Power solutions for Johan Sverdrup field in phase 1 and for full field

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Author(s)/Source(s): **Trond Sagstad**	
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Techn. responsible (Organisation unit / Name): **Øyvind Håstø**	Date/Signature: X
Responsible (Organisation unit/ Name): **Trond Sagstad**	Date/Signature: X
Recommended (Organisation unit/ Name): **Sigreid Borthen Toven**	Date/Signature: X
Approved by (Organisation unit/ Name): **Øivind Reinertsen**	Date/Signature: X

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1 Introduction

Johan Sverdrup development is planned as a phased development project, with production start of Phase 1 planned late 2019.

- The field will be developed with a field center (Ekofisk analog)
- Power supply from shore
- Initial production as high as possible with production start in late 2019.
- Offshore stabilization of oil
- Oil export through a dedicated pipeline to Mongstad
- Gas export to Kårstø

The Johan Sverdrup production facilities will use significant amount of energy in the form of mechanical power and heat. Rotating power is primarily needed for pumps and compressors while the main consumer of heat is the oil stabilization process.

The objective is to select a rotating/heat power generation alternative which covers the following criteria:

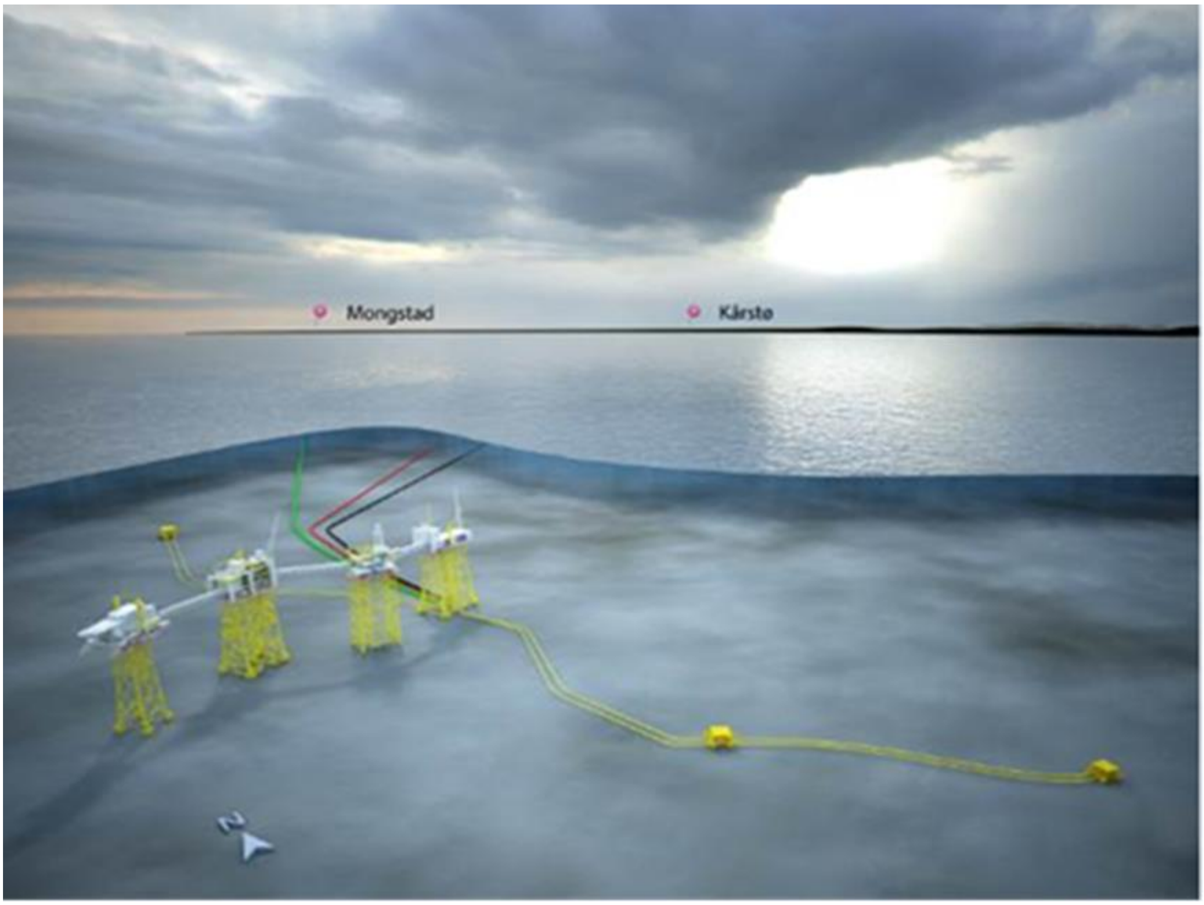
- Minimize CO_2 and NO_x
- Technical and operational robust
- Flexible with sufficient redundancy
- Economic viable

Different alternatives have been evaluated based on profiles and power from shore.
This report describes the solutions adopted for supplying power from onshore Kårstø/Haugsneset to Johan Sverdrup offshore field center and the background of the chosen solution. Furthermore, it describes how the future solutions with further expansion and connection of other installations in the area could be implemented. The report is a supplement to the impact assessment for Johan Sverdrup field development.

2 Summary

The Johan Sverdrup field will be supplied by electric power form shore. The concept includes expansion of the existing 300 kV substation at Kårstø, AC cables from the plant to Haugsneset, converter station at Haugsneset, 200 km direct current subsea cables and a power module located on the riser platform (RP) Johan Sverdrup for phase 1. The power module on the RP is converting and transforming power to meet the needs of the Johan Sverdrup platforms.

The power solution will be a phased development in 2 steps. Step 1 will cover power needs for Johan Sverdrup phase one with a capacity according to demand. Step 2 will cover future development phases of Johan Sverdrup field and the power need at Gina Krog, Edvard Grieg and Ivar Aasen, giving a preliminary total power need estimated to be in a range of 200 – 250 MW. Due to loss of power this mean an out take of approx. 280 MW of the total 300 MW capacity from shore that is confirmed by Statnett.



3 Background

In line with the recommendation nr.114 (1995-1996) from the Energy and Environment Committee, Norwegian policy towards climate change and emissions of nitrogen oxides (NOx), the parliament adopted on 22 February 1996 the following; "With each new field developments it will be presented an overview of energy supply and the cost of electrifying device rather than using gas turbines."
The Utsira area has been assessed to be well suited for a PFS solution due to the distance from shore (approx. 200 km), power need for four fields and waters depths (100 – 120 meters).

3.1 Utsira High Power Project

The operators for Edvard Grieg, Ivar Aasen and Gina Krog started in 2010 a study of a common power from shore solution for the fields. The study then concluded that Power-From-Shore (PFS) to Utsira High was technically realizable using high voltage direct current transmission (HVDC technology), but the solution was costly and therefor turned down. An AC transmission solution was considered technical infeasible due to high transmission loss.

When Johan Sverdrup (Aldous/Avaldsnes) was discovered in 2010/2011 the PFS study was revitalized on MPE's initiative. Statoil accepted to be the project leader for the study and a study agreement was entered into in 2012 between the partners in the Edvard Grieg, Ivar Aasen, Gina Krog and Johan Sverdrup field groups. The mandate was to establish a common framework and technical solution as basis for a PFS concept selection and investment decision.

The Utsira area was assessed to be well suited for a PFS solution due to distance from shore (approx. 200 km), power need for four fields and waters depths (100 – 120 meters). The UHPH project included technical studies, concept assessment and development of commercial agreements for a PFS solution.

Johan Sverdrup has a planned start-up late 2019 and Gina Krog, Edvard Grieg and Ivar Aasen have prepared the installations of PFS when a PFS solution is available. The Gina Krog field is planned to start up in 2017 and has pre-invested in equipment to prepare for PFS and only one gas turbine is being installed. The gas turbine will serve as back-up after PFS is implemented.

Equally, the Edvard Grieg field starts up in 2015 and has pre-invested in equipment for receive PFS. Edvard Grieg has two gas turbines installed. Ivar Aasen planned start up is in 2016 and covers the power demand through a dedicated AC cable from the Edvard Grieg platform.

