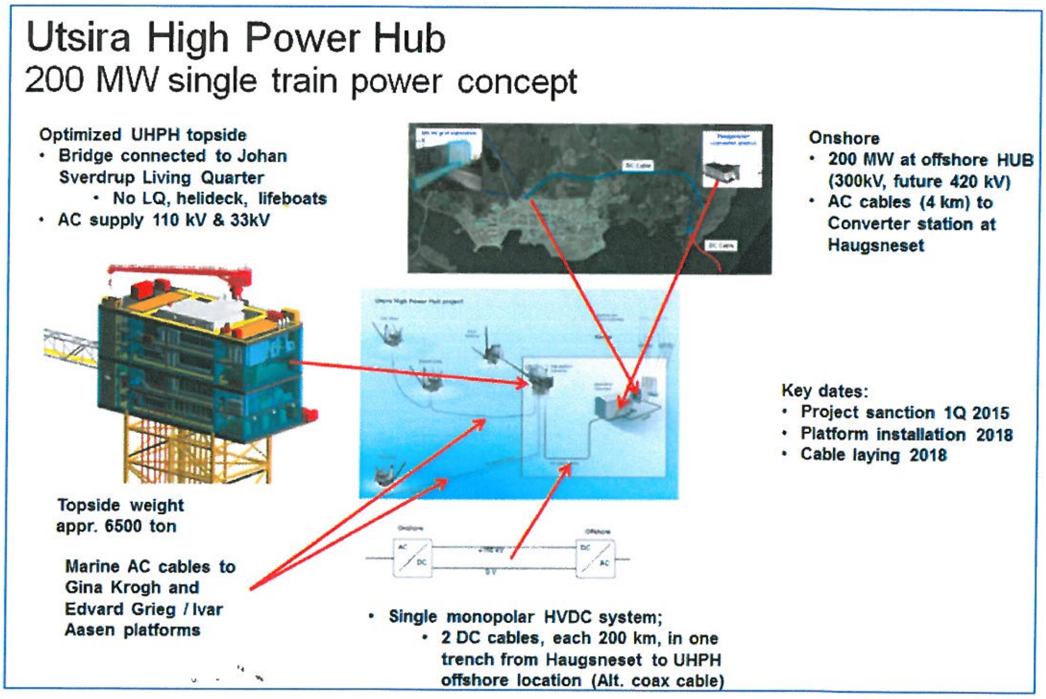
3.1 Utsira High Power Hub solution

The Utsira High Power Hub project objective is to develop a technical and commercial concept for distribution of power from shore to a Hub platform located in the Utsira High area with further power distribution to field installations on Gina Krog, Edvard Grieg, Ivar Aasen and Johan Sverdrup.

The project is a joint project between the partners of Gina Krog, Edvard Grieg, Ivar Aasen and Johan Sverdrup licences.

3.1.1 Utsira High Power Hub – 200 MW single train power concept

The figure below sums up the UHPH 200 MW single train concept.



The scope of Utsira High Power Hub project includes a complete HVDC (High Voltage Direct Current) transmission system to an offshore hub platform and HVAC (High Voltage Alternate Current) distribution of electricity to the user field platforms, as follows:

- ➢ 200 MW power available at offshore hub (power outtake at Kårstø appr. 220 MW)
- ➢ New onshore installations:
  - o A converter station for single power train

- Extension of grid station inside Kårstø plant
- Single set of AC cables and all other equipment required to connect to the onshore 300 kV (future 420 kV) grid

➢ Two 200 km subsea power HVDC cables (+/-) shall be installed and buried at the sea bottom for protection against fishing gears.
➢ An offshore hub platform including converter and all other equipment needed for operation and maintenance
➢ Distribution HVAC cables to supply electricity from the power hub platform to the various user field installations
  - 110kV distribution to Gina Krog and Edvard Grieg/Ivar Aasen
  - 33 kV distribution to Johan Sverdrup over the bridge to the various topsides

➢ The UHPH offshore platform is bridge connected to the Johan Sverdrup Living Quarter.

