University of Stavanger

Faculty of Science and Technology

MASTER'S THESIS

Study program/ Specialization: Industrial Economics/Contract Administration and Risk Management	Spring semester, 2016 Open access
Writer: Frode Rudolfsen	………………………………………… (Writer's signature)
Faculty supervisor: Professor Petter Osmundsen, UIS External supervisor(s):	
Thesis title: **Procurement strategy for offshore electrification projects**	
Credits (ECTS): 30	
Key words: - Submarine cables - Converter stations - Limited competition - Division in Lots	Pages: 52 + enclosure: 6 appendixes Stavanger, 12.06.2016 Date/year

Executive Summary

Research focus

Electrification of offshore installations has been an evaluated option for several platforms on the Norwegian Continental shelf (NCS). Offshore installations consume huge quantities of energy and for the majority of the installations the energy is made from burning natural gas in gas turbines locally.

Electrification or Power From Shore solution, also called PFS-solution, is a technically complex system of components like submarine cables, offshore cable installation, transformer stations/converter stations, all which requires manufacturers and contractors with high competence and expertise. The PFS-solution must be safe, reliable and long lasting. Every meter of the submarine cable must work; only one weak spot in the cable will bring the whole power supply out of work, leaving the offshore platform without electricity.

There are limited number of qualified suppliers available in the market to deliver such type of solution, and the research aim is to focus on how the procurement strategy can be developed to achieve a technical viable and cost effective PFS-solution in a market with limited competition.

Methods used

Transporting electrical power over long distances by cables is a technical challenge that is not being dealt with in detail in this report, but knowledge from other studies and projects are used to describe a feasible PFS-solution similar to other systems already built to date.

The aim for this thesis is to develop a procurement strategy that best suits a technical solution, reduces the costs and gives an acceptable quality for the offshore electrification. HSE (Health Safety and Environment) is also a high priority factor in today's projects and will be part of the award criteria in tender evaluation.

To realize PFS-solution for an offshore platform is to a large degree depending on the total cost. If the cost can be kept down, chances for the implementation is much higher.

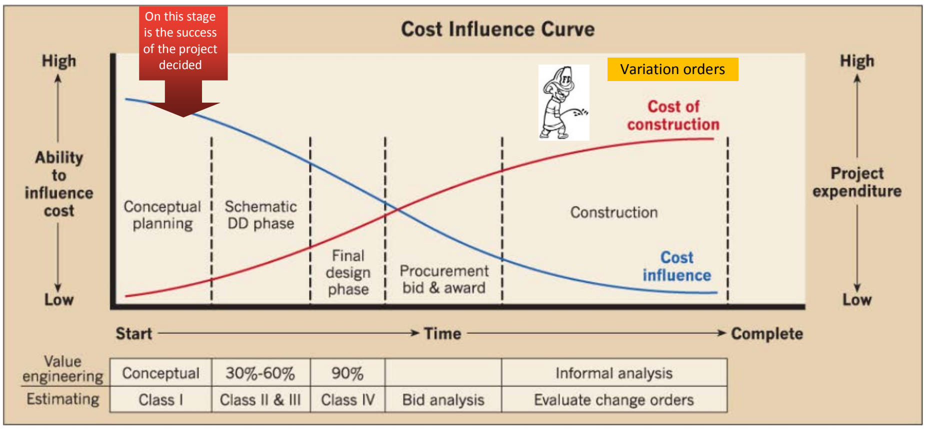
PFS-solution is depending on both a technical viable solution, the supplier market must be large enough to give competition and sufficient manufacturing capacity and experience to deliver in time, with reliable quality to a competitive cost.

If the procurement strategy is able to join all these factors the probability for a successful project will be high.

Results and findings of the research

Procurement strategy determines how the project in the best possible way can be specified and tendered to achieve the best possible and optimal result. By joining technical and contract knowledge with input from market situation and supplier competition, the probability for a successful project increases.

Project of this size might have impact on competition between suppliers. The technical specification, cable manufacturing capacity, limited available capacity from few suppliers are key points to investigate as part of the procurement strategy development. Limited competition is a challenge and to create competition between the few suppliers the scope needs to be split in packages.



The cost influence curve illustrates that the success of the projcect is decided in an early phase. By trying not to limit the technical PFS-alternatives and to keep both HVDC and HVAC solutions open until procurement phase, will give competition and alternatives for the developing company. Also allowing extruded DC cables as well as MI DC cables will give more competition.

Utsira selected as example PFS-project (200 km from shore to field center):

(Example is based on open published references and documentation. There has been no contact with Statoil or other partners in the Utsira development project. All assumptions except from the ones in the reference list are writer's own opinion based on experience).

- Objective and goal is to supply the four offshore platforms at Utsira with up to 250-300 MW of electrical power from shore
- Technically feasible with both DC-solution and AC solution. (AC solution is limited to about 240 to 250 MW)
- Limited number of suppliers/contractors available in market. Important to involve as many suppliers as possible to create competition and urge for cost effective solutions

Definition of lots:

- Lot 1: HVDC Converters (one onshore and one offshore)
- Lot 2: Submarine HVDC cable(s) – approx. 200 km single core x 2. Voltage 200 kV
- Lot 3: Submarine AC cable(s) – approx. 82 km three core 66 kV
- Lot 4: HVDC Converters + Submarine HVDC cable and AC cable(s)
- Lot 5: AC substations (one onshore 300 kV to 230 kV and one offshore 230 kV to 66 kV)
- Lot 6: Submarine HVAC cable – approx. 200 km three core 230 kV

Cost estimate of FPS-solution for Utsira example project is about 3500 MNOK for HVAC solution and about 4500 MNOK for HVDC solution. Estimated implementation time is about 4 years. AC solution is somewhat more cost effective that DC solution.

Conclusions and recommendations

Electrification of offshore platforms with power from shore requires a complex and costly system of submarine cables and transformer stations/converter stations. By applying specification allowing for more competition will bring down cost and provide for cost effective PFS-solution. Enough time needs to be allocated to secure a proper prequalification, tender and contract negotiation phase.

By splitting the contract packages in Lots suitable for the contractors in the market, will allow focus on their core business, but also create interfaces. Company need experienced personnel to handle these complex interfaces. Target is to establish these interfaces where they are logic and clear, for example at the end of the submarine cable, connection to substation or converter station.

ABBREVIATIONS AND ACRONYMS

Abbreviations and acronyms used in this report are listed below.

A – Ampere (unit for current)
FIDIC – International Federation of Consulting Engineers
HSE – Health, Safety & Environment
HVAC – High Voltage Alternating Current (Also written **AC** – Alternating Current)
HVDC – High Voltage Direct Current (Also written **DC** – Direct Current)
kV – kilo Volt
LCC – Line-commutated Converter (Thyristor based converter technology)
LD – Liquidated Damages (penalties)
MI cable – Mass Impregnated cable (insulation material for cables made of paper and oil-mass)
MVA – Mega Volt Ampere (unit for relative power)
MVAr – Mega Volt Ampere reactive (unit for reactive power)
MW – Mega Watt (unit for power)
NCS – Norwegian Continental Shelf
NF 07 – Norsk Fabrikasjonskontrakt 07 (Norwegian Fabrication Contract 07)
NPD – Norwegian Petroleum Directorate
NSC 05 – Norwegian Subsea Contract 05
NTK 07 – Norsk Totalkontrakt 07 (Norwegian Total Contract 07)
OLF – Oljeindustriens Landsforening (Has now changed name to Norsk olje og gass, and is part of NHO - Næringslivets Hovedorganisasjon)
PFS-solution – Power From Shore solution
PSA – Petroleum Safety Authority
VSC-converter – Voltage Source Converter (Transistor based converter technology)
XLPE – Cross Linked Polyethylene (insulation material for cables)

TERMINOLOGY

Some of the central terminology used in this report is further described below.

"Black-start" capability	"Black-start" capability is the process of restoring electric power in a distribution network that does not have local production (island operation). In relation to HVDC systems "black-start" capabilities means that the converter can manage to start up the load without any support from other generator plants.
Company	When written with a capital, C, the Company refers to a customer or owner of the contract in this report. If not, it denotes any company.
Contractor	The party selling a service or certain goods in a contractual relationship. When written with a capital letter, *C*, the Contractor refers to the Service Company in this report.
Contract	Contract written with capital C means the specific contract between Company and Contractor based on Conditions of Contract and Exhibits.

Extruded cable	Extruded cable or XLPE cable is a cable where the insulation system is made of extruded cross linked polyethylene. The advantage is that it does not contain oil and it can sustain higher conductor temperature and therefore larger current. XLPE cables are often defined as “new “ technology insulation system.
EPC contract	EPC stands for Engineering, Procurement and Construction. EPC/Turnkey contractor is responsible for design, procurement, construction, commissioning and handover to Company/Owner.
Field Operator	A company which is responsible for developing and producing petroleum from a reservoir. Often acts as the executive party of a larger license group, owning the largest share in a field. Also known as “operator”. Field operator can be different from development phase and for operation phase.
HVDC converter	The HVDC converter converts the electric power from AC to DC and vice versa. Normally a HVDC system consists of two HVDC converters with two or more HVDC cables between them. There are two main types of converters: The LCC-type and VSC-type. The VSC-type is the only one that can be used for offshore platforms with only passive load (no other generators offshore).
MI cable	A MI cable is a high voltage cable where the insulation material is made up by thin layers of paper impregnated with thick oil, non-drainable at maximum operating temperature.
PFS-solution	Power From Shore solution is a definition used for electrification of offshore platforms with power from the onshore grid. The PFS-solution involves submarine high voltage cables, transformers and sometimes high voltage DC cables and converter stations.
Tenderer	A contractor that has delivered a tender/bid for a certain contract. There can be several tenderers to a certain job or contract. When the tenderer signs a contract with Company he becomes the Contractor with a capital C.
The Spread	A collective term covering all equipment, consumables, personnel, vessels and barges provided by a service company, or contractor, in connection with the work performed in accordance with a contract. In this context the Spread means a laying vessel, trenching vessel etcetera.

Contents

1 INTRODUCTION 1
1.1 Background 1
1.2 Problem definition 1
2 PROCUREMENT STRATEGY THEORY 3
2.1 Contract models and selection criteria 3
2.2 Contract standards 5
2.2.1 FIDIC contract 5
2.2.2 NF 07 and NTK 07 6
2.2.3 NSC 05 6
2.3 Standardization vs new technology 7
2.4 Interfaces 8
2.5 Competition 9
2.6 Risk and success criteria 10
2.6.1 Risk 10
2.6.2 How to control Risk 11
2.6.3 Success criteria 11
2.6.4 Cash-flow for Contractors 13
3 PROCUREMENT STRATEGY FOR ELECTRIFICATION 14
3.1 Introduction to chapter 14
3.2 Objective and goals 15
3.3 Technical solution and considerations 16
3.3.1 Distance from shore and power requirements 17
3.3.2 Technical solution, AC or DC 18
3.3.3 Considerations 19
3.4 Scope – Example Utsirahøyden HVDC 20
3.5 Scope – Example Utsirahøyden HVAC 21
3.6 Supplier market 21
3.6.1 Submarine cable AC/DC 22
3.6.2 Substation AC or Converter stations AC/DC 22
3.6.3 Available capacity for electrification project/Considerations 23
3.7 Tender strategy 24
3.8 Definition of lots – Allow for competition 25
3.9 Prequalification 26

3.10 Structure tender procedure 27
3.11 Time schedule 27
3.12 Cost estimate 28
3.13 Company organization 29
3.14 Type of tender procedure 30
3.15 Award criteria 30
3.16 Risk and success criteria 31
3.16.1 Risks 31
3.16.2 Handling of risks 33
3.16.3 Tools for getting progress 34
3.16.4 Interfaces 34
4 ANALYSIS AND DISCUSSION 36
5 CONCLUSION 39
5.1 Further work 39
6 REFERENCES 40

FIGURES, TABLES AND APPENDIXES:

List of figures:

Figure 1 – Selection criteria for contract compensation format [1] 4
Figure 2 – The FIDIC contract standard conditions family – fidic.org 6
Figure 3 – Interface example 9
Figure 4 – Cost Influence Curve * http://ecmweb.com, with comments and illustrations..... 12
Figure 5 – The procurement process 14
Figure 6 – Illustration of the geographical positioning of the platforms [11] 15
Figure 7 – Relevance tree for an electrification project 16
Figure 8 – Illustration of platform situation and connection to shore [11] 16
Figure 9 – Indication of limit for transmission capacity as a function of cable length [14]..... 18
Figure 10 – Limit of power flow as a function of length for the cable types 3x1x1000 mm^2, 400, 230, 150 and 132 kV. 400 kV cable is single core 1x1200 mm^2 [15] 18
Figure 11 – Limit of power flow as a function of length for the cable types 3x1x1000mm^2 [16] 19
Figure 12 – Single line diagram HVDC solution 21
Figure 13 – Single line diagram HVAC solution 21
Figure 14 – Illustration of Lot definition... 26
Figure 15 – Interface Utsira HVDC solution 35

List of tables:

Table 1 – Estimated distance as well power requirements [12] and [13] 17
Table 2 – Utsira power requirement, length and voltage level 19
Table 3 – Submarine cable suppliers qualified (own estimate based on experience)............ 22
Table 4 – HVDC converter station or AC substations qualified suppliers (own experience)... 22
Table 5 – Time schedule 28
Table 6 – Summary cost estimate 29
Table 7 – Award Criteria 30

Appendixes:

Appendix 1 – Cable calculations 400 kV
Appendix 2 – Cable calculations 230 kV
Appendix 3 – Cable calculations 66 kV
Appendix 4 – Cost estimate HVDC
Appendix 5 – Cost estimate 230 kV HVAC 200 km
Appendix 6 – Cost estimate 66 kV HVAC

ACKNOWLEDGEMENTS

This report completes my work and results carried out over the last semester and closes of the two year master's degree in industrial economics at the University of Stavanger.