Several concepts have been assessed and after the screening phase the following concept were brought forward:

1. An independent stand-alone distribution (HUB) platform with up to 300 MW
2. Phased development
    a) As 1, but with approx. 50% capacity from start-up and increase to full capacity at Johan Sverdrup start-up
    b) As 2a, except that a converter module is installed on the Johan Sverdrup-platform with connection to the HUB platform

3. An unmanned HUB platform with bridge connection to Johan Sverdrup with capacity up to 300 MW.
    a) HUB topside- solution with LQ, helideck and lifeboats
    b) HUB-topside solution with common use of support systems on Johan Sverdrup
4. A minimum solution with capacity of 150 MW and offshore turbines to cover for excess

Alternative 2 and 4 were screened out in dialog with partners and authorities. The distribution platform with bridge connection to Johan Sverdrup living quarter was a solution with a converter onshore, DC cables from shore to a distribution platform with converter and AC cables for further distribution of power to Johan Sverdrup, Gina Krog and Edvard Grieg/Ivar Aasen.

Kårstø is recommended by Statnett as the tie-in point to the onshore power grid. Statoil applied in March 2012 to Statnett (as main grid operator) for grid connection to Kårstø. Statnett has in letters and meetings confirmed that Statnett will enter into a grid connection agreement with Statoil (as concessionaire on behalf of Johan Sverdrup) as soon as NVE has granted necessary mandatory licenses for the electrical assets as provided for in the Energy Act. Statnett has also confirmed that the main grid transmission capacity is sufficient up to 300 MW.

Statnett is the owner of the 300 kV transmission lines connecting to the Kårstø substation and Gassled is the owner of the existing 300 kV substation itself at Kårstø. In addition to the grid connection agreement with Statnett, it is also required to enter into a tie-in agreement with Gassled to accommodate the extension of the Kårstø substation.

The investment in a PFS solution to the Utsira area proved to be costly. Investment cost for a double train power solution with a hub platform connected to the Johan Sverdrup living quarter and a capacity of 300 MW from the onshore grid, was estimated to 16,2 Billion NOK $_{2013}$. (+/- 30%), giving an abatement cost of approx. NOK 2200 / 3000 per tones CO_2. (5% / 8% discount rate, 2014-kroner).

Update of power demand late 2013 from the four fields indicated a lower power requirement than previously reported. 200 MW from Kårstø was assessed by the partners in the license groups to be sufficient in combination with offshore power generation as back-up. Estimated cost with a single train power system showed a reduction in cost to 12,5 Billion NOK 2013. (+/- 30%). Abatement cost was reduced to approx. NOK 1700 / 2300 per tones CO_2. (5% / 8% discount rate, 2014-kroner).

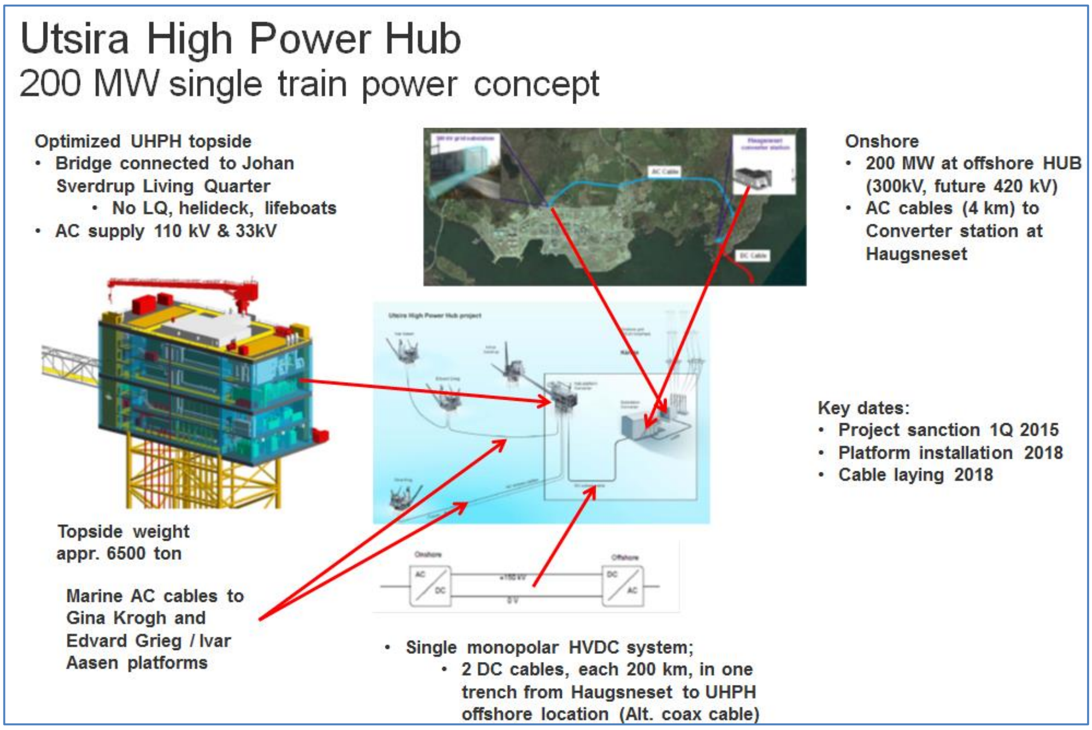


Figure .1 below shows the development in investment cost for a PFS solution From Kårstø to a bridge connected hub platform at Johan Sverdrup field center.

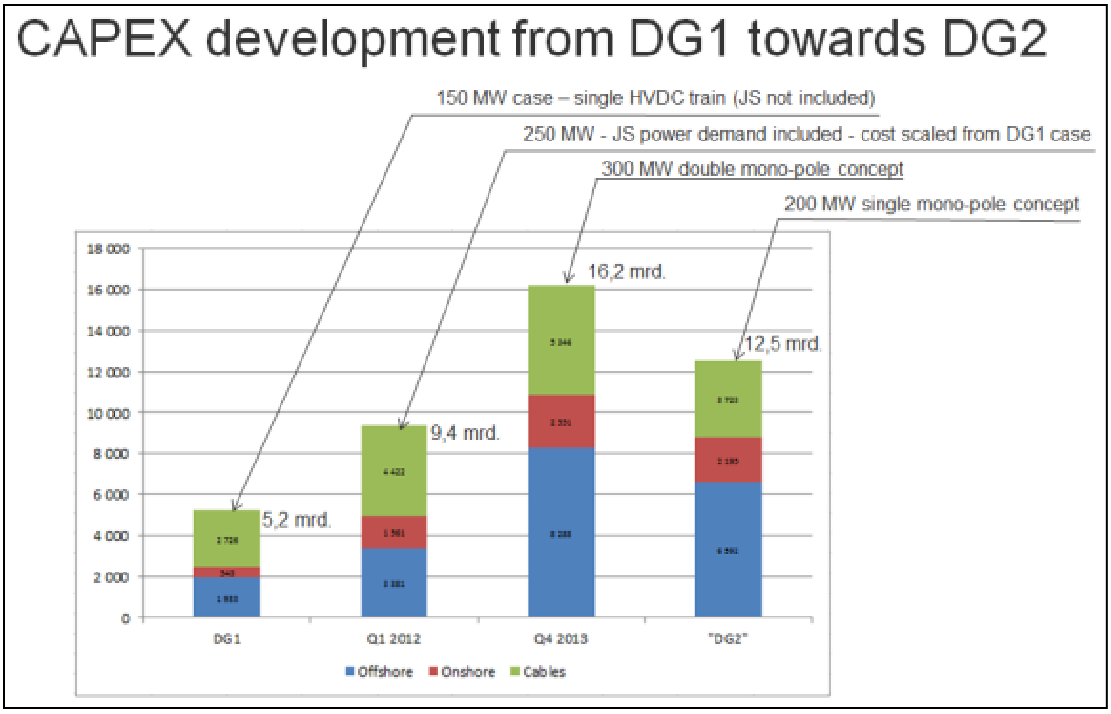


Figure 3.1.2 Development of investment cost for an Utsira High Power Hub system.

When the UHPH project got feedback from suppliers in late 2013, reports showed that the studied solutions were more expensive than previously thought. It had been a considerably increase in market due to increased activity levels, both within the petroleum sector and wind energy segment. It is referred to specific examples from other projects in execution. As a result of the high total CAPEX, the project was forced to postpone the planned concept and start studying a more cost-effective solution.

However, due to the situation, it proved late in 2013 to be very difficult to agree on a concept and a DG2 decision in the UHPH project in line with the Johan Sverdrup DG2. Due to the uncertain situation, an alternative power solution dedicated to cover Johan Sverdrup in fase 1 and with a PFS to the area solution intergated in Johan Sverdrup phase 2 was establised as the basis for the Johan Sverdrup DG2 decision. The UHPH project was therefore terminated and the power from shore assessment was included in the Johan Sverdrup project.