In dialogue with Statnett the project has recommended that Kårstø is the connection point to the grid in the area. The Kårstø/Karmøy area has a strong grid at 300 kV level with good redundancy (3 lines). Statnett has confirmed a sufficient grid capacity for the Utsira High electrification project (max. 300 MW), given the present situation at Hydro Karmøy. This includes an increased potential power demand caused by a possible pilot smelter project at Hydro Karmøy.

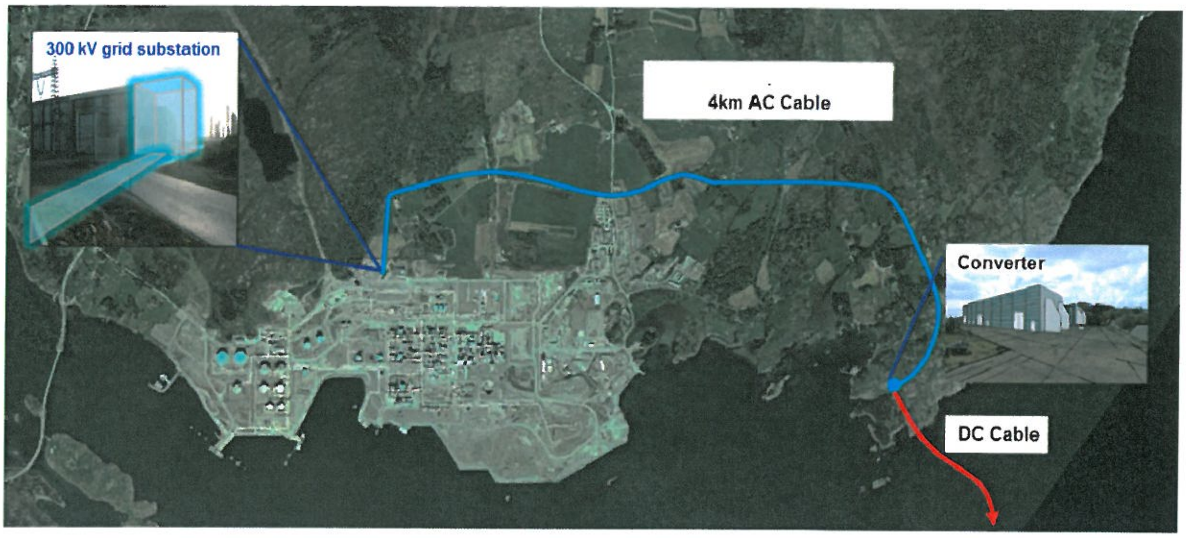
Utsira High Power Hub has requested Gassco for project services and later possible operational services and Gassco have replied positively with regard to tie-in to the grid at Kårstø main intake station.

Johan Sverdrup project has for this case included a back-up generator (30 MW) to secure available power in case of UHPH delay.

The UHPH 200 MW single power train case is based on the following parameters:

➢ Design Life: 50 years operations
➢ Water Depth (appr. 115 metres),
➢ Operations: Normally Not Manned philosophy
➢ Platform:
  - No LQ, helideck or Life Boat arrangement
  - 12 J-tubes, 4 spare tubes

Onshore facility and tie-in to onshore grid Kårstø (Gassco) and Haugsneset 200 MW single power train



3.1.2 150 MW alternative case

This 200 MW power concept can be adjusted to supply 150 MW at the offshore hub. The total CAPEX will be reduced compared to 200 MW case, however, CAPEX per MW will increase and hence abatement cost will increase. This alternative is considered technically feasible, but will only support Johan Sverdrup power needs.