14 years ago, in spring 2002, I wrote a similar master thesis, about electrification of offshore installations. That time from a different perspective, rather the technical side of electrification of offshore platforms using AC submarine cables. Since then several platforms and wind farms have been built and connected to the onshore grid utilizing AC submarine cables or HVDC submarine cables including HVDC converter stations. Operational experience has been gained and opened up for new technology and new thinking related to application of submarine cables.

During my work career since 2002 I have worked on various cable projects including technical calculations, budgeting, tender documents, contract negotiation and construction management. I have learnt that being good at the technical side of a project is not always enough when developing, procuring and managing the implementation of projects of such technical size and complexity. Procurement strategy, contract management is something I saw the need to acquire more knowledge about and thus this thesis in contract administration and risk management.

I would like to direct a great thanks to professor Petter Osmundsen for motivating and guiding me through this semester, ending up in this report and for giving me access to his huge knowledge in contracts and strategy. We also share a special interest in the field of electrification of offshore platforms but from a different perspective.
I would also like to thank my Statnett colleagues working together with me for years developing and implementing submarine cable projects. Thank you for your great support and sharing of vast knowledge within cable technology and procurement strategy.
Thanks to my mother as discussion partner and for helping me to find the "red line" through the thesis.

Last but not least I would like to thank my dear family; Unni, Madelen, Tor Erik and Nicolai for supporting me throughout my studies. Thank you Unni for reading through and pointing out grammar and spelling mistakes.

Signature

Frode Rudolfsen
Flekkefjord 12th June 2016

1 INTRODUCTION

This chapter introduces the thesis within the topic of procurement strategy for offshore electrification projects. Based on the experience made in previously executed electrification projects on the NCS (Norwegian continental shelf) and new upcoming projects this thesis is looking into the contract conditions and strategy to be put in place for a cost effective, technical functional and long lasting solution.

The thesis does not evaluate the politics about or the socioeconomic cost and consequences of supplying offshore platforms with electrical power from the onshore transmission grid.

1.1 Background

Supplying offshore platforms with electrical power from shore is normally called "electrification" or PFS-solution (Power From Shore solution). Despite that most offshore platforms have in previous years been (and still are) supplied by electrical power generated by gas powered turbines and generators causing large quantities of greenhouse emissions.

PFS-solution require submarine cables either HVAC, HVDC or a combination of HVAC and HVDC cables. PFS-solution also requires transformer stations for AC and converter stations if HVDC cables are applied.

1.2 Problem definition

Procurement of large submarine cable systems might have significant impact on the capacity of suppliers available in the market. Submarine cable systems are manufactured by specialist companies requiring high competence and experience. There are limited number of manufacturing companies worldwide with limited cable manufacturing capacity.

The same applies for HVDC converter stations where there are limited number of suppliers with the required experience and competence to create technically good and long lasting solutions.

Creating sufficient competition is any electrification projects major success criteria since monopoly situation will always bring the prices up.

Submarine cable supply market and offshore converter market is with its small number of suppliers characterized as a market with limited competition. To develop or qualify more suppliers is a time consuming and costly process and new suppliers (and existing supplier) are therefore depending on a predictable market and volume.

This thesis aims to provide a recommended optimal procurement strategy for electrification projects on the Norwegian Continental Shelf. The procurement strategy can also be applied to similar projects involving transmission of power in submarine cables or procurement of goods in a marked with limited competition.

Key issues to be addressed:

- Complex technology requiring high technical expertise and reliable quality
- Monopoly situation amongst suppliers?

- How can an optimal strategy be made when suppliers are in a situation with limited competition?
- Technically good and functional solution
- Timeframe from development to implementation/completion?
    - Is time too short to do a proper development phase and execution phase?
    - Will a short implementation schedule drive the price up and make PFS-solution impossible?
    - Is it important to spend enough time in development and procurement phase to allow for a worked through, negotiated and clear contract scope before signature?
- Development of new suppliers/contractors?
- Contract structure with balance in sharing of risk
- Using a case example, calculating investment cost based on expert knowledge/experience from technical, contract and implementation of this kind of projects, with background from cable department in Statnett

To illustrate the submarine cable and converter/substation market this thesis will look into an example case based on the Utsira electrification project. There has been no contact with Statoil or other licence partners and all documentation referenced is found in open sources.

The problem definition covers the general topic of procurement in a market with limited competition and is therefore valid for similar cases.

2 PROCUREMENT STRATEGY THEORY

This chapter introduces selected theory about procurement strategy and how the strategy can be custom made to fit the purpose of a PFS-solution.

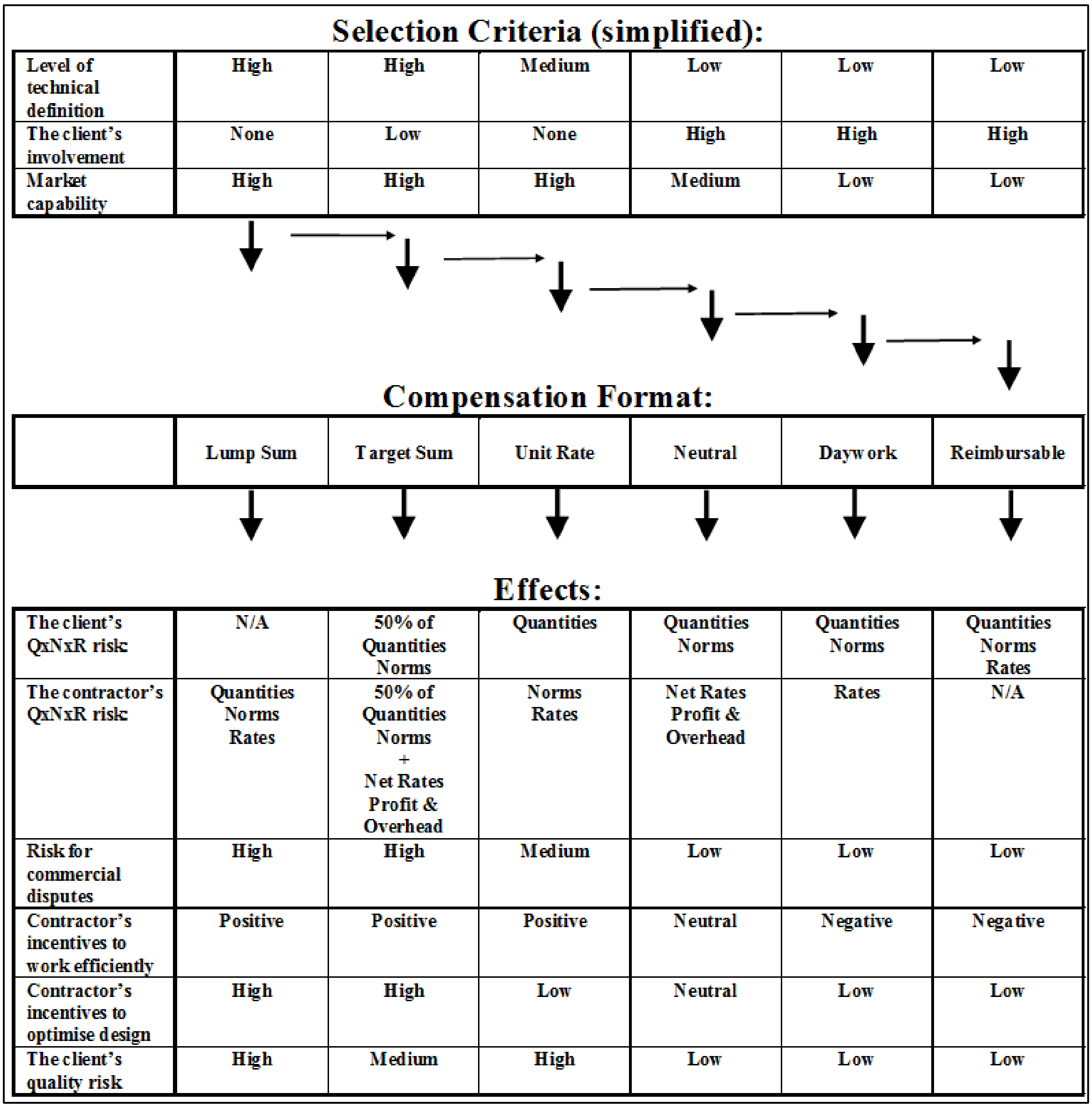
Procurement strategy is the strategy describing goals and directions of a project and how the contract structure and procurement should be established to reach set goals in a best possible way [1] and [2].
The procurement strategy can consist of several part-strategies that are closely connected to each other.
The procurement strategy shall describe how to secure sufficient competition in tender phase and how tasks are divided as well as scope and responsibility. Risk and compensation models will be established as steering tools in the execution phase.

The procurement strategy need to address the following issues:

- The project overall goals
- Complexity of the project
- Competence requirements
- Functional specifications or detailed specifications (EPC og E & PC)
- For many products the suppliers have the expert knowledge and they can deliver turnkey solutions
    - Consider if it is better for the supplier to do the detail design or if Company should provide detail design
- Lump sum prices or provisional sums
- Milestone plan
- Payment plan and incentive schemes
- Penalty LD’s applied if milestones are not achieved

2.1 Contract models and selection criteria

The most common Contract- and compensation models used in strategies worldwide is given in the Figure 1. In addition there are several other contracts and compensation models used.



Selection Criteria (simplified):

Level of technical definition	High	High	Medium	Low	Low	Low
The client's involvement	None	Low	None	High	High	High
Market capability	High	High	High	Medium	Low	Low

Compensation Format:

	Lump Sum	Target Sum	Unit Rate	Neutral	Daywork	Reimbursable

Effects:

The client's QxNxR risk	N/A	50% of Quantities Norms	Quantities	Quantities Norms	Quantities Norms	Quantities Norms Rates
The contractor's QxNxR risk	Quantities Norms Rates	50% of Quantities Norms + Net Rates Profit & Overhead	Norms Rates	Net Rates Profit & Overhead	Rates	N/A
Risk for commercial disputes	High	High	Medium	Low	Low	Low
Contractor's incentives to work efficiently	Positive	Positive	Positive	Neutral	Negative	Negative
Contractor's incentives to optimise design	High	High	Low	Neutral	Low	Low
The client's quality risk	High	Medium	High	Low	Low	Low

Figure 1 – Selection criteria for contract compensation format [1]

Q – Quantities
N – Norms
R – Rates

These selection criteria given in Figure 1 gives common compensation formats. The goal is not to eliminate risk, but to find a compensation format that gives the best balance between Company and Contractor for a specific project or contract. In addition incentives as bonuses or penalties can be applied on top of a specific compensation format, but the main incentive is actually given in the compensation format chosen [1].
For example a compensation per meter rate gives the supplier the incentive to work faster, while a day rate might give the opposite incentive to work more slow, since an additional day will give more profit instead of completing the same job with one day less.

Other factors to be taken into account is the timeframe of the project and the maturity technically. From Figure 1 it can be read that Lump sum contracts are generally good if the level of technical details is high and well defined. Changes at a later stage, after contract signature, will be costly so it is to great advantage to spend necessary time preparing the technical requirements and specifications upfront the contract signature.