4 Johan Sverdrup power solution

Johan Sverdrup decided early in 2013(?) that power from shore from the Utsira High Power Hub was the basis for all concepts being assessed towards DG2.

Power and heat solutions assessed according to standard process by Johan Sverdrup:

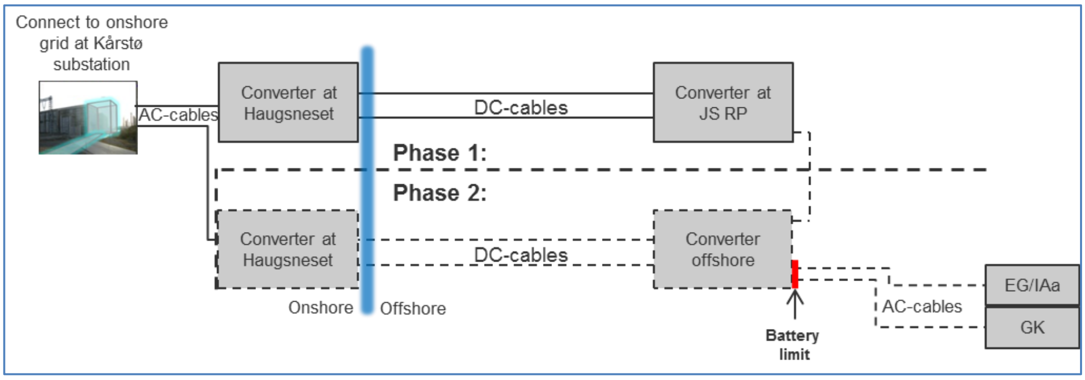
1. Power and heat requirements covered by PFS
2. Power and heat requirements covered by offshore gas turbines
3. Power requirement covered by PFS and process heat requirement covered by gas fired heaters.
4. Partial gas turbines (GT) combined heat & power generation + electrical heaters

It was concluded that solution 3 was the preferred one. The assessment was soon followed by a decision regarding design basis concluding power from shore as the power solution
Emphasis was put on the fact that the Parliament had expressed a goal to replace gas turbines offshore with PFS combined with acceptable project economy at the time of the decision. Furthermore the assessment was that solution 3 is energy efficient and has the lowest CO_2-emission globally compared to 2 when taking into account that more sustainable power will be exported to replace fossil fueled power generation. The heat demand will be generated from a 3 x 10, 5 MW gas fired solution. It will be installed a low NO_x essential power generator on the riser platform, this will be a dual fuel turbine, in phase 1 it will be installed with diesel fuel only. In addition it will also be installed 3 x 2,8MW of diesel engine driven emergency generators on the field.

The power solution for Johan Sverdrup and the other fields in the Utsira area is being developed in two phases. At DG2 the power capacity in phase 1 was 78 MW and for phase 2 a parallel power system of 122 MW was anticipated to be necessary cover a total estimated power demand of 200 MW.

Phase 1 includes the expansion of existing 300 kV substation at Kårstø, AC cables from the plant to Haugsneset, AC / DC converter station at Haugsneset, direct current submarine cables and a power module located on the riser platform (RP) Johan Sverdrup. The power module is converting and transforming direct current (DC) to 33 kV, 60 Hz alternating current (AC) to meet the needs of the Johan Sverdrup installations in phase 1. As part of the phase 1, pre-investments will be made in the Kårstø substation, AC-cable to

Haugsneset, civil and land preparation, land fall preparation at Haugsneset to accommodate for the next phase.



Power for Johan Sverdrup future phases and the fields in the Utsira areas is scheduled to be in place in 2022 as part of the Johan Sverdrup phase 2. All ongoing evaluation for the future phases of the Johan Sverdrup is based on the power requirements for these stages being covered through expansion of land-based power solution chosen for Phase 1. All concepts facilitates that Edvard Grieg / Ivar Aasen and Gina Krog can tie-in to a Johan Sverdrup installation with AC-cables.

At DG2 the estimated cost for the Johan Sverdrup phased power from shore solution (78 MW in phase 1 and 122 MW in phase 2) was 13,5 Billion NOK 2013. Abatement cost was calculated to approx. NOK 1700 / 2300 per tones CO_2. (5% / 8% discount rate, 2014-kroner).

4.1 Johan Sverdrup Phase 1 power solution

Power from shore will connect to Kårstø Grid 300KV National electric net as recommended by Statnett. This connection will be performed without any disconnection of National Grid. Maximum power take out/consumption from Statnett will be 300MW.

4.1.1 *Concept for power solution to Johan Sverdrup phase 1*

New load calculations from Johan Sverdrup FEED indicate that the offshore phase 1 is dependent on the capacity of 100MW to capture the potential upside in the production profiles and to cover technical uncertainties related to produced water rates and associated gas lift requirements.

. Inside the Kårstø Grid, the PFS project will do all modification needed in phase1 to also include next phases This includes the building extension, the 300KV switchgear for both phase 1 and 2, and the AC cables from Kårstø to Haugsneset, where the HVDC system will be located. The dimension of the AC cables will be two 3x630 mm^2.

The HVDC converter station at Haugsneset for phase 1 will be built to deliver 100MW offshore at the JS Riser platform.

The 300KV cable will be connected to the system with a 300KV GIS (Gas Insulated Switchgear), in order to ensure technical security towards Kårstø and to maintain the interlock system.

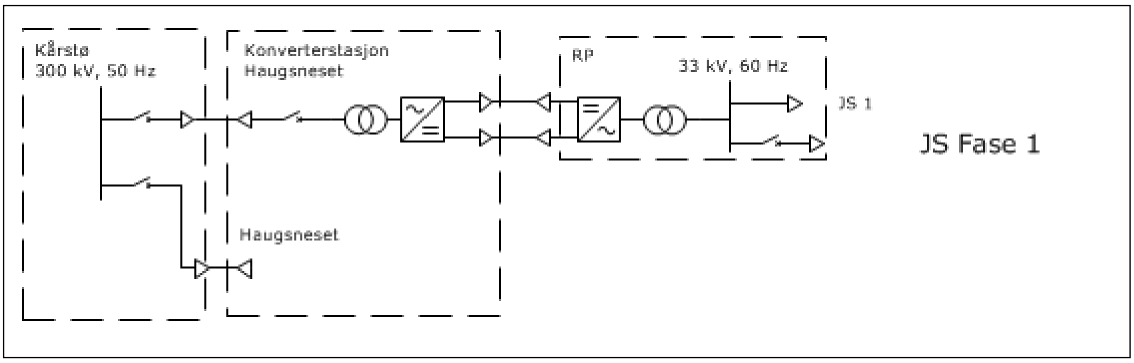
Main transformer, 300/105, 5/22KV and capacity of 120/4MVA, will have natural cooling and no need for any additional cooling system.

HVDC system with VSC technology (HVDC Light), is a well-known technology which has been used since 1957. ABB have a total of approx. 3000 systems delivered all over the world.

The converter station at Haugsneset will require cooling. This could be achieved either by use of sea water, or by use of air vents. Studies have confirmed that both solutions will comply with existing authority requirements regarding noise received at third parties.

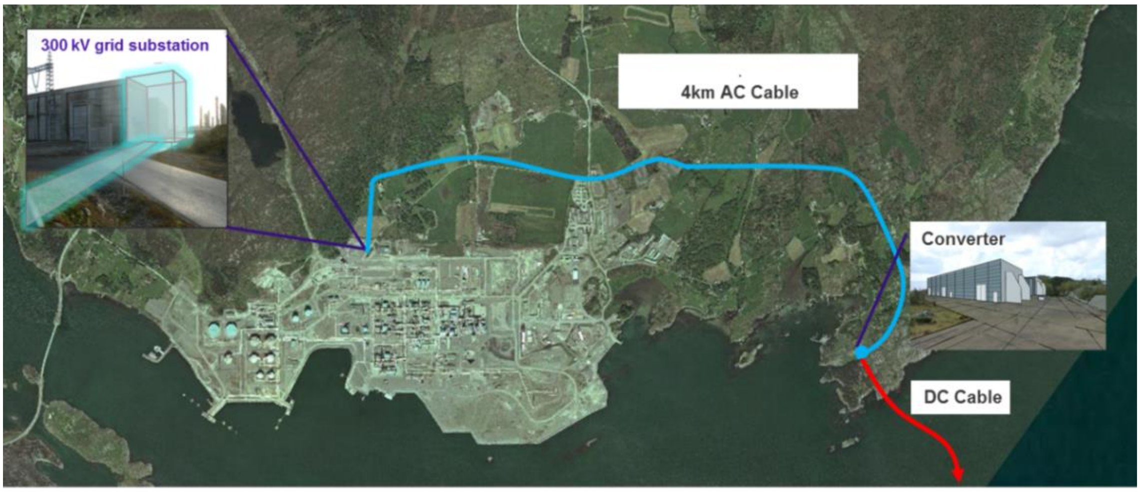
The power DC cables out to JS Riser platform will be 2 x 800mm2 subsea cables. (Final dimension is still to be decided). The routing has been through a detailed survey and both cables will be placed in the same trench and protected against fishing gear and connected to riser platform topside. The power transfer will be done with +80/-80KV.