3.1.3 Schedule

[redacted]

[redacted]

3.2 Johan Sverdrup power from shore

3.2.1 78 MW for phase 1

3.2.1.1 Power demand JS phase 1

The power requirement for phase 1 was estimated internally by Statoil to verify that the 78MW HVDC module would provide sufficient power for up to the first five years of production. Five years were selected as this would provide some margin if phase 2 was delayed. The phase 1 production profile was used with a peak production of 50 000 Sm3/sd. Sensitivity analyses were performed with 60 000 Sm3/sd oil production and also with higher gas lift rates to account for higher water production.

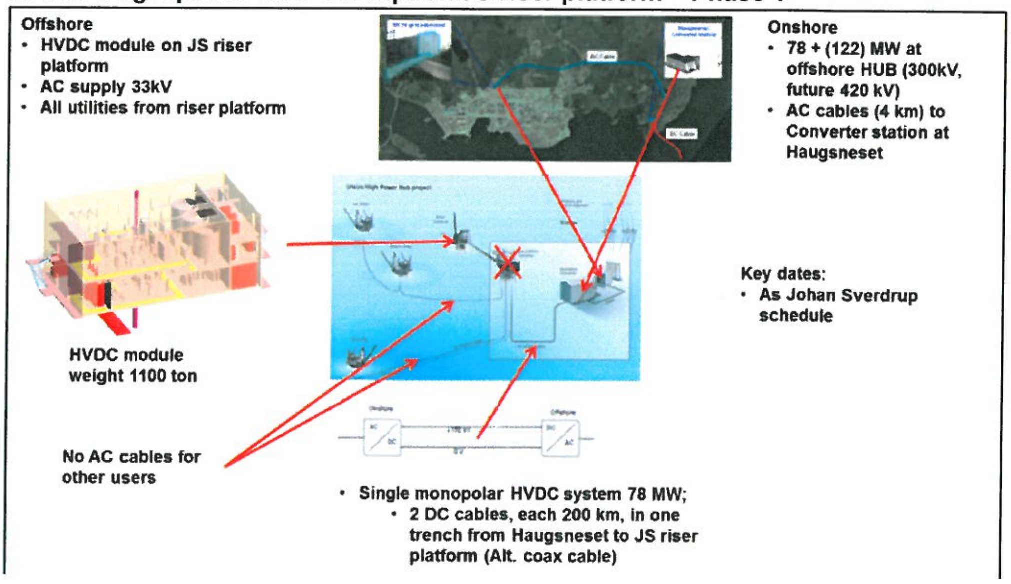
The calculations used data from process simulations to identify the electrical load of major process consumers. In addition, the electrical load lists from the concept study was used for minor consumers. Contingency, mechanical and electrical losses were also included in the calculations. The conclusion was that the 78 MW module would provide sufficient power for the first five years of phase 1.

Aker has been asked to verify the power requirements as part of the ongoing FEED. Preliminary indications are that the power requirements for phase 1 will increase slightly to accommodate safety margins. However, the overall footprint and design of the HVDC module is expected to be the same.

3.2.1.2 Technical solution

The power module for phase 1 will be located on the Riser Platform (RP) in the area used for the back-up turbine in the UHPH solution. However more work needs to be done to determine the best location on RP. The HVDC cables will be connected directly to Riser Platform Topside.

78 MW single power train concept on JS riser platform – Phase 1



The scope includes a complete HVDC transmission system to an offshore hub platform and HVAC distribution of electricity to the user field platforms, as follows:

- 78 MW power available at offshore hub (power outtake at Kårstø appr. 85 MW)
- New onshore installations:
  - A converter station for single power train prepared for future extension for another power train
  - Extension of grid station inside Kårstø plant
  - Two sets of AC cables and all other equipment required to connect to the onshore 300 kV (future 420 kV) grid , i.e. prepared for future phase
- Two 200 km subsea power HVDC cables (+/-) shall be installed and buried at the sea bottom for protection against fishing gears connected to Riser Platform Topside.
- An offshore module for the HVDC equipment, and all other services from topside itself.
- 33 kV distribution from HVDC system

The existing power solution for the Valhall field has been used to confirm the technical feasibility of this solution. In addition ABB has performed a study validating feasibility of the Johan Sverdrup solution (see reference list).