There are risks related to all compensation formats, but the different compensation formats is a way of sharing the risk between Contractor and Company. The compensation format is intended to reflect risk and cost drivers based on the following:

- Technical maturity
- Quantity, Norms, Rates
- Commercial disputes
- Incentives to work efficiently
- Incentives to optimise design
- Quality

The lump sum contract gives the Contractor freedom to find technical solutions within the functional specifications and can then save money if he manages to develop and deliver the scope in an effective manner. The risk for the Company is that quality is often compromised to save money and lump sum contracts requires that Company spends more effort on verifying that agreed quality is delivered. Reduced focus on Health, Safety and Environment (HSE) is also a way for the Contractor to save money and it is therefore important for Company to verify that Contractor follows national standards and regulations.

2.2 Contract standards

2.2.1 FIDIC contract

For many years and especially in onshore construction sector, standard contract conditions of the FIDIC organisation (International Federation of Consulting Engineers) have been applied. This standard has its advantage within the construction industry worldwide.

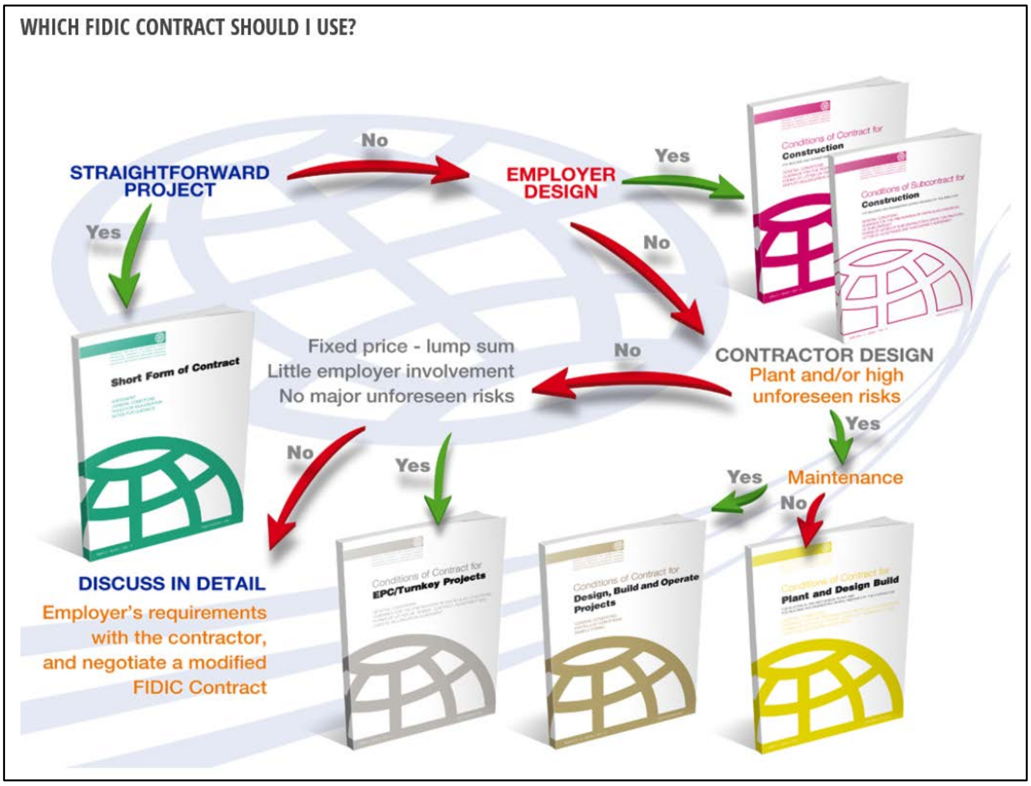


Figure 2 – The FIDIC contract standard conditions family – fidic.org

The FIDIC contract standard applied for offshore construction and installation project in an EPC lump sum contract is less attractive for contractors due to the amount of risk involved. Few contractors are large and experienced enough to offer an EPC lump sum contract for the entire project. Such risks can for example be duration of offshore installation activities involving expensive installation vessels, weather limitations ("waiting on weather"). FIDIC is therefore not much used in the offshore industry on NCS (Norwegian Continental Shelf).

2.2.2 NF 07 and NTK 07

Norwegian Fabrication Contract 07 (NF 07) and Norwegian Total Contract 07 (NTK 07)
are contract standard conditions that are commonly used on the NCS. The NF and NTK standard conditions are negotiated between the major players on the NCS, like Statoil, Hydro and Norsk Industri [3] and [4].

NF 07 is used as contract standard for fabrication of modules to the NCS, while NTK 07 is used for Engineering, Procurement, Construction (Installation). NF 07 and NTK 07 is therefore not especially suited for offshore cable manufacturing and installation where vessels and marine operations are major part of the works.
The first version of the NF standard was negotiated in the 1980s and resulted in NF 87. Further on it was renegotiated several times. Just recently the NF and NTK-contracts were renegotiated and latest revision is NF 15 and NTK 15, released late 2015 and early 2016.

2.2.3 NSC 05

The Norwegian Subsea Contract 05 (NSC 05) is a set of standard contract conditions that was developed by the major players on both the Company, Contractor and Consultant side of the

Norwegian oil sector, OLF (basically the same players as for the NF and NTK contracts but also involving the major installation vessel contractors like Stolt Offshore, Subsea 7 etc.). The NSC 05 is based on NTK but modified to better suit projects involving marine operations and installations.
The intended application of the NSC 05 contract standard is for marine operations such as covering full EPC contracts and installation only. It addresses specific risks in connection with subsea work and the operation of vessels [5].

The NSC 05 contract format is regulated Company friendly and experienced balanced by Contractors.

Balanced:

- Regulation of Variation Orders, Insurance scheme, Liability, Guarantee, Permits, Suspension, Termination
- Provides a sound legal framework for a complex scope of work

Contract chapters in NSC 05 - Example
Inquiry Documents could comprise:
Invitation Letter
Tender rules
Form of Agreement
Conditions of Contract
Exhibit A: Scope of Work
Exhibit B: Compensation
Exhibit C: Contract Schedule
Exhibit D: Administration Requirements
Exhibit E: Specifications
Exhibit F: Drawings
Exhibit G: Company Provided Items and Services.
Exhibit H: Subcontractors
Exhibit I: Company's Insurances
Exhibit J: Standard Bank Guarantee
Exhibit K: Contractor's Proprietary Information
Exhibit L: Parent Company Guarantee

For PFS-solution the preferred contract standard is NSC 05 since it is especially suited for marine installations of cables and other subsea structures.

2.3 Standardization vs new technology

Standardization vs new technology will always be a driver for cost and risk and does not traditionally complement each other [6].

For PFS-solution there has been a development resent years when it comes to the extruded DC cables versus the MI DC cables. Both cable solutions are still being manufactured while extruded DC is taking more market share.

AC cables, and especially for long HVAC cables in the area from 132 kV and up to 400 kV there has been development in providing longer and longer cables. All long AC cables in the range of about 50 km and longer has to be made of XLPE insulation due to the higher charging current for an oil-filled paper insulated cable system [7]. The technology is basically the same for a short XLPE cable length as a long, but quality wise the longer the cable gets the higher is the risk for occurring a fault in the cable. This applies for both AC and DC cables.
All submarine cables are custom made, and the submarine cable industry is to a certain degree standardized, meaning that a cable from one supplier is constructed in a very similar way compared to the other suppliers.
Standardization will always bring prices down as long as there is competition between the suppliers.

Also for the converter manufacturers the technology towards the VSC-technology compared to the traditionally LCC-technology is driving the space requirements down and also allowing "black start" capabilities. VSC-technology is therefore an important step towards making the PFS-solutions more cost efficient as well as providing a HVDC converter system able to feed offshore platforms with only passive loads.

Seen from an overall perspective submarine cables and substations are sort of custom made based on standardized products as well as installation of these. Converter stations have also previously been installed on several offshore platforms. The technology is rather new, but some suppliers have experience with similar installations. It can therefore be categorized as semi-standardized.

2.4 Interfaces

Handling of interfaces between contracts is a key point to achieve coordinated progress, technical solutions that function well together and an overall good system performance.

Interface Management is the effective information exchange through regulated procedures for communication between all parties in each interface point. Interface Management is therefore an important part of every projects quality system.

Interfaces will always exist in large projects and in certain contract strategies the developers target to minimize numbers of interfaces by creating large EPC contracts. Large EPC contracts containing most of the project scope might create less interface points for the developers, but within the project the interfaces will still be there but managed by the EPC contractor.

Sometimes it is said that we need a EPC lump sum contract in order to remove interfaces. It is to remove interfaces. There will always be interfaces. The question is which party has the best competence/ability to manage the interfaces. [1].

Large projects require complex interface management systems and high skills within this area of expertise to manage and execute the interface coordination.

Example of interfaces is illustrated in Figure 3. In addition there will be many internal interfaces within for example the converter stations and cable systems.

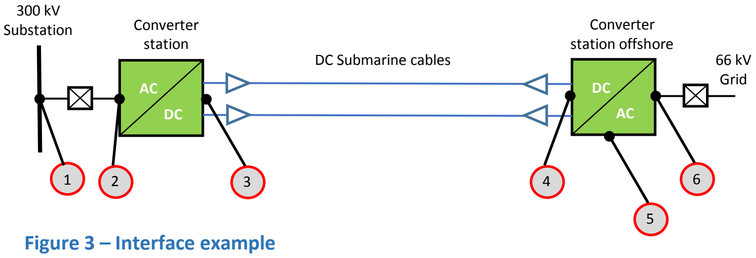


Figure 3 – Interface example

1. Interface between 300 kV grid owner and extension of 300 kV substation
2. Interface between 300 kV substation and onshore converter station
3. Interface between onshore converter and submarine cables
4. Interface between submarine cables and converter offshore
5. Interface between converter offshore and offshore platform contractor
6. Interface between converter offshore and AC grid

2.5 Competition

Supplier market for PFS-solution is characterized by limited competition. There are few qualified suppliers and with limited manufacturing capacity for the supply of submarine HVAC and HVDC cables. The same apply for converter stations.

V. Grimm, R. Pachini, G. Spangnolo and M. Zanza describes in the article *Division in Lots and Competition in Procurement [8]* how the procurement and division in Lots influences directly in the competition in the tendering process. They describe how the supplier market in the short and long run will be affected and define two rules to achieve good competition:

1. *The number of lots should be smaller than the expected number of participants*
2. *Define at least one lot more than the number of incumbents and reserve it to new entrants*

The tool of dividing for example cable supply in Lots is commonly used in the submarine cable business. One example is the Monita project (interconnector between Montenegro and Italy), where the submarine cable supplier Nexans supplied one cable while Prysmian supplied the other. It is also the same for the NordLink project (interconnector between Norway and Germany) where Nexans is supplying 2/3 of the submarine cable while ABB is supplying the last 1/3 of the submarine cable.

There are two main reasons for splitting in Lots and the first is to split the workload on two different factories. This will reduce the implementation time since two factories can produce longer lengths per year compared to one factory. Second reason is to create competition since each Lot is smaller and therefore perhaps more manufacturers have available capacity to deliver one Lot.

The submarine cable manufacturing industry and the grid operators is generally a conservative business. Traditionally only manufacturing companies for cables and products with proven long track record have been considered to be qualified while newcomers with new products have been disqualified.

Recently it has been observed that manufacturers of new products have entered the European market. One example is the cable supplier J-Power (from Japan) that was awarded a contract for the NEMO project (interconnector between UK and Belgium) [9]. J-Power was given a contract to supply and install world first use of a 400 kV XLPE insulated HVDC cable.

This contract award was a big surprise to the established European submarine cable marked that in recent years have been controlled by three major European cable manufacturers.

Allowing newcomers into the market is perhaps the best way of showing established manufacturing companies in a marked with limited competition that they must price their products competitive.

In this context the developing company also plays an important role on how the project is split in Lots and if they will allow newcomers.

2.6 Risk and success criteria

2.6.1 Risk

Definition from ISO 31000 – Risk is “effect of uncertainty on objectives”.

It is not a goal to eliminate risk, but to find a systematic method to monitor and control the risks from the beginning of the project to completion. By identifying risks and focusing on risk mitigation actions, risks can be monitored and to a certain degree controlled and reduced.

Examples of risk areas:

- Local content requirements
- Civil unrest in the immediate area
- Harsh physical environment or climate
- Political instability
- Unstable Regulatory Regime
- High Potential for Craft Labour Shortages
- Currency Exchange Risk

Other risks examples:

- Uncapped liability provisions
- Responsibility for consequential damages
- Payment provisions
- Provisions for processing change and schedule extensions
- Broad definitions of gross negligence

Contractors take these risk factors into account when making decisions for their bids.