A similar HVDC system to that installed at Haugsneset will be placed on the riser platform. At this station the DC power will be converted to AC and transformed down to 33KV for distribution to Johan Sverdrup installations.



4.1.2 Onshore facilities

Onshore facility and tie-in to onshore grid Kårstø (Gassco) and Haugsneset 100 MW single power train



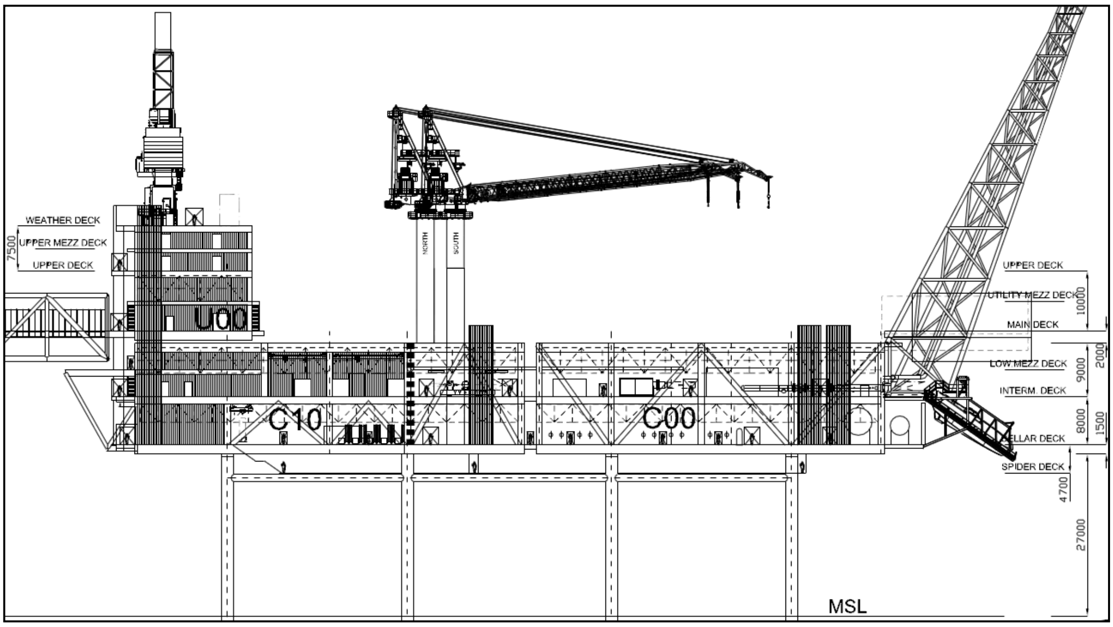
The Kårstø/Karmøy area has a strong grid at 300 kV level with good redundancy (3 lines). Statnett has confirmed a sufficient grid capacity for the Utsira High electrification project of up to 300 MW given the present situation at Hydro Karmøy. This includes an increased potential power demand caused by a possible pilot smelter project at Hydro Karmøy. The company 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.

4.1.3 Power module offshore

100MW is the design capacity for the first 3-5 years of phase 1 production. The power module for phase 1 will be located on the Riser Platform (RP). The design lifetime will be 50 years.

The existing power solution for the Valhall (78 MW) was used to confirm the technical feasibility of this solution. In addition ABB has performed a study validating feasibility of the Johan Sverdrup solution up to 100 MW within existing design.

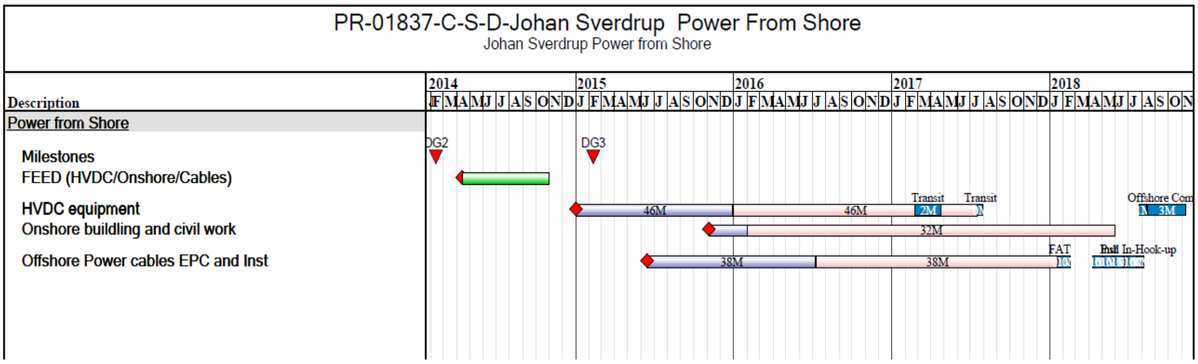
A HVDC module will be integrated in module U00 located on the west side of the weather deck on the Riser Platform.



A technical assessment study has been performed by Aker based on the Valhall HVDC module. Installation of the module is concluded as feasible with ample margin.

4.1.4 Schedule phase 1

The master schedule for the power from shore solution to Johan Sverdrup is shown below. When finally decided the schedule will be implemented in the overall Johan Sverdrup schedule.



4.1.5 Power unavailability and production efficiency loss – Phase 1

Power outages of the 1x100% power supply from shore leads to full production shutdown on Johan Sverdrup phase 1. Due to ramp-up times offshore the unavailability of oil production on Johan Sverdrup caused by outages will be higher than the system unavailability of power from shore.

An analysis of how much Johan Sverdrup Production Efficiency (PE) is affected by unplanned outages of PFS is summarized in Table 4-1 below. The main assumptions behind the analysis are given in Table 4-2

Table 4-1 Power unavailability and PE loss for phase 1 production

Segment	Frequency (per yr.)	Average event downtime (hrs.)	Average JS production downtime (hrs.)	Power unavailability	JS PE loss
Land grid	0.27	0.13	12.13	0.00 %	0.04 %
Cable failures	0.008	2190.00	2202.00	0.20 %	0.20 %
ABB systems	2.33	27.00	39.00	0.72 %	1.04 %
Total	2.608	30.85	42.85	0.92 %	1.28 %

Table 4-2 Assumption list

Segment	Assumptions	Comments
Land-grid	Average of 0.27 outages every year with an average duration of 8 minutes	Based on experience from Kårstø
	Assumed that ABB installations can handle all power dips in the land grid system	May be an optimistic assumption, but ABB will look into the issue with power dips. Troll A has experienced some trips due to power dips in the Mongstad grid.
Cable failures	0.008 failures per year (Mean Time To Failure of 118 years) and a mean downtime of 3 months	Based on DG 2 production availability analysis
ABB systems	2.3 events per year with average duration 27 hours	Based on Sept. 2014 updated ABB RAM report.
	Spare (redundancy) for the following main components: - Power transformers (onshore 1+1, offshore 3+1) - Converter reactors (Onshore 3+1, offshore 3+1) - Smoothing reactors (2+1 for converter/inverter, common spare)	- Power transformers are different onshore and offshore - Converter reactors on converter/inverter station are different - smoothing reactors are equal onshore and offshore
	Transformers Minor failures 24 hours mobilisation onshore and offshore Failure requiring replacement 336 hours mobilisation onshore 672 hours mobilisation offshore	
	Reactors Failures require replacement 24 hours mobilisation onshore 168 hours mobilisation offshore	
Johan Sverdrup ramp-up	24 hours ramp-up approached as 12 hours full shutdown	24 hour ramp-up time is assumed after complete shutdowns of Johan Sverdrup. In the calculations the ramp-up is approached with 12 hours additional full shutdown followed by full production

4.1.6 Capital expenditure (capex) and operational expenses (opex)– Phase 1

Capex

Total capex for phase 1 is estimated to 6,0 billion NOK 2013.