UHPH has been in dialogue with Statnett, and they recommend Kårstø to be the connection point to the grid in the area. The Kårstø/Karmøy area has a strong grid at 300 kV level with good redundancy (3 lines). Statnett has confirmed a sufficient grid capacity for the Utsira High electrification project (max. 300 MW), given the present situation at Hydro Karmøy. This includes an increased potential power demand caused by a possible pilot smelter project at Hydro Karmøy.

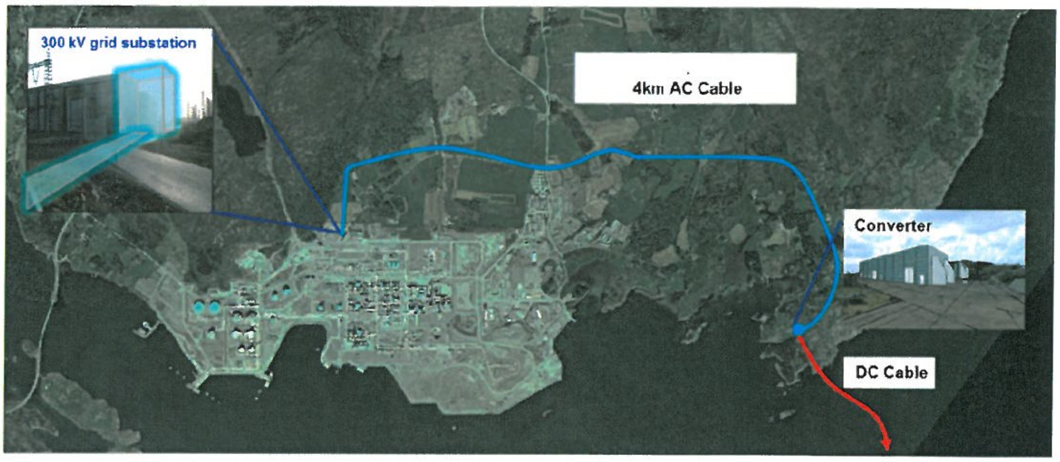
Utsira High Power Hub has requested Gassco for project services and later possible operational services, and Gassco has replied with a positive answer with regard to tie-in to the grid at Kårstø main intake station.

Johan Sverdrup will have to continue the dialogue with NVE, Statnett and Gassco, when the power concept is concluded.

The 78 MW single power train case is based on the following parameters:

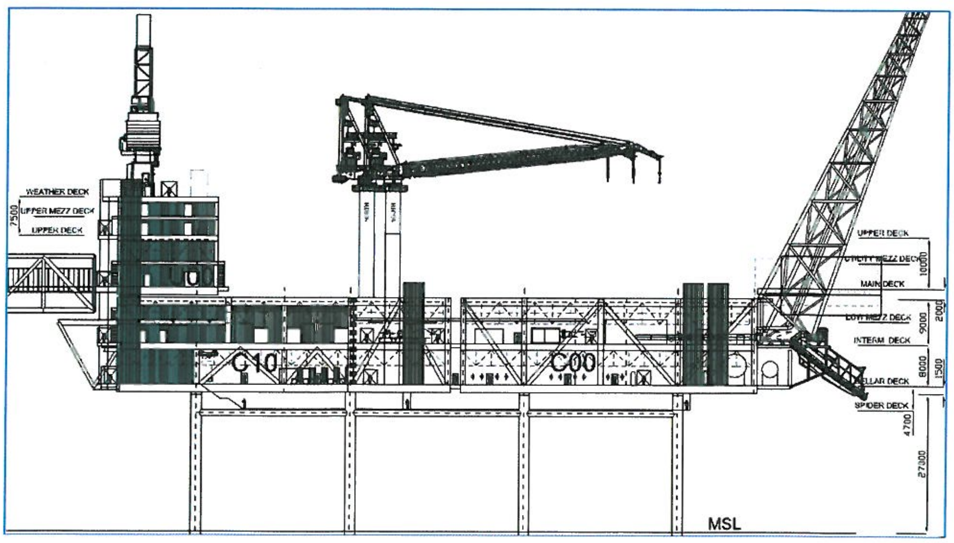
- Design Life: 50 years operations
- Offshore converter installed on Johan Sverdrup riser platform