HSE-risks (Health, Safety and Environments) are important for the safety for people working on the project and for the environment. HSE-risks is not specifically focused on in this thesis since specific HSE-requirements will be specified in the tender documents. This report is focusing on the project risks to procurement, performance, quality, costs overruns etc.

2.6.2 How to control Risk

The following key points are listed as important factors to control and minimize risk:

- Use contractor which successfully has done the same project or similar before
- Skilled personnel
  - High competence at Company's management and technical team
  - High competence at Contractor's management and technical team
  - Contractor's lead personnel should have worked with and had similar experience from previous project
- Contractor and Company dedicated team. The team managers on each side should have worked together as a team before
- Continuity in the Company and Contractors team thorough the project
- Risk management system used continuously to monitor and manage risks. Minimise effect of risks by applying risk reducing actions

2.6.3 Success criteria

In dialogue with experienced project managers in Statnett some of the key success criteria were discussed and listed based on a qualitative based approach.

Jan Erik Skog (Senior project manager Statnett) – 09.02.2016

- *Best procurement strategy is when technical, legal, commercial and financial personnel cooperate to develop the strategy and tender/contract documents. The same team and competence to participate in the whole procurement process as well as the contract negotiation process*
- *Important not to block competition in the market, for example to ask for a product where there is only one supplier*
- *Important general experiences:*
  - *Technical thinking (since these kind of projects, electrification, is a technical project)*
  - *Create "will" for suppliers to tender and to create competition*
- *Other tools to create a good project:*
  - *Splitting of the project in contract packages to enable competition*
  - *Split the contract packages so that the logic and experienced contractors can tender on the contract packages. For example split civil works out from a cable contract since it is not core business for a cable contractor*
  - *Splitting in contract packages will give more interfaces between the contracts. This requires more staffing and coordination by Company. Important to get the right balance*
- *Risk – Strategy for how the risk is divided between Company and Contractor*

Jan Nyborg (Senior project manager Statnett) – 03.03.2016

- *Most important criteria for success is that both Company and Contractor has the same understanding and interpretation of scope of work and the details within the scope of work*
- *To create competition even in a market that is characterized by few suppliers with limited capacity*
- *The breakthrough in a contract negotiation situation will appear when a contractor is certain that they will get the job suddenly see that they might lose the contract. Contractor will then stretch far to get the contract*

Cost Influence Curve

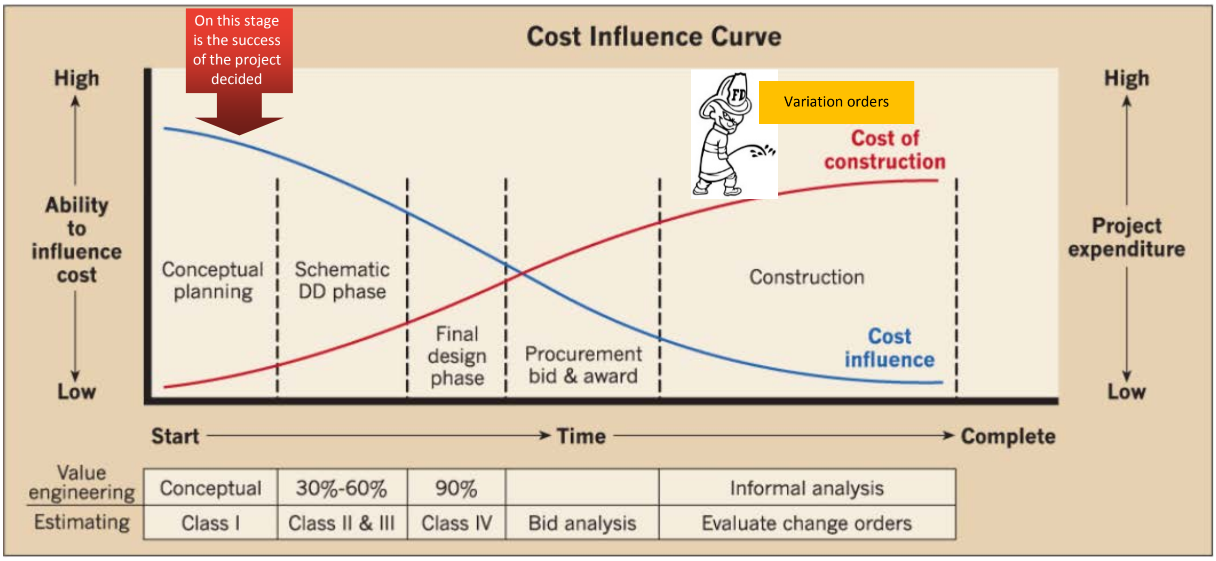


Figure 4 – Cost Influence Curve * http://ecmweb.com, with comments and illustrations

The success of the project is decided in the conceptual planning phase. The Cost Influence Curve in Figure 4 show the ability to influence the cost of the project during the time from start to completion. As can be drawn out from Figure 4 is that during the initial stage the major project definitions and decisions are made, and have large influence on the ability to alter the cost.

During the final design phase and procurement/bid stage the ability to influence the project cost is significantly lower compared to early phase.

The procurement strategy should therefore be developed on an early stage of the project in order to influence the outcome and total project cost.

Other success criteria are:

- Experienced and competent personnel on both Contractor side and Company side
- Focus on same goals

2.6.4 Cash-flow for Contractors

Most Contractors are not finance institutions but they live by doing projects and to generate money by making profit from each project they deliver. The survival of contractors is depending on making profit over time, otherwise they will go bankrupt.

A contractor is therefore depending on having a neutral or positive cash-flow in each project. Material and labour costs will start to run from the beginning of the project execution and the compensation model must therefore be shaped so that contractors project cost is balanced with the payments from Company/developer/owner. The developer will on his side make sure that he pays according to project value generated for him. This will secure him of having the ownership to project progress in case of a potential bankruptcy for the Contractor.

"Contractor always have been and always will be better at contracting games than owners. Their lives depend on it" [10].
The meaning of this can be drawn back to the fact that contractors generates their income by delivering for example Engineering (detail design), Procurement (manufacturing) and Construction (labour). In most cases contractors need to go into a competition to win a contract and if the competition is hard the contractor's margins/profit will be low. Their only way to generate more income is to claim for additional works on the project not specified in the Contract scope of works. There are no limits to how a contractor losing money on a project will try to get additional payment by all means. And as quoted *"Their lives depend on it".* Worst consequence for the contractor is bankruptcy.

Solidity and finance situation for the contractor is one of the key evaluation criteria for a developer. A contractor with a strong financial situation has a better chance to survive challenges in a project and will also have the financial strength to complete a project even if he loses money on it. In the opposite case a financially weak contractor will have difficulty to complete projects where he loses money.

3 PROCUREMENT STRATEGY FOR ELECTRIFICATION

3.1 Introduction to chapter

This chapter contains the procurement strategy for an example project. The electrification of Utsirahøyden is selected as a case study. (The correctness of names, distances or power demands is not important for this thesis since the strategy could be used on any similar configuration). Example is based on open published references and documentation. There has been no contact with Statoil or other partners in the Utsira development project (Johan Sverdrup). All assumptions and conclusions, except from the ones in the reference list, are writer's opinions based on own experience.

In this report the focus is on the electrical system, assuming that the platform itself is part of other contracts so that the space needed offshore for the electrical equipment is made available for the electrification project. Station and civil works onshore is part of electrification works covered by this example project.

The cost for the electrical system necessary to connect the Utsirahøyden to the onshore grid can be compared with the investment cost for installing gas turbines for generating the electrical power. The comparison between grid supply and gas turbines is not part of this thesis.

The purpose of this project specific procurement strategy is to describe how to secure competition in the tender phase, how to split the contract packages, how to split the risk between Company and Contractor and what type of contract form to be selected.

This procurement strategy is the recommended strategy based on long experience in this business. Other strategies might work as well but can give higher project costs.

Upfront the procurement/contract strategy it is assumed that basic and conceptual engineering is done to provide the basis for the technical solution selected. The output of this engineering is listed in the following chapters as input to the strategy.

Figure 5 is presenting the procurement process from contract strategy up to final investment decision (FID). This strategy will focus on the contract strategy part, but giving the input to the strategy for the implementation of the whole procurement process up to FID (final investment decision) and contract signature. The order of each step in the procurement process is important for the outcome and content of the contract. To have a FID done prior to final contract negotiation will give Company the strength and security to achieve better prices and conditions compared to if contract is signed upfront FID (based on the condition that FID is made).

Figure 5 – The procurement process

3.2 Objective and goals

The objective is to perform electrification of Utsirahøyden with electrical power from the onshore grid at Kårstø.

Goals:

- HSE – Zero accidents and injuries
- Quality – 40 years lifetime and minimal operational failures
- Time – Complete project within 4 years
- Cost – Complete within budget

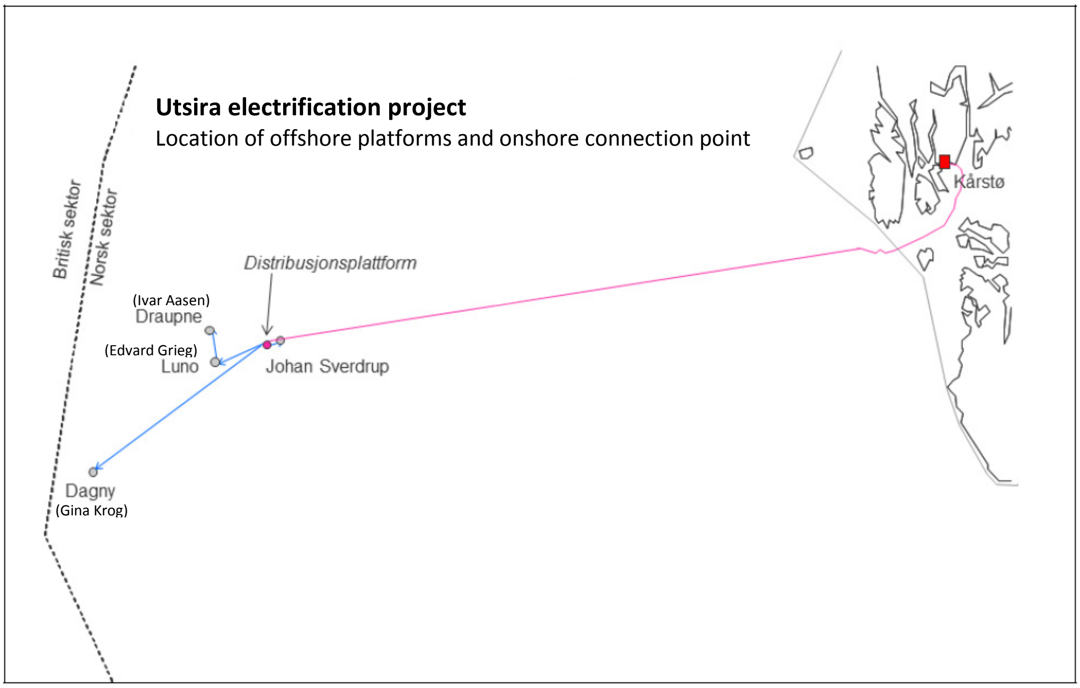


Figure 6 – Illustration of the geographical positioning of the platforms [11]

As can be drawn out from Figure 6 showing the geographical positions and distances between the feeding source (Kårstø) and the loads at the platforms Johan Sverdrup, Ivar Aasen, Edvard Grieg and Gina Krog. The size of loads are determined by the peak load in MW and the timing when the loads will occur on the various platforms.