Johan Sverdrup 100 MW single power train concept

- **Kårstø:** New onshore installations include a converter station and all equipment required to connect to the onshore 300 kV grid. AC cables (4 km) from power connection at Kårstø Grid Station to Converter station Haugsneset. HVDC equipment in Converter Station.
- **Offshore:** HVDC equipment in module on JS Riser Platform (RP). AC supply 33kV. All utilities from riser platform
- **Cable:** Single monopolar HVDC system. 2 DC cables, each 200 km, installed and buried in one trench at the sea bottom for protection against fishing gears from Haugsneset to JS RP (Alt. coax cable)

DG2 cost estimate of 6048 MNOK is covering Phase 1 only.

Phase 2 elements covered in this estimate are as follows:

- Roads and Civil preparation for second building
- AC cables from/to Haugsneset
- Preparation of corridor for offshore cables
- Cable feeders
- HMI system

Opex

Total OPEX for Johan Sverdrup phase 1 will be around 50 million NOK per year included property tax. The property tax for phase 1 development is estimated to 11 million NOK per year.

Operating expenditure – Phase 1 Procurement of electric power is to be handled as a tariff and not part of this report. The below OPEX estimate covers operations onshore, power cable inspection, offshore operation and maintenance, logistics and property tax of onshore plants. Insurance is not included.

Johan Sverdrup approved DG2 with a land-based power concept that involves a phased solution. Phase 1, will consist of a land-based power solution that only provides the Johan Sverdrup field center.
The power solution for Phase 1 includes the expansion of existing 300 kV switching station at Kårstø, AC cables from the plant to Haugsneset, AC / DC converter station at Haugsneset, 200km direct current subsea cables and a power module located on the riser platform (RP) Johan Sverdrup. The power module on the RP is converting and transforming power to 33 kV, 60 Hz alternating current (AC) to meet the needs of the platforms in phase 1 of the Johan Sverdrup field center.

4.2 Johan Sverdrup Future phases power solution (screening level)

Future phases of Johan Sverdrup will be powered from shore. Power to future phases is scheduled to be in place in 2022. All ongoing evaluation for the future phases of the Johan Sverdrup, are based on the power requirements for these stages being covered through expansion of land-based power solution chosen for Phase 1. Production start for Johan Sverdrup phase 2 is 2022. All concepts will facilitate that Edvard Grieg, Ivar Aasen and Gina Krog can tie-in cables and connect in order to get their installations supplied with power from shore.

In phase 2 of Johan Sverdrup, the design for additional PFS will be decided based on updated power profiles for Johan Sverdrup, including other fields in the area. Due to a grid loss of 11 - 12% from shore to Johan Sverdrup, a total of approximately 270 MW is possible to be delivered offshore.

The total power need for future phases including other installations on Utsira High is estimated to up to 250 MW at present time. To be able to supply up to a total of ~250MW offshore, a phase 2 development of 150MW will be assessed.

The scope for phase 2 includes an extension of existing HVDC transmission of power at Johan Sverdrup future platform, as follows:

- 150 MW power available offshore(power take out (PTO) at Kårstø of approx. 170 MW)
- Extension of existing converter station onshore for a new single power train
- Two 200 km subsea power HVDC cables (+/-) will be installed covered and connected to a future installation at Johan Sverdrup.
- An offshore module for the HVDC equipment, and necessary support systems at a future Johan Sverdrup installation.
- 33 kV distribution from HVDC system to Johan Sverdrup installations and 110 kV AC supply to other fields with hang-off at a Johan Sverdrup installation.
- Connection to the already installed 100 MW HVDC system to create redundancy.

The 150MW single power train case is based on the following parameters:

- Design Life: 50 years operations
- Offshore converter installed at P2 or other installation at Johan Sverdrup

In addition the essential power turbine will be able to run on both gas and diesel.

4.2.1 Concept for alternative power solutions to Johan Sverdrup future phase

The final area solution for power cannot be established before configuration, location and capacity for future process expansion on Johan Sverdrup is selected. Development concepts under consideration differ significantly regarding future energy demand and distribution solutions. The impact assessment for Johan Sverdrup describes some scenarios for the development of future phases, but these phases will be subject to separate PDO treatment at a later date. Concept Selection for the future phases is planned in 2016.

In Decision on Continuation (BOV) for Johan Sverdrup Phase 1, it was presented a possible solution for the electrification of the whole Utsira High area which included a new power module placed on a future process platform (P2) at the field center. A power module on P2 is one of several options that can provide area electrification of the entire Utsira High. It may also be possible to locate the new HVDC module on the riser platform. The optimum location will depend on the development scenario chosen for Johan Sverdrup future phases, and the amount of space available on each platform.

Because of long submarine cables to Edvard Grieg / Ivar Aasen and Gina Krog, the voltage level on the basis of a new power module must be in the range of 90 to 110 kV to transmit power to these fields. This voltage level is not established as part of Phase 1 power module, which will make a power module in future phase different from the module in Phase1. A sketch of the BOV solution is shown in Figure 1.

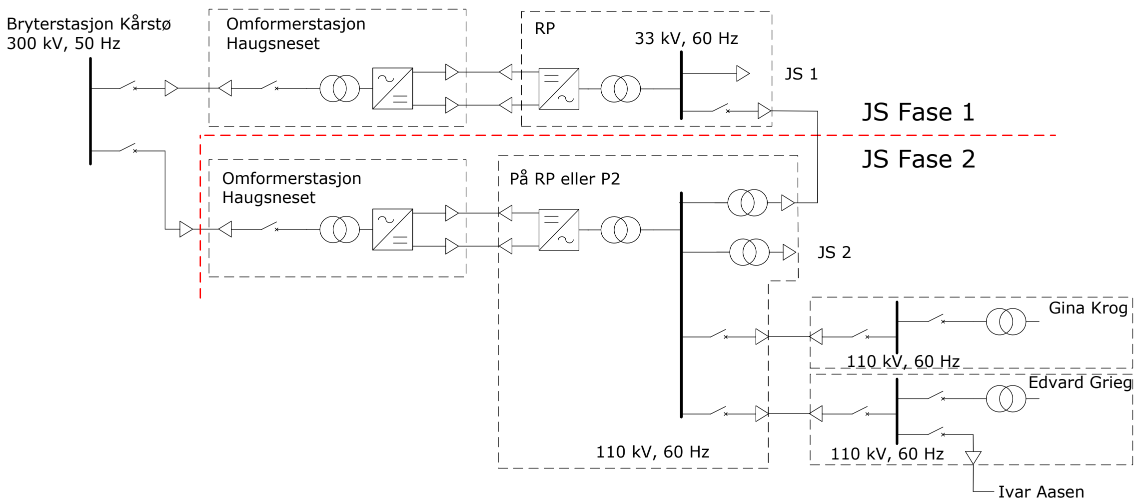


Figure 4-1 Phased Expansion of Johan Sverdrup Power Solution to Cover Utsira High Area

Parts of the plant that is being built onshore for delivering of power in phase 1, will be sized to supply the power needs of Johan Sverdrup future phase, Edvard Grieg, Ivar Aasen and Gina Krog as described earlier in this report. This includes the modification of the existing 300 kV substation at Kårstø, AC cables between Kårstø and Haugsneset, roads and site preparation on Haugsneset and necessary facilities for pulling in cables to the converter station. The converter station and DC subsea cables to the field will be designed for Phase 1, because the future power needs and technical solutions are unclear. Site surveys have been carried out for two alternative cable routes between Haugsneset and the Johan Sverdrup field. One of these routes will be used for the phase 1 cables, the other one for the future phase cables.

Power from shore to Johan Sverdrup future phase, Edvard Grieg, Ivar Aasen and Gina Krog will require agreement between the fields.

4.2.2 Power unavailability and production efficiency loss for alternative power solutions

The effect of power outage will be different for phase 1 and future phase productions. When an unplanned outage of one power supply train happens, future phase production will be load shredded. The essential generator on Johan Sverdrup will be utilized to restart the future phase production to limit the production losses.

Hence, only phase 1 production will be affected by power outage events caused by land grid outages. The production efficiency loss for phase 1 production will therefore decrease when future phase starts.