Onshore facility and tie-in to onshore grid Kårstø (Gassco) and Haugsneset 78 MW single power train



3.2.1.3 Integration on RP

A HVDC module will be located on the west side of the weather deck on the Riser Platform.



A technical assessment study has been performed by Aker based on the Valhall HVDC module. (see reference list). Summary from this report is included below:

"An alternative philosophy with direct supply of power to the Johan Sverdrup Riser Platform (RP) has been coarsely assessed. The power supply system to RP is to be designed for the John Sverdrup phase 1 development only and Company has specified a capacity of 78 MW.

With the alternative power philosophy an additional HVDC module is required at RP. Company has specified that the Valhall HVDC module shall be used as a reference and has supplied some information about the module for use in this assessment. Some information from the UHPH project and a fast track study for the Johan Sverdrup RP HVDC module performed by ABB has also been provided.

[redacted]

The WO preference is that the HVDC module is to be located on top of the small utility module U00 that is supported on one of two Main Support Frame modules on RP. Locating the HVDC module adjacent to the existing U00 has been considered as an alternative. In both options it is assumed that U00 and the HVDC module will be integrated. A comparison of the preliminary base case and the alternative layout is provided in

Figure 3-1. In the alternative layout some of the space reserved for future modules is utilized to accommodate the HVDC module. In both cases some extension of at least one of the pedestal cranes will be required.

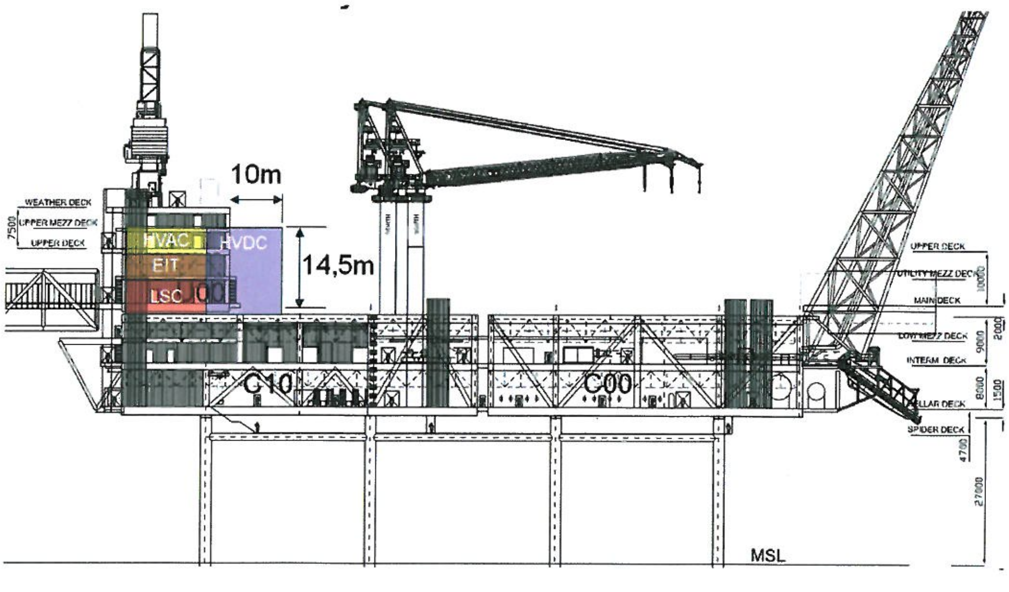


Figure 3-1: Comparison between the base case HVDC layout and the alternative layout (alternative layout is shown in colours).