Relevance tree for an electrification project:

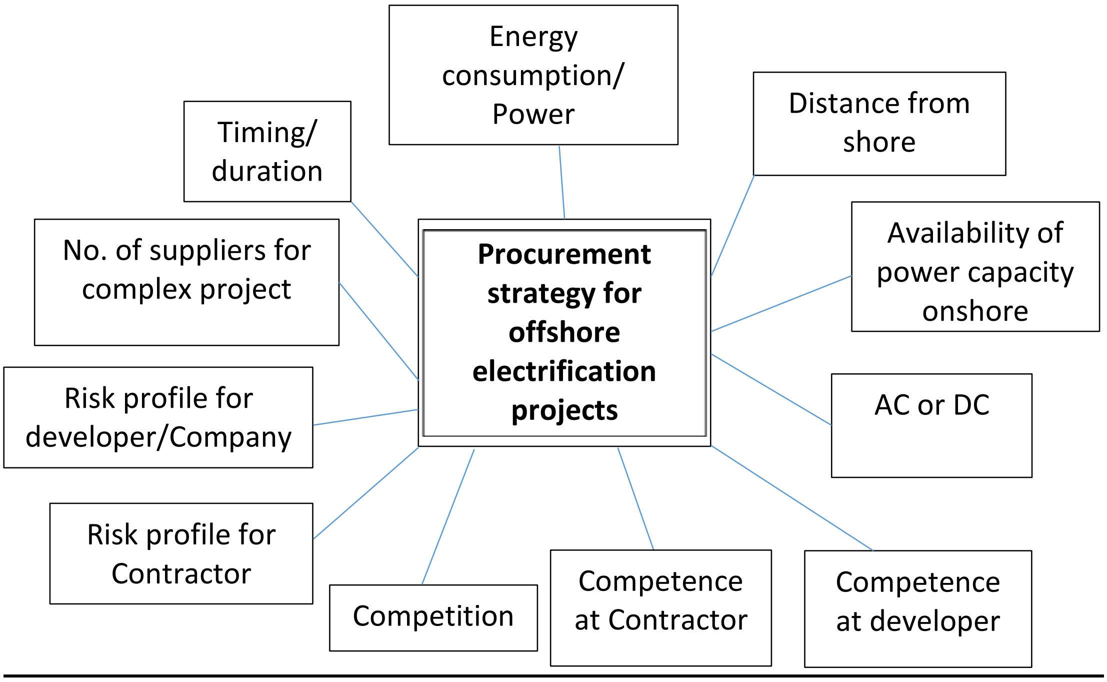


Figure 7 – Relevance tree for an electrification project

Figure 7 presents various parameters relevant for the procurement strategy for an offshore electrification project. Each of the elements are key parameters deciding and influencing the strategy and will be described in the following chapters.

3.3 Technical solution and considerations

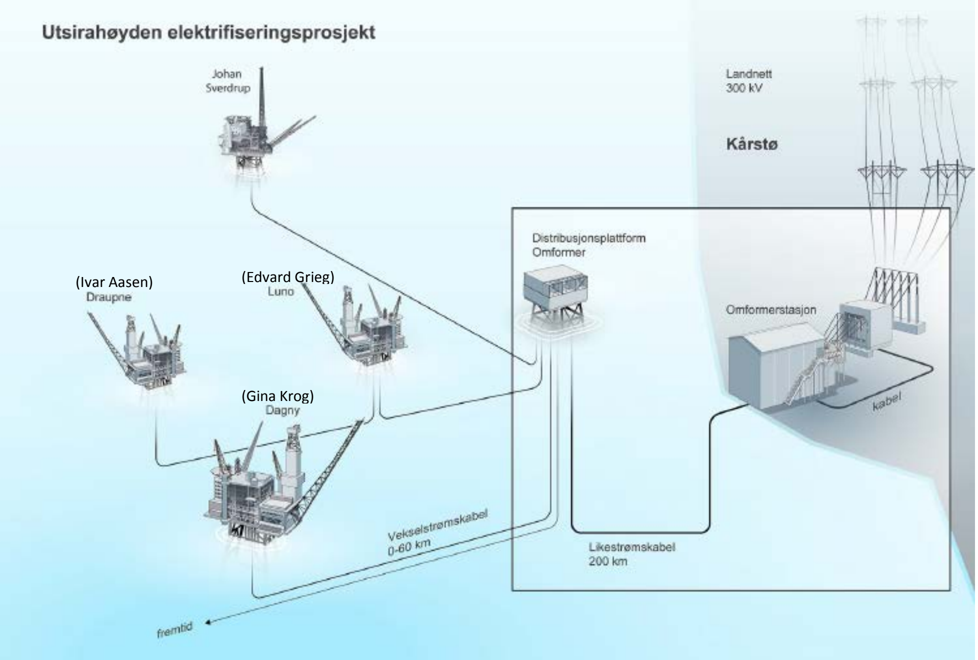


Figure 8 – Illustration of platform situation and connection to shore [11]

Figure 8 illustrates the model of how the platforms at the Utsira area can be connected to the onshore 300 kV grid at Kårstø via submarine cables. A HVDC solution will require a converter station onshore and a converter station offshore, before the AC network between the offshore converter station hub is used to distribute the power to each platform.

A HVAC solution will require a similar solution with a 200 km submarine cable (HVAC) between an AC substation at Kårstø and an AC substation at Utsira hub offshore. The HVAC offshore distribution grid between the platforms will be the same for both solutions.

3.3.1 Distance from shore and power requirements

Table 1 is presenting the geographical distances between cable connection points and the power requirements on each platform. It is assumed that the lengths in km is equal to submarine cable lengths. As for the power requirements the values are estimated based on reference [12] and [13].

Table 1 – Estimated distance as well power requirements [12] and [13]

Section	Distance [km]	Estimated max power [MW]	Comment
Kårstø to Utsira hub	200 km	300 MW[1] (253 MW)	Sum of loads are 253 MW
Utsira hub to Johan Sverdrup	0.5 km	180 MW	It is assumed that Utsira hub and Johan Sverdrup is the same platform and that power from the converter can be fed directly to the process system
Utsira hub to Gina Krog	55 km	25 MW	
Utsira hub to Edvard Grieg	17 km	23 MW	Cable feeding Edvard Grieg will also carry the power to Ivar Aasen (sum 48 MW)
Edvard Grieg to Ivar Aasen	10 km	25 MW	

---

[1] Capacity of 300 MW allows for future expansion in addition to the named platforms and is in line with the maximum power Statnett has allowed to take off at Kårstø [13].

3.3.2 Technical solution, AC or DC

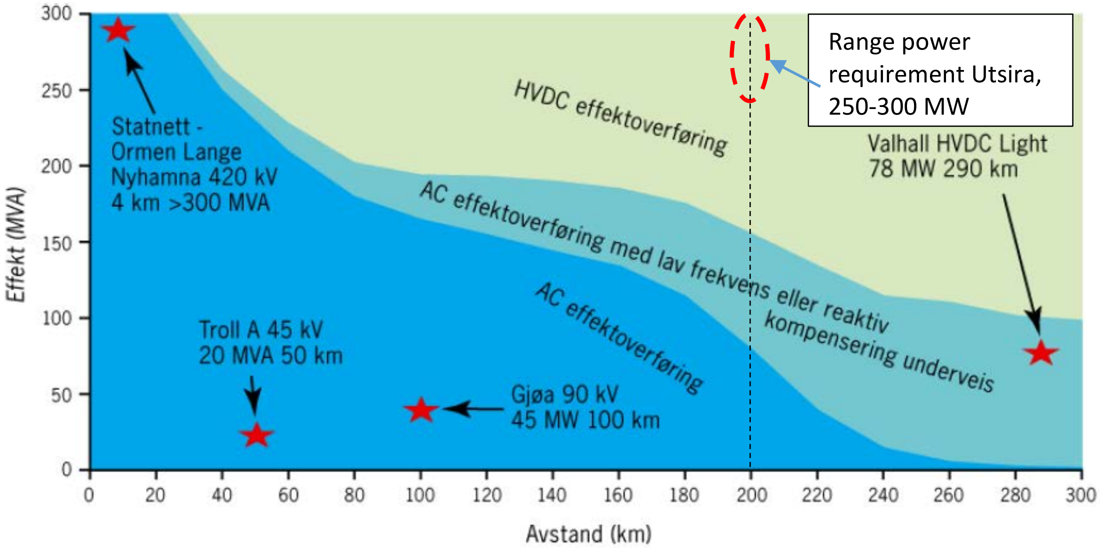


Figure 9 – Indication of limit for transmission capacity as a function of cable length [14]

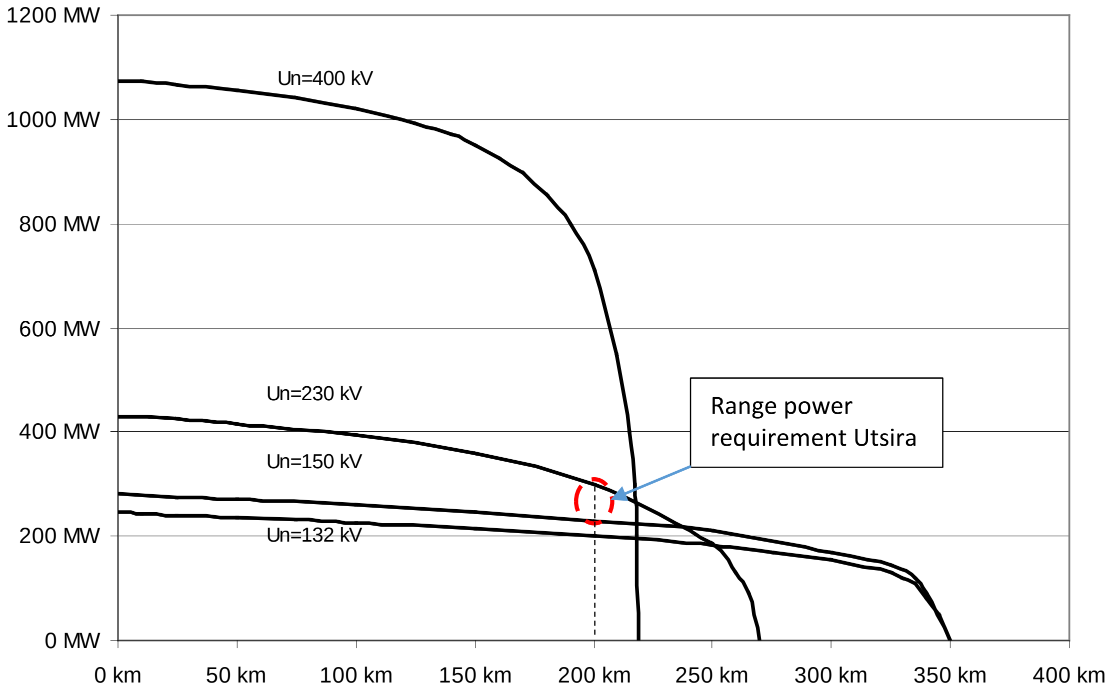


Figure 10 – Limit of power flow as a function of length for the cable types 3x1x1000 mm², 400, 230, 150 and 132 kV. 400 kV cable is single core 1x1200 mm² [15]

Figure 9 indicate that HVDC is the only solution for the 200 km long transmission link between Kårstø and Utsira hub, while Figure 10 indicate that HVAC solution might be an alternative. According to NVE in their report "Kraft fra land til norsk sokkel" [14] HVDC is the only alternative for this length and power, while reference [15] "Energy transmission on long three core/three foil XLPE power cables" concludes that HVAC cables can supply up to about 250 MW at a 200 km distance.

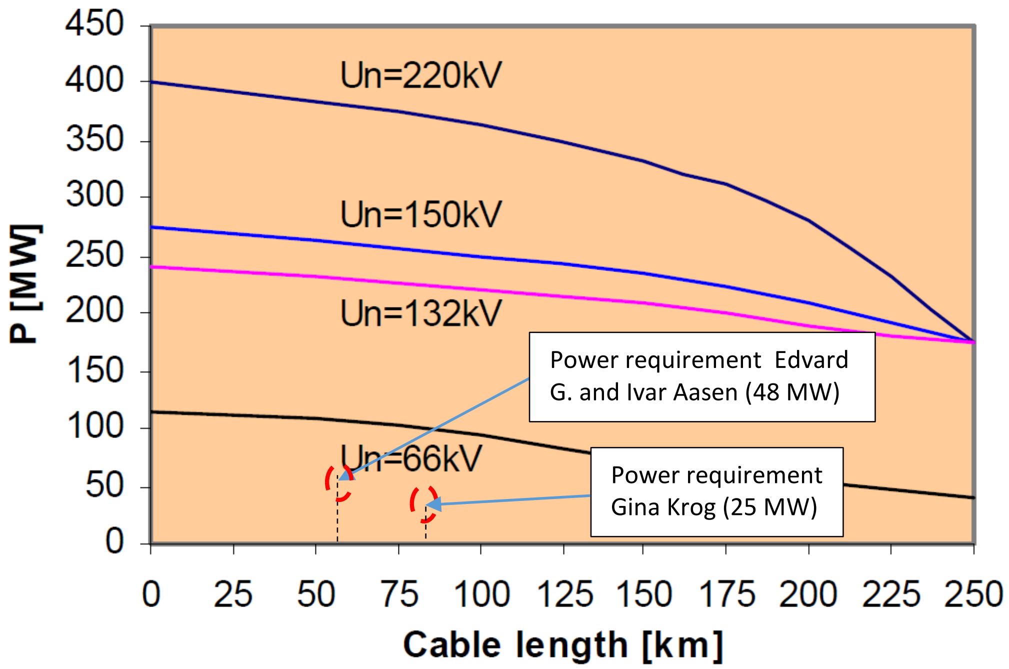


Figure 11 – Limit of power flow as a function of length for the cable types 3x1x1000mm^2 [16]

Figure 11 indicate that length and power requirement for the feeding cables between Utsira hub and the platforms Gina Krog, Edvard Grieg and Ivar Aasen can be fed by 66 kV HVAC cables.