Based on this and other assumptions the production efficiency losses related to PFS will decrease from 1, 2% in phase 1 to 0,7% for the future phase production.

Table 4-3: Power unavailability and PE loss for phase 1 and future phase production

Segment	Frequency (per yr.)	Average event downtime (hrs.)	Average JS production downtime (hrs.)	Both power trains unavailable	One power train unavailable	JS Phase 1 PE loss	JS Phase 2 PE loss
Land grid	0.27	0.13	12.13	0.00 %		0.04 %	0.04 %
Cable failures	0.016	2190.00	12.00		0.40 %		0.00 %
ABB systems	4.66	27.00	12.00		1.44 %		0.64 %
Total	4.946	32.53	12.01	0.00 %	1.84 %	0.04 %	0.68 %

Table 4-4: Assumptions

Segment	Assumptions	Comments
Land-grid	Average of 0.27 outages every year with an average duration of 8 minutes	Based on experience from Kårstø
	Assumed that ABB installations can handle all power dips in the land grid	May be an optimistic assumption, but ABB will look into the issue with power dips. Troll A has experienced some trips due to power dips in the Mongstad grid.
Cable failures	0.008 failures per year per cable (Mean Time To Failure of 118 years) and a mean downtime of 3 months	Based on DG 2 production availability analysis
ABB systems	2.3 events per year per train with average duration 27 hours	Based on Sept. 2014 updated ABB RAM report.
	Spare (redundancy) for the following main components: - Power transformers (onshore 1+1, offshore 3+1) - Converter reactors (Onshore 3+1, offshore 3+1) - Smoothing reactors (2+1 for converter/inverter, common spare)	- Power transformers are different offshore and offshore - Converter reactors on Converter/inverter station are different - smoothing reactors are equal onshore and offshore
	<u>Transformers</u> Minor failures 24 hours mobilisation onshore and offshore Failure requiring replacement 336 hours mobilisation onshore 672 hours mobilisation offshore	
	<u>Reactors</u> Failures require replacement 24 hours mobilisation onshore 168 hours mobilisation offshore	
Johan Sverdrup ramp-up	24 hours ramp-up approached as 12 hours full shutdown	24 hour ramp-up time is assumed after complete shutdowns of Johan Sverdrup. In the calculations the ramp-up is approached with 12 hours additional full shutdown followed by full production
Phase 1 priority	If one of the power supply trains is out of operation a load shedding system will enter into force. Future phase production will be restarted by utilizing the essential generator to limit the production losses.	
Phase 2 systems	It is assumed that the Future phase systems will be similar to the phase 1 power systems. And that the phase 1 estimates provided in the ABB RAM-report is valid for future phase as well.	

4.2.3 Capital expenditure (capex) and operational expenditure (opex) for future phases power solution

Capex

The total cost of expanding the Phase 1 power from shore with a further 100 to 150 MW, is estimated to be between 6 to 8 Billion NOK 2013, including the cost of onshore modifications at Haugsneset, DC cables to the field, a converter module at a Johan Sverdrup installation and necessary preparation for transmission of power to hang-off of at Johan Sverdrup installation, but excluding the cost of tie-in of AC- cables from the Utsira High fields.

Opex

The below OPEX estimate covers operations onshore, power line inspection, offshore operation and maintenance, logistics and property tax of onshore plants. Insurance is not included.

Procurement of power is not included in the operating cost estimates.

Total OPEX for Johan Sverdrup Future will be around 35 million NOK per year included property tax. The property tax is estimated to 10 million NOK per year.

5 Future need for heat generated by gas/electrical power

For the electric heater there are benefits with respect to zero emissions and that weight and space requirements could be smaller compared to a gas fired system. Regarding cost, both CAPEX and OPEX are higher compared to the gas fired alternative and hence in disfavor for this concept.

Gas fired heaters has a lower CAPEX and OPEX and with an efficiency of 85% it has high utilization of the energy in the combusted gas. The selected use of low NOx burners will ensure that NOx emissions are within the level considered by EU as BAT.

It is recommended that final selection of the heat generation system for Johan Sverdrup phase 2 is done when the maturity of the well streams, field concept and the process have been matured. For a low thermal process heat demand an electrical system may be found beneficial even though it has a higher CAPEX and OPEX. For a high thermal demand case, use of a gas fired heater system will most likely be the best option.

	Gas Fired Heater			Electrical High Voltage Heater		
	5 MW	10 MW	20 MW	5 MW	10 MW	20 MW
CO_2 [t/year]	10 100	20 300	40 600	0	0	0
NOx [t/year]	6	12	24	0	0	0
Operating weight [tones]	80	127	254	20	22	25
Foot print [l x b x h]	4x5x22	5,2x6,3x23	10,4x6,3x23	7,5x3x6	7,5x3x6	7,5x3x6
CAPEX [MNOK*]						
Heater	160	240	450	140	170	220
Transmission system	**-**	**-**	**-**	200	400	800
Total CAPEX	**160**	**240**	**450**	**340**	**570**	**1020**
Average OPEX [MNOK*/y]						
Fuel gas	11	21	42	-	-	-
CO_2 tax	5	11	21	-	-	-
NOx	0,1	0,3	1	-	-	-
Total average OPEX	**16**	**32**	**64**	**28**	**57**	**114**
Assumptions						
CO_2 factor [kg/Sm3]	2,948	2,948	2,948	0	0	0
NOx factor [g/Sm3]	1,7	1,7	1,7	0	0	0
Heater efficiency [%]	85	85	85	NA	NA	NA
Plant regularity [%]	90,5	90,5	90,5	90,5	90,5	90,5
Start up	2022	2022	2022	2022	2022	2022
Field end of life	2058	2058	2058	2058	2058	2058

Table5 – Comparison of alternatives (*Note: MNOK'14)

6 Power requirement

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.

6.1 Johan Sverdrup power requirement phase 1

Originally 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. Firstly the phase 1 production profile was used with a peak production of 50 000 Sm^3/sd. Sensitivity analyses were performed with 60 000 Sm^3/sd oil production and also with higher gas lift rates to account for higher water production.

Later it was recommended a peak production of 60000 Sm^3/sd and increased power demand up to 100 MW. 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 100 MW module would provide sufficient power for the first five years of phase 1.

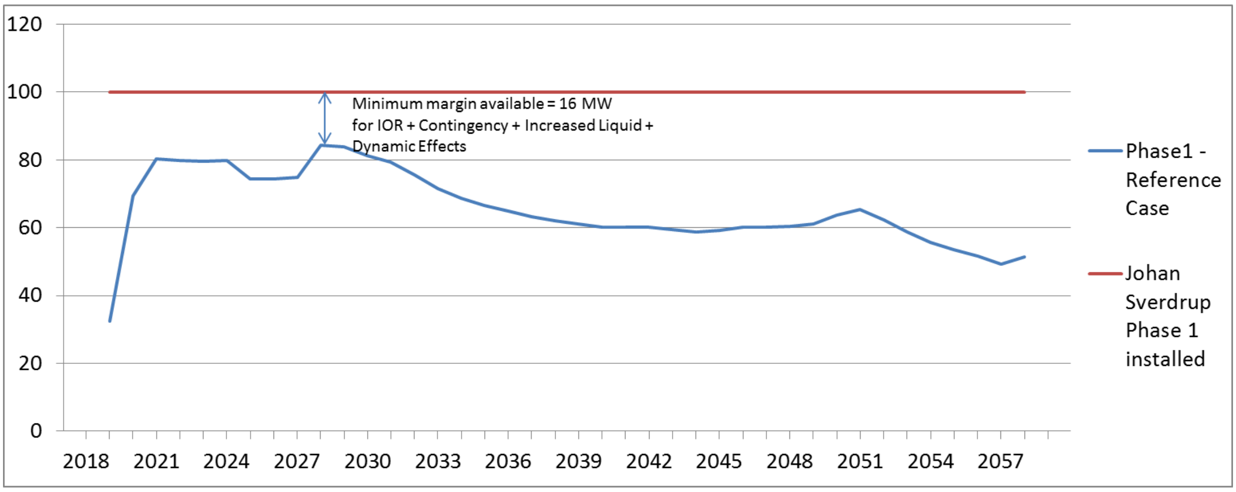


Figure 6-1 Johan Sverdrup Phase 1 Power Profile (MW)

6.2 Future Power requirements for Johan Sverdrup (included IOR)

It is assumed that the energy requirements for the future phases will be covered by power from shore, and that a solution for future phases will be in place by 2022 at the latest.