Installation of both options for the combined U00/HVDC module is concluded as feasible with ample margin.

The layout needs to be further matured and optimized. This should be done in close co-operation with the HVDC equipment supplier. The location of the gas turbine generator, especially in the base case, may be inappropriate and needs to be studied in more detail. Ensuring a design that is acceptable with regards to working environment is another issue. EMF studies should be performed.

Further there are some technology differences between the Valhall system compared to the system proposed for Johan Sverdrup by ABB. These should be evaluated in more detail both with regards to electrical design as well as layout implications. It must also be ensured that the installed capacity is sufficient for phase 1 including that there is sufficient margin to account for uncertainties.

The capacity of different utility & support systems at RP has been evaluated and no step changes have been identified. However, some implications at the other field centre platforms have been identified such as need for electrical VSD equipment for 1st & 2nd stage compressors at P1 and need for an additional firewater pump diesel generator at LQ. There will possibly be need for some additional control functions in the Central Control Room in LQ and changes to the telecom philosophy are concluded required. It should also be looked into if there with the alternative design is sufficient redundancy in the electrical supply to different consumers at the Field Centre, e.g. to drilling consumers.

The assessment has been performed within a very short time frame and the performed evaluations should be considered as a starting point for further work only. "

[redacted]

[redacted]

3.2.1.4 Schedule phase 1

[redacted]

3.2.2 Alternative power solutions for future phases

Three alternatives for future power supply to Johan Sverdrup are feasible and will be studied as part of Phase 2:

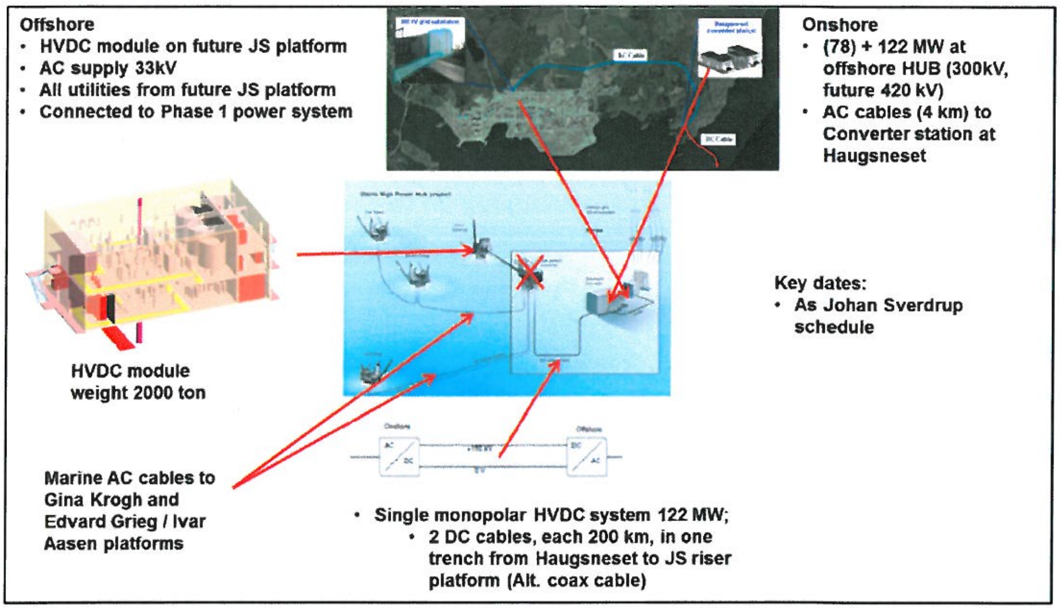
- Area solution – 200MW(78 + 122MW) from shore available offshore at Johan Sverdrup
- Johan Sverdrup solution – All power from shore covering JS power requirements
- Johan Sverdrup solution - 78 MW from shore combined with offshore power generation

Current assumption is to place equipment for phase 2 on future P2 platform.