Table 2 – Utsira power requirement, length and voltage level

Section	Estimated max power [MW]	Distance [km]	AC or DC	Voltage level [kV]
Utsira hub	300 MW (253 MW)	200 km	DC or AC	200 kV DC or 230 kV AC
Johan Sverdrup	180 MW	0.5 km	AC	Assume on same platform
Gina Krog	25 MW	55 km	AC	66 kV
Edvard Grieg	23 MW	17 km	AC	66 kV
Ivar Aasen	25 MW	10 km	AC	66 kV

3.3.3 Considerations

Transmission Kårstø to Utsira 200 km

To use 400 kV HVAC for the 200 km long submarine cable section would require close to 1300 MVAr of reactive compensation, due to the high charging current. A 400 kV HVAC is therefore not a recommended alternative since the charging current will be higher than the permitted current capacity.[2]

To use 230 kV HVAC for the 200 km long submarine cable section can be an option. A three core 230 kV cable would require about 430 MVAr of compensation, half on the onshore station

---

[2] Calculations included in Appendix 1 – Cable calculations 400 kV

and the other half on the offshore station[3]. Calculations show that the power capacity for a 200 km length is limited to about 240 MW, and this is also equivalent to Figure 10. 240 MW is still a bit low to feed the whole Utsira, but it is close to the required power need (Sum all platform loads are 253 MW). It might therefore be considered as an option in the tender in order to price a competitive alternative to a HVDC solution.

A DC cable do not generate charging current and is therefore more suited to carry large amounts of power on long distances. The disadvantage with DC cables is that it needs a converter station in each end of the cable. Converter stations are costly, require large space, are heavy, generates losses and needs regular full stop maintenance. For offshore platforms especially space and weight is costly, but additional space and weight for the offshore converter compared to a AC solution substation is not considered in this thesis.
Due to the long transmission distance and relatively high power demand a DC cable solution for the long section of 200 km and to use converter stations onshore and offshore is preferred for large power needs. Another reason for selecting DC as preferred solution is the fact that offshore platforms are often operated with at AC frequency of 60 Hz while the onshore grid is operated with 50 Hz. This would therefore require a conversion of frequency offshore.

Following the recommendation given in reference [17] a HVAC solution is the most cost effective solution for cable lengths up to 200 km and 250 MW. It is therefore decided to also include the HVAC solution feeding the 200 km length from Kårstø to Utsira hub. Getting prices in for both HVDC and HVAC alternative will generate more competition between the solutions and will give Company the choice to select the Most Economically Advantageous Tender/solution.

For any new offshore platform it would be a benefit for a PFS-solution to operate with a AC frequency of 50 Hz as this will make it easier for a direct AC supply from shore with step down transformer offshore. This is similar to the Troll A phase 1 power supply with a 52 kV AC cable directly connected to the onshore grid at Kollsnes.

Distribution from Utsira hub to platforms
For the cables between the offshore converter station/substation and the platforms Gina Krog, Edvard Grieg and Ivar Aasen HVAC submarine cables can be used. The lengths are much shorter, power demand is smaller and thus the voltage level needed is lower. Based on Figure 11 and calculations in appendix, the 66 kV voltage level is chosen with a three core submarine cable[4]. In an optimization process it might be found that a better voltage level would be preferred.

3.4 Scope – Example Utsirahøyden HVDC

The electrification project contains the following main components:

- One onshore converter station (complete with AC substation and grid connection)
- One converter station offshore (complete with AC substation)

---

[3] Calculations included in Appendix 2 – Cable calculations 230 kV
[4] Calculations included in Appendix 3 – Cable calculations 66 kV

- HVDC submarine cable(s) between onshore converter station to the offshore converter station. Distance approx. 200 km
- HVAC submarine cable including necessary pull-in, terminations, switchgear and transformer/reactors to supply the platform electrical distribution system

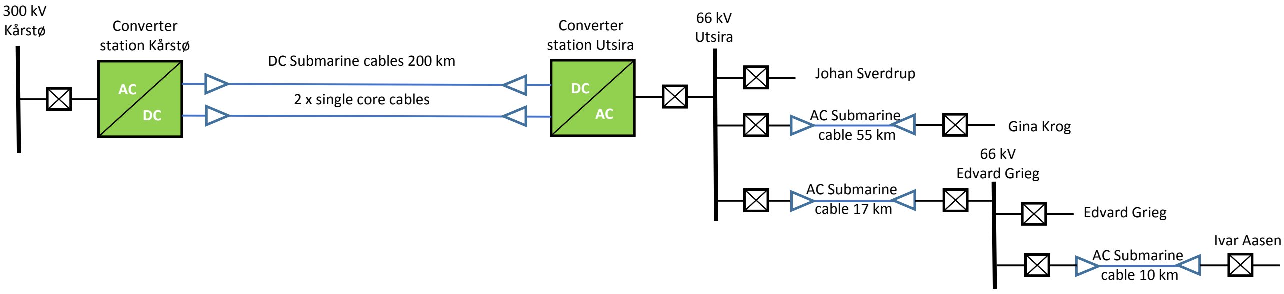


Figure 12 – Single line diagram HVDC solution

3.5 Scope – Example Utsirahøyden HVAC

In case the whole network was to be supplied only with HVAC cables the scope would be as follows:

- AC substation grid connection at Kårstø. Transformer from 300 kV to 230 kV
- AC transformer station hub offshore. Transform from 230 kV to 66 kV
- HVAC 230 kV submarine cable between Kårstø and Utsira hub
- HVAC 66 kV submarine cable between Utsira hub to the platforms

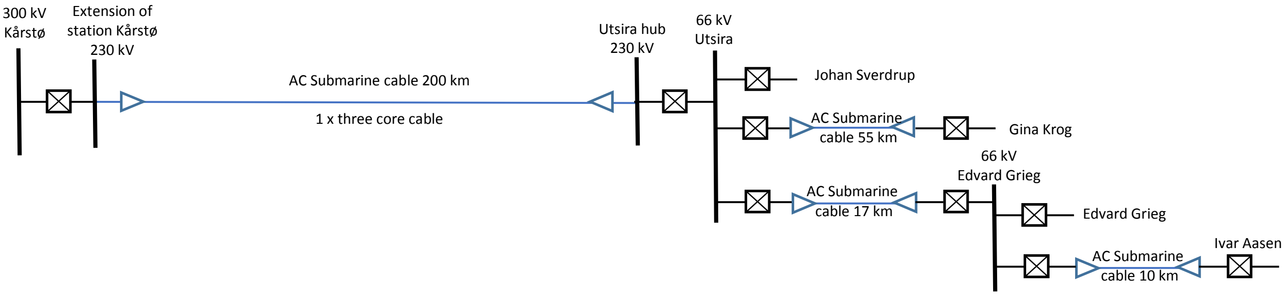


Figure 13 – Single line diagram HVAC solution

3.6 Supplier market

The supplier market for offshore projects as of 2016 is still marked by low oil prices and reduced activity on the global market. Despite that there are numbers of large interconnector cable projects and offshore wind farm projects under construction that has ordered quite large quantities of submarine cable.

In the following the relevant suppliers are listed and their manufacturing ability and capacity is evaluated. Cables needed for the example project is used as basis for the assessment for the manufacturing capacity. The assessment is based on knowledge from similar projects and factory visits. None of the cable manufacturers are willing to reveal their manufacturing capacity as this is seen as their business secret. The accuracy of the estimate will therefore vary as manufacturing plants are under constant development and expansion. The lengths will also vary depending on voltage level, conductor size, etcetera.

3.6.1 Submarine cable AC/DC

Table 3 – Submarine cable suppliers qualified (own estimate based on experience)

Supplier	**AC – XLPE 230 kV level (Three core)**	**AC – XLPE 66 kV level (Three core)**	**DC – XLPE 200 kV level**	**DC – MI 200 kV level**	**Available capacity**	**Turnkey (supply and install)**
ABB	+/- 800 km/year	+/- 1000 km/year	+/- 1000 km/year	+/- 300 km/year	Yes	Yes
Nexans	+/- 700 km/year	+/- 800 km/year	Under development	+/- 550 km/year	Yes	Yes
Prysmian	+/- 1000 km/year	+/- 1200 km/year	+/- 1000 km/year	+/- 500 km/year	Yes	Yes
LS Cables	+/- 700 km/year	+/- 800 km/year	Under development	+/- 70 km/year	Yes	Limited experience
General Cable/NSW	+/- 700 km/year	+/- 800 km/year	Under development	No	Yes	Limited experience
J-Power systems	+/- 800 km/year	+/- 1000 km/year	+/- 1000 km/year		Yes	Yes
SUM “World wide”	**+/-4700 km/year**	**+/-5600 km/year**	**+/- 3000 km/year**	**+/- 1420 km/year**		

A factory for manufacturing XLPE cable can usually manufacture extruded cables for both AC and DC. The capacity given in the tables are based on manufacturing capacity by manufacturing only one type for the whole year, not combined.

3.6.2 Substation AC or Converter stations AC/DC

Table 4 – HVDC converter station or AC substations qualified suppliers (own experience)

Supplier	**Converter stations**	**Substations AC**	**Experience Converter stations**	**Experience substations AC**	**Turnkey (supply and install)**
ABB	Yes	Yes	High	High	Yes
Siemens	Yes	Yes	High	High	Yes
Alstom/General Electric	Yes	Yes	High	High	Yes
XD Electric	Yes (but mainly LCC)	Yes	High, but limited offshore	High	Yes
Toshiba	Yes (but mainly LCC)	Yes	High, but limited offshore	High	Yes
Mitsubishi Electric	Yes (but mainly LCC)	Yes	High, but limited offshore	High	Yes
SUM “World wide”	**3 to 6 suppliers**	**6 suppliers + others not mentioned**	**3 suppliers with offshore experience**	**Several suppliers with high AC experience**	**All suppliers deliver turnkey supply and install**

3.6.3 Available capacity for electrification project/Considerations

Submarine cables HVDC
Needed lengths of cable to Utsira project is for the HVDC solution 2x200 km Kårstø to Utsira hub (total 400 km single core cable).
Estimated manufacturing time is about 2 years so the given quantity for DC will be 400 km out of a capacity 3000 km/year for extruded DC and 1420 km/year for MI DC.

$$\frac{200}{4420} = 4.5\ \%$$

Combined it equals about 4.5 % of the world-wide manufacturing capacity per year for DC cables.
On the contrary if the DC cable supply is limited to only MI-type and to include a requirement to manufacture 400 km in one year, suddenly close to 30 % of the world-wide manufacturing capacity would be required.

Submarine cables HVAC
Needed lengths for HVAC solution to Utsira will require 200 km of 230 kV cable and approximately 82 km for the 66 kV cable. Assuming that the 230 kV and 66 kV cables does not come from the same factory and that manufacturing time is 2 years it can be calculated (200 km over 2 years is 100 km per year. 82 km over 2 years is 41 km per year):

$$\frac{100}{4700} = 2.1\ \%$$

$$\frac{41}{5600} = 0.73\ \%$$

HVAC cable lengths required for Utsira project will require about 2.1 % of world-wide manufacturing capacity for the 230 kV cable while about 0.73 % for the 66 kV cable(s).
(These assessments are just rough estimates and purpose is to evaluate if the projects market share is significant of not).

HVDC converter stations
There are identified three converter manufacturers with offshore experience and three others that have shown will to develop and gain offshore technology and experience. It is considered to be a market with limited competition and it is therefore better to have an alternative to the use of offshore converter stations.

Considerations
Based on Table 3 and Table 4 and the choice to tender for both HVDC and HVAC solutions it is considered that a project of this size does not influence significant on the market situation as long as the scope is split on several suppliers. The number of suppliers are limited so it will be important to engage all potential suppliers in order to get sufficient competition.