All ongoing evaluations for the future phases are based on expanding the phase 1 power from shore solution, and all concepts assume that the chosen solution will have sufficient capacity and the required facilities such that Edvard Grieg/Ivar Aasen and Gina Krog can install cables and connect to the overall system in order to operate with power from shore.

To make a final selection for the power from shore solution before the configuration, location, and process capacity expansion at Johan Sverdrup have been selected is not possible.

The development concepts that are being considered have a considerable variation both with respect to the requirements for future power and the required solution for power distribution. In addition confirmation of the requirements for other field in the area is necessary.

The total peak power requirement for Johan Sverdrup, including future phases will depend primarily on the following factors:

- Selected field wide production plateau
- Timing of water breakthrough and liquid production levels
- Drilling solution and schedule
- Timing of IOR measures

Preliminary calculations estimate that the maximum power demand occurs at peak production. The power requirement at this point in time will depend on the chosen development solution but is estimated to be within the range from 120 to 170 MW for the full field corresponding to a production plateau level ranging from 90 000 to 115 000 Sm3/sd. Note that these figures do not include any design allowances or contingencies, or future IOR requirements. Based on the uncertainties at this stage it is recommended that the final design requirement is established as part of the concept selection for the future phases.

The current ''anticipated power requirement'' included IOR risked requirements for Johan Sverdrup alone is 185 MW in the period between 2025 and 2028. This is based on a calculated demand of 153 MW given a production of 100 000 Sm3/sd, and a 20% allowance, as shown in Figure 6-2. Depending on the timing of the demand, it is possible that this allowance is sufficient to cover increased production and/or IOR measures, but there is a risk that production could be limited by available power.

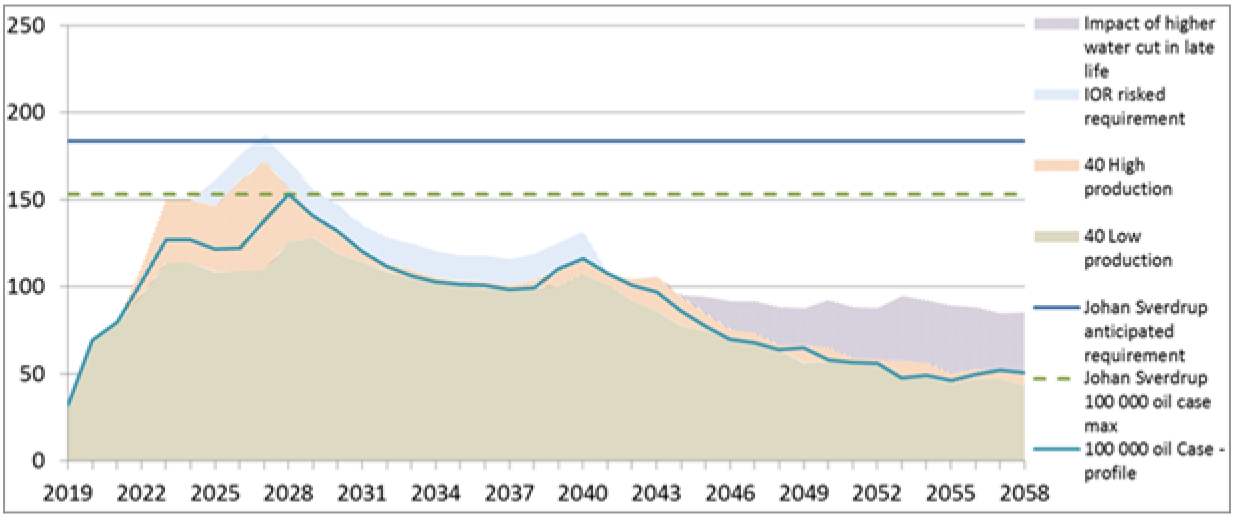


Figure 6-2 Johan Sverdrup Full Field Power Profiles (MW)

Different IOR measures have been considered, including Water Alternating Gas (WAG) and Polymer injection either with or without low salt water injection. The estimated power requirement for these IOR measures is in the range from 5 to 15 MW and their impact on the peak power demand will depend both on the selected option and timing.

6.3 Future Power requirement for other fields in the Utsira High Area (Edvard Grieg, Ivar Aasen and Gina Krog)

The power requirements for other fields used for assessments are based on profiles used in the Johan Sverdrup DG2 and these are shown in Figure 6-3 below.

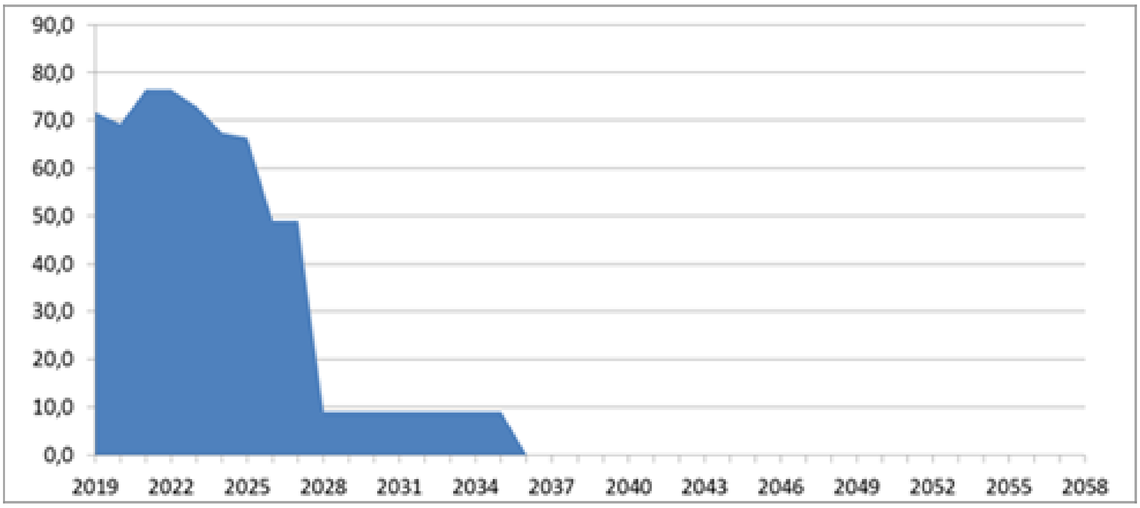


Figure 6-3 Power Demand from other fields (MW)

Based on the Johan Sverdrup requirements described in section 4.2 above, and input given to the UHPH project demand from third parties, the total required capacity for an area solution is estimated to be within the range of 200 to 250 MW, ie an additional requirement of 100 to 150 MW above Phase 1 capacity.

Figure 6-4 below shows the Johan Sverdrup Profiles plotted above the third party requirements, and indicates the a realistic area requirement of 240 MW Depending on actual production levels, water breakthrough and timing of potential IOR measures, this requirement may be exceeded.