3.2.2.1 Area solution – 200 MW from shore available offshore at Johan Sverdrup

In phase 2 of Johan Sverdrup the design for additional power generated offshore will be decided based on updated power profiles for Johan Sverdrup including other fields in the area.

78 MW will be available for Johan Sverdrup in phase 1. To be able to supply a total of 200 MW a phase 2 development of 122 MW has been assessed as illustrated below.



The scope includes an extension of existing HVDC transmission with additional 122 MW power at Johan Sverdrup future platform, as follows:

- 122 MW power available at offshore hub (power outtake at Kårstø appr. 135 MW)
- Extension of existing converter station onshore for a new single power train
- Two 200 km subsea power HVDC cables (+/-) shall be installed and buried at the sea bottom for protection against fishing gears connected to a future platform.
- An offshore module for the HVDC equipment, and all other services from topside itself at a future Johan Sverdrup P2-platform.
- 33 kV distribution from HVDC system to JS and 110 kV AC supply to other users through sea cables.
- Connection to installed 78 MW HVDC system to create redundancy.

The 122 MW single power train case is based on the following parameters:

- Design Life: 50 years operations
- Offshore converter installed at P2

3.2.2.2 Johan Sverdrup solution – All power from shore covering JS power requirements

In phase 2 of Johan Sverdrup the design for additional power from shore will be decided based on more firm power profiles for Johan Sverdrup.

3.2.2.3 Johan Sverdrup solution - 78 MW from shore combined with offshore power generation

In phase 2 of Johan Sverdrup the design for additional power generated offshore from Gas Turbines with waste heat recovery will be decided based on updated power profiles for Johan Sverdrup.

4 Availability of power solutions and consequence for Johan Sverdrup Production Efficiency

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

5 Economy

Capex

The tale below shows the capex for the UHPH 200 MW single train concept and the Johan Sverdrup (78 + 122MW) solution.

Mill. NOK-13

Power from shore	200 MW case	JS 78 MW	JS 122 MW	JS 78+122 MW
Onshore	[redacted]	[redacted]	[redacted]	[redacted]
Topside / module	[redacted]	[redacted]	[redacted]	[redacted]
Bridge to Johan Sverdrup	[redacted]	[redacted]	[redacted]	[redacted]
Flotel	[redacted]	[redacted]	[redacted]	[redacted]
Ground Fee Johan Sverdrup future	[redacted]	[redacted]	[redacted]	[redacted]
Jacket	[redacted]	[redacted]	[redacted]	[redacted]
JS back-up gas turbine*	[redacted]	[redacted]	[redacted]	[redacted]
DC cables	[redacted]	[redacted]	[redacted]	[redacted]
AC cables	[redacted]	[redacted]	[redacted]	[redacted]
Total excl market	[redacted]	[redacted]	[redacted]	[redacted]
Market adjustment	[redacted]	[redacted]	[redacted]	[redacted]
TOTAL Excpected Cost	13260	5520	8083	13603

[redacted]

The pre-DG3 cost is estimated to ~ 300 MNOK13 for both cases and is not included in the table above.

The UHPH 200 MW solution assumes that a back-up turbine is being installed on the JS riser platform. [redacted]

Opex

Operating expenses for the UHPH 200 MW solution are estimated to be 78 MNOK13 per year in normal operation.

Operating expenses for the Johan Sverdrup (78 + 122 MW) solution are estimated to be 50 MNOK13 per year in normal operation.

[redacted]

The table below shows the abatement cost for the UHPH 200 MW single train concept and the Johan Sverdrup (78 + 122MW) solution.