It is only one supplier that can supply the whole project with both submarine cables and substations/converter stations (ABB). It will therefore be a limitation for the competition (monopolistic market) if the project is only tendered as one contract without possibilities to split the work between different contractors.

3.7 Tender strategy

In previous chapters the market situation was considered to be characterized by sufficient capacity, but with limited number of potential suppliers. Both for cable and converter(s)/substation(s) the tender strategy is to engage all potential suppliers in the early project phase and prequalification process. The predictability of the project, meaning the certainty that the project will be realized, need to be emphasized to the contractors to gain their motivation to first enter the prequalification and later the tender stage. Contractors require predictability to make commitments and the decision to spend the large amounts of money and effort it takes to be prequalified and to tender for this size of project.

If there are too many contractors tendering for the same contract the chances to get the job will drop and the interest between the contractors will drop as a consequence.
Given the limited number of suppliers, engagement by Company is necessary to get the contractors interested in the job. Such engagement can be factory visits, marketing the project towards the suppliers as well as inviting suppliers for pre-tender meetings.

The contract packages should be divided in lots such that competition is not limited, as well as accepting for example HVDC submarine cables made by extruded as well as mass impregnated insulation material (XLPE and MI). This will allow for more cable manufacturers to be prequalified.
For the onshore stations there will be a significant part of the works that is purely civil works like ground works and site preparation, concrete works and buildings. An option could be to split civil works from the onshore station contract/converter contract and tender civil works separately.

Contractors should be given the opportunity to bid on one or more of the lots since if the same contractor holds several lots there can be less interfaces and perhaps lower prices.

Trying out experienced suppliers with new products
As can be seen from Table 3 and Table 4 all suppliers represent large multi-billion USD companies with long track record in the world-wide energy transmission market. Developing new products and solutions in order to enter into a new market is a costly process and often suppliers finance such development through projects. In order to be competitive new suppliers needs to price themselves down compared to the competition since they know that in a tender evaluation they will not gain as many points due to lack of references and experience with this new product.
Selecting a supplier with successful experience from a similar PFS-project will be a risk reducing action, but if the price from a competing supplier is significant lower the fact that the competing supplier is a multi-billion USD company will count in the direction of that the supplier has the financial muscles to complete the project.

3.8 Definition of lots – Allow for competition

The lots are defined based on logic knowledge related to marked and core business of the available suppliers. It is also based on the choice of getting prices for both HVDC and HVAC solution so that it is possible on a later stage in the procurement process to make a decision on the most economically advantageous tender and solution.

The following considerations are done prior to the definition of lots:

- Only one supplier is capable of supplying the whole scope (ABB). It is therefore included Lot 4 in case the one supplier gives the most economically advantageous tender for the complete project
- There are several suppliers that can supply and install the converter onshore and still several that can supply both the onshore and offshore converter. Only one of these suppliers can supply submarine cables. For technical reasons the same supplier must supply and install both the onshore converter and the offshore converter
- Several suppliers that can supply and install the AC submarine cables. There are some cable suppliers that can only supply AC cables while most of them in the shortlist can supply both AC and DC cables
- The HVDC cables can be supplied either as XLPE insulated cable or MI cable (Mass Impregnated cable). This will give competition and alternatives for Company as long as both XLPE insulated cables and MI cables can be tendered
- Several suppliers can supply AC substations

Definition of lots:

- Lot 1: HVDC Converters (one onshore and one offshore)
- Lot 2: Submarine HVDC cable(s) – approx. 200 km single core x 2. Voltage 200 kV
- Lot 3: Submarine AC cable(s) – approx. 82 km three core 66 kV
- Lot 4: HVDC Converters + Submarine HVDC cable and AC cable(s)
- Lot 5: AC substations (one onshore 300 kV to 230 kV and one offshore 230 kV to 66 kV)
- Lot 6: Submarine HVAC cable – approx. 200 km three core 230 kV

Tenderers should note that to be eligible to tender for Lot 4, they must also complete a tender for at least Lot 1, 2 or 3. (It is assumed that AC substations on the platforms Edvard Grieg, Ivar Aasen and Gina Krog is part of platform contract as they normally would be when feed by gas turbine generators).

An option in Lot 1 could be to remove civil works. If civil works is removed from Lot 1 it has to be tendered as a separate contract. Time wise civil works has short time from tender to start-up of works on site compared to the electro technical part of substations so no delay is expected if civil works is tendered as a separate contract.

Insurance:

Construction Insurance for a large project can be very costly and requires a thorough consideration. Either each Lot can be insured with an all risk insurance individually by each Contractor or the whole project can be insured through one combined insurance policy. Each lot can therefore include an option to take out/remove construction insurance and replace by a Company provided insurance policy covering the whole project. Decision on insurance can be taken in the bid evaluation and contract negotiation stage.

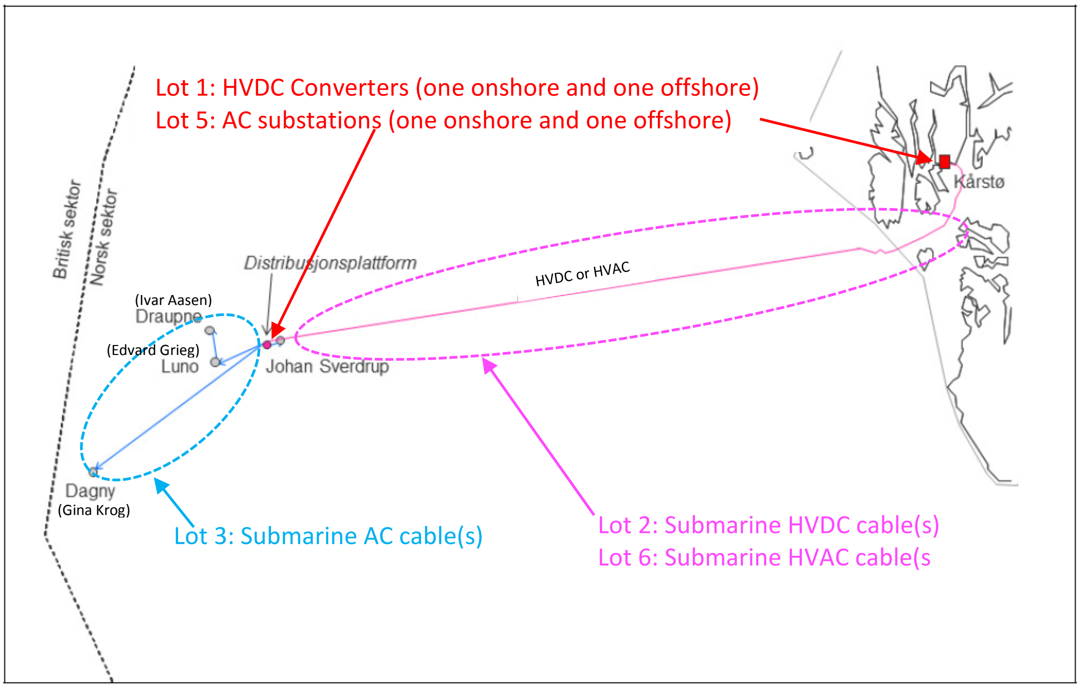


Figure 14 – Illustration of Lot definition

3.9 *Prequalification*

Prequalification process should start as early as possible after the procurement strategy is completed. This will save time and get focus on the suppliers qualified to deliver tender for the project or parts of the project (lots).

The goal with the prequalification procedures is:

- Prequalification of suppliers (get qualified suppliers)
- Target not to limit competition
- Make sure that the prequalified suppliers are interested to deliver a tender for the project

The prequalification shall include and document the following [1]:

- Capacity evaluations
- Competence evaluation
- Previous experiences
- Technical & operational requirements
- Ethical guidelines and labour rights
- Commercial and financial conditions

The requirements aim to secure that contractors are technical and commercial qualified and that they have the capacity to deliver the required project or lots. The prequalification requirements/criteria must not be too strict so competition is limited. As a rule of thumb there should always be three or more tenderers to the same contract. As for the prequalification to achieve three or more tenders there should be perhaps five to six prequalified contractors, since some prequalified contractors might decide not to deliver a tender.

If there is lack of qualified suppliers a process of prequalifying and developing new suppliers might be necessary for improving the competition. For the Utsira project it is considered to have sufficient numbers of qualified suppliers, as long as technical requirements and timeframe will allow multiple contractors to tender.

3.10 Structure tender procedure

Based on the definition of lots the following tender procedures will be as follows:

1. Tender procedure including all lots:

- Lot 1: HVDC Converters (one onshore and one offshore)
- Lot 2: Submarine HVDC cable(s) – approx. 200 km single core x 2. Voltage 200 kV
- Lot 3: Submarine AC cable(s) – approx. 82 km three core 66 kV
- Lot 4: HVDC Converters + Submarine HVDC cable and AC cable(s)
- Lot 5: AC substations (one onshore 300 kV to 230 kV and one offshore 230 kV to 66 kV)
- Lot 6: Submarine HVAC cable – approx. 200 km three core 230 kV

NSC05 standard contract format will be used as contract conditions as it is well known for contractors and well suited for this type of contract.

The tender documents comprise:
Invitation Letter
Tender rules
Form of Agreement
Conditions of Contract (NSC 05)
Exhibit A: Scope of Work
Exhibit B: Compensation
Exhibit C: Contract Schedule
Exhibit D: Administration Requirements
Exhibit E: Specifications
Exhibit F: Drawings
Exhibit G: Company Provided Items and Services.
Exhibit H: Subcontractors
Exhibit I: Company's Insurances
Exhibit J: Standard Bank Guarantee
Exhibit K: Contractor's Proprietary Information
Exhibit L: Parent Company Guarantee

The NSC05 contract standard is selected since this standard is custom made for this type of offshore operations involving subsea work and operation of cable installation vessels. This contract standard is well known to contractors operating on the NCS.

3.11 Time schedule

A time schedule is developed based on experience from similar projects. See Table 5. As stated in chapter 3.1 it is assumed that basic and conceptual engineering is done upfront this procurement strategy.

Preparations of tender documents should start early in year 1 so that they are ready to be sent out in the middle of first year. The remaining half year could then be used to tender process and contract negotiations. The contract negotiations process might take longer and it is important to agree with a contract content that is “well worked through” and understood by both parties and that the price is as fixed as possible. Bringing the uncertainty down and securing the implementation are main goals in the procurement phase.
The application and permit process might also take longer than in the schedule. It is therefore a question if contracts for cable manufacturing should be negotiated, signed and manufacturing started before all licences are in place. In this case it is assumed that manufacturing is started as soon as necessary planning and procurement is ready, otherwise the implementation could easily be delayed with one year.

Table 5 – Time schedule

Activity	**Year 1**		**Year 2**	**Year 3**	**Year 4**	
Planning and application for permit	■	■	▒			
Start prequalification and procurement process	■					
Procurement procedures and contract negotiations		■				
Manufacturing			■	■		
Installation				■	■	■
Commissioning						■

The schedule could be compressed with about 1 year if all manufacturing capacity at one supplier could be reserved for this project, but it might bring up the cost. An alternative is to split for example the two long DC cables between to different factories, manufacturing 200 km each during 1 year. That would probably also bring up the cost but shorten the implementation schedule.

3.12 Cost estimate

The supply and construction costs estimates are calculated on the basis of current market prices excluding VAT and other taxes. Having worked in the cable and substation/converter business, both in Norway and in the international market the reference projects and cost database is large. All costs are calculated and cross-checked with similar projects and equipment. Of confidentiality reasons it cannot be referenced to specific projects and prices.

There are some items and raw material prices that brings uncertainty to the pricing of each component. For submarine cables it is the copper and lead prices that are often subject to price adjustments in order to generate an equal “playing field” for the various cable manufacturers in a tender situation.

A more detailed cost estimate can be seen in Appendix 4, 5 and 6.
Included in the cost estimate is the complete EPC cost including all detailed engineering, material and manufacturing costs for cables and equipment complete, installed and commissioned. Included is also the civil works like buildings and space needed onshore.
Uncertainty is estimated to about ± 30 %, similar to an early phase estimate.