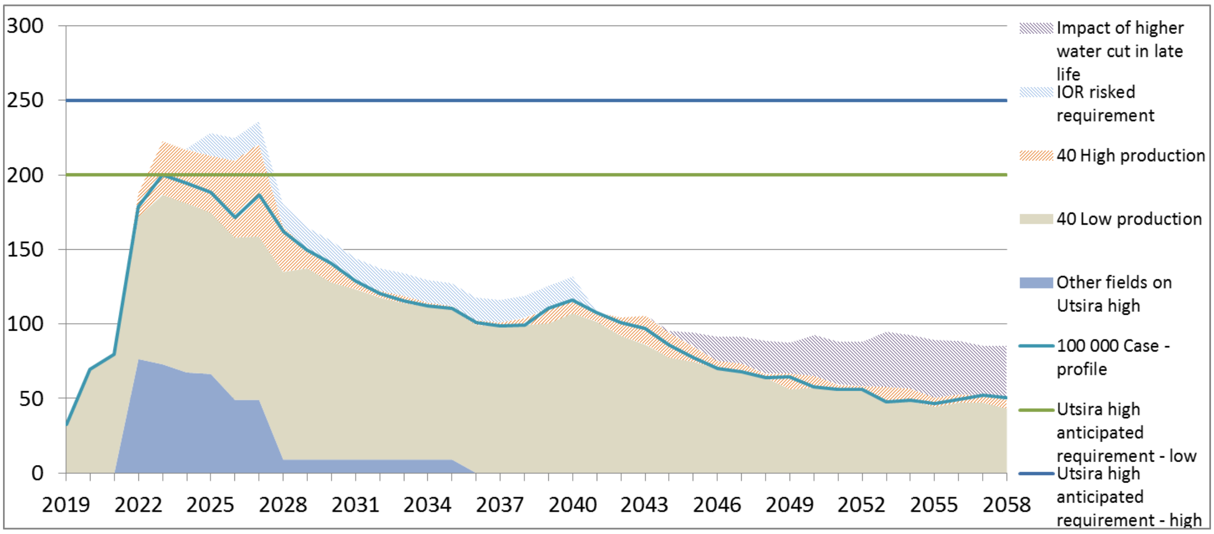
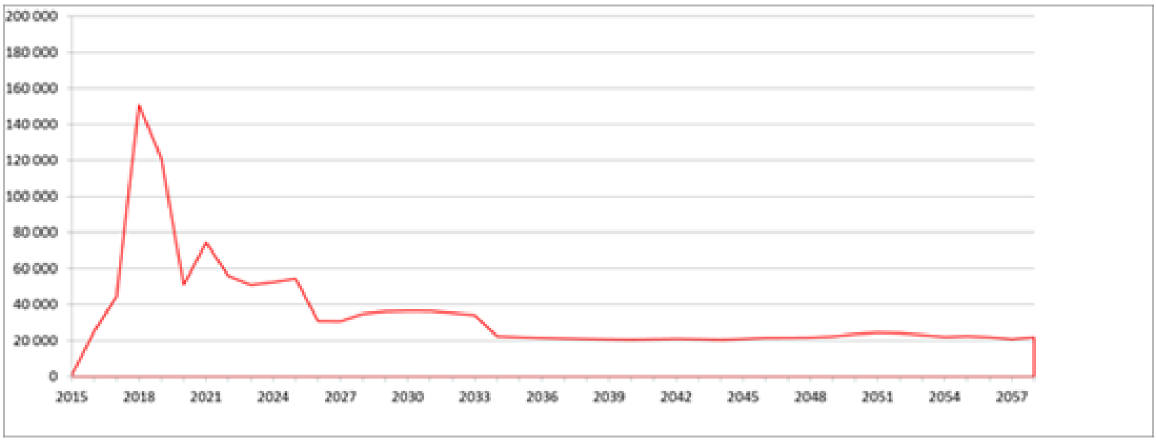


Figure 6-4 Johan Sverdrup Profiles with Utsira High Area Requirements (MW)

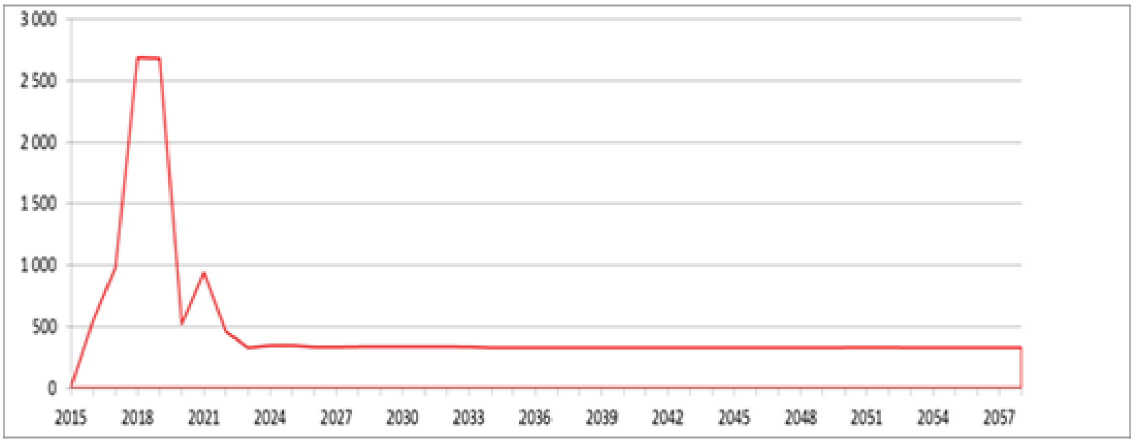
7 Johan Sverdrup CO_2 and NO_X emissions.

7.1 Phase 1 power solution

It is estimated that the power from shore solution for the Phase 1development will lead to a an expected reduction in CO_2 emissions in the range of 11,6 - 13,9 million tonnes over Production life time compared to an offshore gas turbine power generation if only phase 1 is developed. It will be CO_2 and NO_x emission from Johan Sverdrup phase 1 due to gas fired heat according to the figures below, in tones.



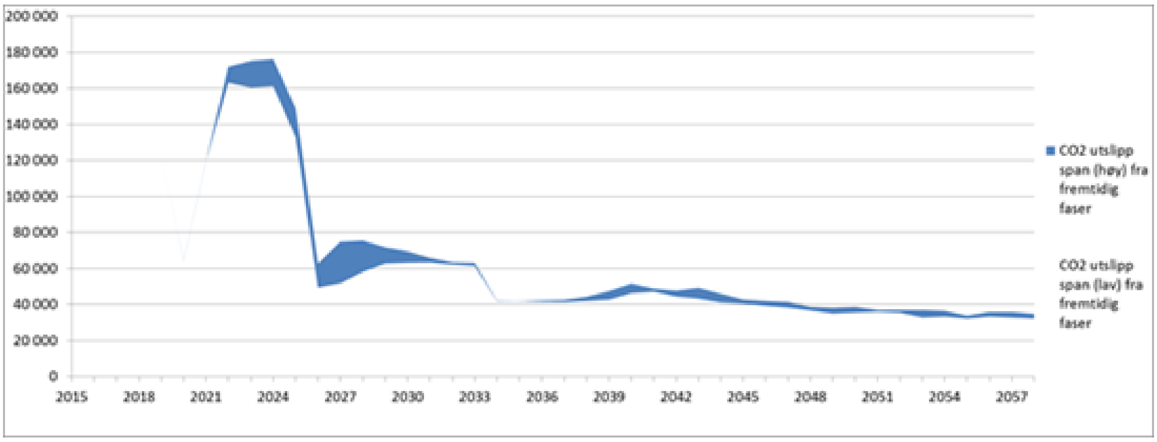
CO_2 emission in tones/year



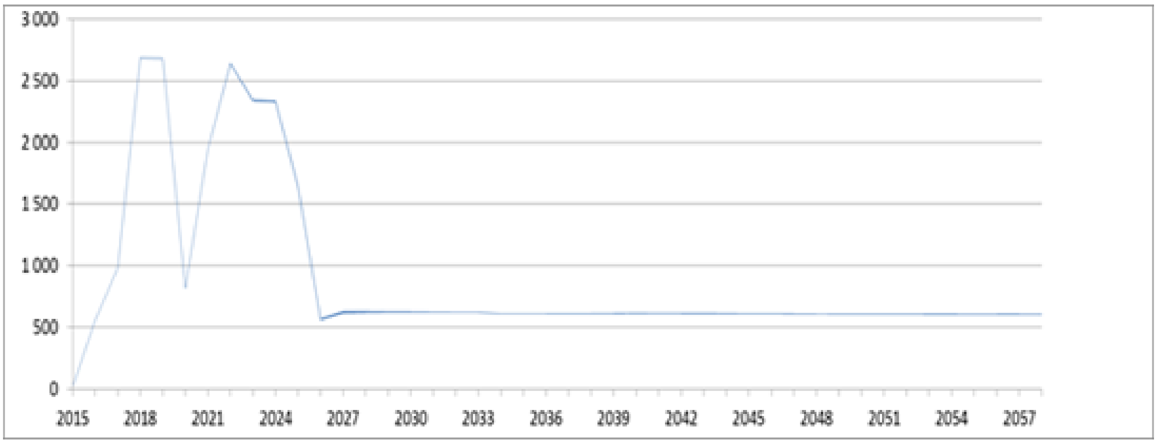
NO_x emission in tones/year

7.2 Future phases power solution

It is estimated that the power from shore solution for the full field development will lead to an expected reduction in CO_2 emissions of approximately 18,9 million tonnes over a production life time compared to an offshore gas turbine power generation for the full field development. It will be CO_2 and NO_x emission from Johan Sverdrup due to gas fired heat according to the figures below, in tones.



CO_2 emission in total after phase 2 in tones/year



NO_x emission in total after phase 2 in tones/year