Case	Input	Abatement 5% NOK'14/ton	Abatement 8% NOK'14/ton	[redacted]	CO2 saved Mill ton
UHPH 200 MW (single train)	License	1701	2343		16,4
JS (78 + 122 MW)	License	1657	2249		15,6
UHPH 200 MW (single train)	Statoil assessm.	975	1333		24,4
JS (78 + 122 MW)	Statoil assessm.	959	1265		23,6

The table below shows the abatement cost for the Johan Sverdrup (78 + 122 MW) solution for phase 1 and phase 2.

Case	Input	Abatement 5% NOK'14/ton	Abatement 8% NOK'14/ton	[redacted]	CO2 saved Mill ton
Johan Sverdrup phase 1	License	1111	1659		11,6
Johan Sverdrup phase 2	License	2441	3041		4
Johan Sverdrup phase 1	Statoil assessm.	952	1425		13,9
Johan Sverdrup phase 2	Statoil assessm.	1178	1416		9,4

- All numbers are 100% project with partner price set from UHPH project
- Saved turbines: UHPH optimized = 5 GTs and JS Phased = 6 GTs (EG 1, GK 1, JS 3/4)
- Discount year 2014, real year 2014
- Abatement cost is before tax, NPV is after tax

[redacted]

Abatement cost is the cost of removing CO2 by using power from shore instead of offshore gas turbines. It is calculated as the delta cost of electrification compared to gas turbines divided by the CO2 volume saved.

$$\frac{\text{Net Present Value before tax (cost of electrification – cost of offshore gas turbines)}}{\text{Present Value (CO2 volumes saved by not using offshore gas turbines)}}$$

If the abatement unit cost is lower than the CO2 tax, it will be profitable to invest in the abatement project. CO2 tax is assumed to be 500 NOK/ton.

6 Commercial agreements

UHPH 200 MW case

The UHPH case assumes that a Joint Venture is formed to own and operate the UHPH power distribution system. The UHPH would then have tie-in agreements with the user fields. The commercial process has been ongoing through 2013 in the Round table set-up as agreed between the companies holding owner shares in Johan Sverdrup, Edvard Grieg, Ivar Aasen and Gina Krog. The authorities have been following the process closely and main principles for the ownership models have been established. The following agreements need to be in place before DG3 for the UHPH.

- UHPH Participating Agreement (JV) before DG3
- UHPH/Fields Tie-in and User Agreement) before DG3
- UHPH/Johan Sverdrup tie-in (bridge connection concept)) before DG3
- Grid Connection Agreement) before DG3
- Gassled Tie-in Agreement) before DG3
- TSP Operations and Maintenance Agreements) before DG3
- Land lease finalize transactions and if necessary initiate expropriation after DG3
- Crossing Agreements after DG3.

The user fields will have to negotiate power supply agreements.

Johan Sverdrup (78 + 122 MW) phased solution.

The following agreements need to be negotiated and finalized towards DG3 for phase 1.

- Johan Sverdrup Power Supply Agreement before DG3
- Grid Connection Agreement with Statnett before DG3
- Gassled Tie-in Agreement before DG3
- TSP Operations and Maintenance Agreements (onshore) before DG3
- Land lease agreements finalize transactions and if necessary initiate expropriation after DG3
- Crossing Agreements after DG3.

An area solution for phase 2 will also introduce need for tie-in agreements between Johan Sverdrup and the other fields before a phase 2 DG3.

7 Qualitative assessment

[redacted]

[redacted]

8 Recommendation

Based on above the JSPU WO recommends a dedicated power from shore solution for Johan Sverdrup phase 1 (i.e. 78 MW Vallhall solution) as basis for the Johan Sverdrup DG2 decision in February 2014.

- The JSPU WO will instruct the FEED contractor to implement this change
- The JSPU WO will extend the Johan Sverdrup project organization to include the HVDC system, the power cable and the onshore scope.

JSPU recommends to issue a letter to UHPH informing the project about Johan Sverdrup project decision.

[redacted]

9 References

[redacted]