The costs are based on the following raw material prices:

Copper	6000 USD/ton
Lead	1900 USD/ton

Currency exchange rates:
1 EURO = 8,70 NOK
1 USD = 7,90 NOK

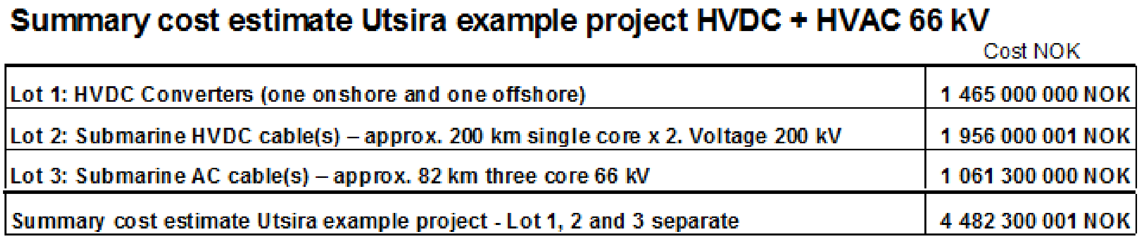
DC systems:
In this cost estimate the MI (Mass Impregnated) cable is used. Since this cable technology is "well proven" technology at large depths, no costs are included for development and for upgrading test equipment at the factory. XLPE DC cables can also be used, but price wise the cost per meter is estimated to be the same. If both MI and XLPE cables can be tendered there are multiple suppliers and supply lines. This will allow for competition.

The HVDC system includes two single core cables laid and buried in two separate laying and burial campaigns.

AC system:
For the AC system the three core submarine cable is chosen.
Transformers, reactors and switchgear are also included.

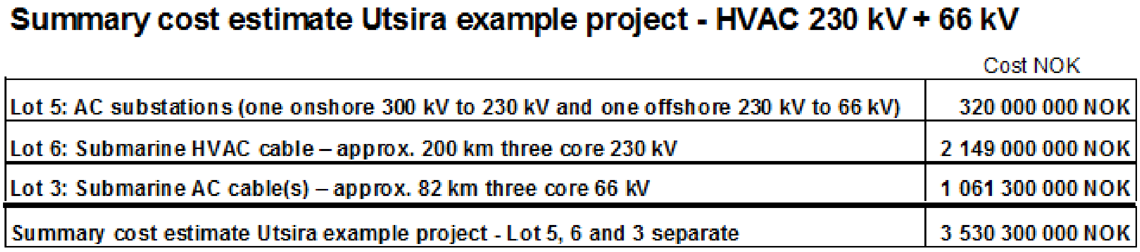
Installation of submarine cable:
- Fixed rate for mobilization of laying vessels and cable laying
- Provisional sum for trenching and protection. (Estimated provisional protection costs are based average costs from similar projects).

Table 6 – Summary cost estimate



Summary cost estimate Utsira example project HVDC + HVAC 66 kV

	Cost NOK
Lot 1: HVDC Converters (one onshore and one offshore)	1 465 000 000 NOK
Lot 2: Submarine HVDC cable(s) – approx. 200 km single core x 2. Voltage 200 kV	1 956 000 001 NOK
Lot 3: Submarine AC cable(s) – approx. 82 km three core 66 kV	1 061 300 000 NOK
Summary cost estimate Utsira example project - Lot 1, 2 and 3 separate	4 482 300 001 NOK



Summary cost estimate Utsira example project - HVAC 230 kV + 66 kV

	Cost NOK
Lot 5: AC substations (one onshore 300 kV to 230 kV and one offshore 230 kV to 66 kV)	320 000 000 NOK
Lot 6: Submarine HVAC cable – approx. 200 km three core 230 kV	2 149 000 000 NOK
Lot 3: Submarine AC cable(s) – approx. 82 km three core 66 kV	1 061 300 000 NOK
Summary cost estimate Utsira example project - Lot 5, 6 and 3 separate	3 530 300 000 NOK

3.13 Company organization

This type of EPC-contract requires a highly competent and experienced technical and contractual team on the Company side. The contractor(s) will be responsible for all engineering, procurement and construction (installation) so Company needs to closely follow-up that contractors engineering satisfies all the specifications and requirements given in the

Contract(s). Company also need to closely follow-up and monitor Contractor’s procurement, manufacturing and installation.
Target with the close follow-up by Company is to secure that quality requirements are met and that HSE is adhered to during the implementation of the Contract. No “short-cuts” to save money should be allowed.

To secure this target a small group of expert persons are needed in the Company team.

3.14 Type of tender procedure

Type of tender procedure will be negotiated procedure. This procedure allows for negotiations after the receipt of tenders and will secure that the tenders can be improved during the procurement process to achieve the best possible contract for both parties. For example scope clarifications can be done, requirements to quality and prices can be discussed and optimised.

With this type of negotiated tenders it is important to keep a very strict confidentiality between the negotiation parties and the various tenderers. Only official meetings should be allowed with traceable and recorded minutes.
Example from other contract negotiations is that prices has been lowered significant during such negotiations.

3.15 Award criteria

The contract should be awarded to the contractor evaluated according to the award criteria to be the Most Economically Advantageous Tender.

The award criteria selected for this electrification project is based on a high technical performance, track record and execution performance. Commercial aspects are also important and is therefore relatively high weighted.

Table 7 – Award Criteria

Award Criteria	Weighting
Commercial aspects: • Tender price • Compliance with commercial requirements • Power losses	45%
Technical aspects: • Cable supply/station supply, installation method and spread • Cable/station system design • Execution of engineering, type testing and trial tests • Interface handling • Compliance with technical requirements of tender documents	25%
Execution performance: • Quality management, assurance and control • Robust solutions, incl. equipment, tools, workability, planning of operations	15%

• HSE • Project organisation, incl. Subcontractors and competences of key persons	
Planning: • Delivery date • Overall planning • Risk management • Continuous improving	15%

The tender must include all relevant information in order to be evaluated according to the above criteria. Supplement documentation can be requested during the evaluation phase.

The award criteria and procurement strategy shall secure equal and fair treatment of all tenderers.

Since this is a negotiated tender each tenderer can during the contract negotiations, if he is shortlisted for negotiations, improve his tender within all the listed award criteria. For example by improving delivery date, project organisation, price, etcetera he might score additional points towards being the highest ranked tender in the competition.

3.16 Risk and success criteria

3.16.1 Risks

Experience from similar projects show that right handling of risks is one of the best success criteria for an executed project.
Historically submarine cable interconnection projects have been executed with a low degree of cost overrun (Statnett experience). This is related to interconnection project divided in lump sum EPC contracts to secure best possible competition and using the NSC 05 contract standard as basis for contract conditions. Offshore operation is based on day rates and weather risk on Company, but strict contract requirements to spreads that are suitable for North Sea weather conditions.

Procurement-related risks fall largely into the following groups:

- Insufficient capacity in "eligible" supplier base with potential schedule and/or cost impact
- Quality issues with potential schedule and/or cost impact
- Problems in interaction and communication between Company/project owners and contractors
- Potential shortage of project competence and resources both for Company and with contractors organization

Risks through execution:

- Delay in one contract will have large impact on the other contract
- Changes in scope after contract award will generate large additional costs
- Work needed but not covered by scope of work of the contracts

- Uncertainty in drawings and specifications
- Unclear definition of interfaces and work split at the interface points
- Uncoordinated interface execution

As for the risks highlighted in chapter 2.6.1 the following considerations are done:

Risk	**Considerations for PFS-solution Utsira**
Local content requirements	This has not been a requirement on NCS, but a target for the Norwegian government to have a local content as high as possible
Civil unrest in the immediate area	Not an issue for NCS
Harsh physical environment or climate	Climate conditions on NCS is quite harsh when it comes to rough weather conditions. Vessels should be fit for purpose
Political instability	Norway is seen as a political stable country
Unstable Regulatory Regime	Regulatory regime is stable and relatively predictable. To a certain degree regulatory regime can be a bit unstable with requirements towards the PFS-solutions to offshore platforms
High Potential for Craft Labour Shortage	With the current downturn in the offshore business the craft labour seems to be sufficient
Currency Exchange Risk	The Norwegian currency has been rather weak compared to foreign currencies latest years. This introduces a risk for contractors procuring for example large quantities of raw materials in the international market and with foreign currency. Solution can be to tender in foreign currency.
Uncapped liability provisions	Uncapped liability provisions can be a costly risk provision for contractors. It can therefore be an alternative for Company to limit contractor liability and to take over more liability risk themselves
Responsibility for consequential damages	Such risk can for example be liability for production stops or power outages in operational phase. Company can limit contractor's liability for consequential damages in order to get a reduced price from contractor. The balance of the risk will then stay with Company
Payment provisions	Payment provisions should be balanced meaning that generated work on the project/product should be paid relatively securing a neutral cash flow for the contractor and project value for the Company

Provisions for processing change and schedule extensions	Budget provisions for changes and flexibility in the schedule to allow for delay on some activities is important success criteria. Provisions should be made with knowledge from similar projects
Broad definitions of gross negligence	Only to use contractors with good reputation and successful track record

3.16.2 Handling of risks

Submarine cable manufacturing:

Submarine cable manufacturing is a controllable process where the factories have vast experience in procurement of materials, processing of materials and assembling all the various components to a complete submarine cable. The recommended compensation model is rate per meter cable delivered, but with adjustment on copper and lead prices in line with prices on the LME (London Metal Exchange) from tender date to contract signature. After contract signature the rate is fixed for the duration of the project. This will secure that all cable suppliers will use the same base LME value in the tender, but giving the manufacturer the right to adjust the price if there are fluctuations between tender stage and contract signature. The risk for raw material prices on copper and lead will therefore stay with the Company until contract signature.

The risk for all other raw materials, labour cost and manufacturing cost will stay with the Contractor/cable manufacturer.

Installation of submarine cables:

Installation of submarine cables consist of vessel mobilisation, cable loading and transport to site, cable laying and cable protection.

Vessel mobilisation, cable loading and transport to site are predictable operations and can be relatively easily calculated to a given number of days and duration. A fixed lump sum price can therefore be given by contractors without any significant risk to them.

Cable laying is an activity that is depending on type of installation vessel and performance during various weather conditions. Vessels used for installation is in contractual terms named “The Spread” and includes all necessary equipment and personnel to perform the job.

The specifications should be written in such a way that the installation Spread shall be able to operate within the normal weather conditions on site (meaning from shore to offshore platform). Contractors should be challenged to tender a fixed price lump sum for the whole laying and pull-in operations. Some contractors might make exceptions and claim cable laying to be on day rates (provisional sum) and on weather stand-by if weather is worse than operational limits. This can be costly for Company, and it is therefore important to secure cable laying vessels suited for the actual weather conditions. Lump sum prices versus day rates and assumed duration to be evaluated and ranked.

Cable protection can be burial by water jetting or protection by rock installation (rock dumping). Water jetting is by far much more cost effective.

Due to the consequences for cable failure the whole length of cable is buried/protected in the seabed. The depth of burial will depend if the soil is soft or hard, if there is fishing/trawling activities or major ship traffic. Cable protection work is therefore very risky for a contractor to give a lump sum price. If he should give a fixed price the risk provision would be very high. Experience from projects executed by Statnett show that day rates, but with clear goals on target depths, requirements to protection tools and skilled personnel/Company Representatives on board gives the best total prices and results.

Converter stations, substations and transformers:
Suppliers for converter stations usually works on EPC lump sum contracts. Scope of work is based on functional specifications and definition of the larger components. Prices should be broken down per structure and group of components to secure right pricing and make sure that all components are included.

3.16.3 Tools for getting progress

"One way to get people to act as you want is to structure their rewards so that it is in their interest to do so" [18].
In the contract the following methods can be used:

- Milestones measuring a certain amount of work completed
- Payment by achievement of milestones
- Creating incentives or bonuses in terms of money if certain targets are met (not commonly used)
- Give penalties if milestones/progress are not achieved

For the Utsira case a combination of milestone payments and liquidated damages is selected. This will give the contractor motivation to achieve milestones and to get progress.

3.16.4 Interfaces

The following interfaces are identified for the HVDC solution:

1. Between Onshore substation and the Utsira onshore substation/converter station
2. Between converter contractor onshore and submarine cable contractor (200 km)
3. Between submarine cable contractor (200 km) and converter contractor offshore
4. Between converter offshore and offshore platform contractor
5. Between converter offshore (incl. 66 kV Utsira) and offshore platform contractor Johan Sverdrup
6. Between converter offshore (incl. 66 kV Utsira) and submarine cable contractor 66 kV Gina Krog
7. Between converter offshore (incl. 66 kV Utsira) and submarine cable contractor 66 kV Edvard Grieg
8. Between submarine cable contractor 66 kV Edvard Grieg and offshore platform contractor Gina Krog
9. Between submarine cable contractor 66 kV Edvard Grieg and offshore platform contractor Edvard Grieg
10. Between offshore platform contractor Edvard Grieg and submarine cable contractor 66 kV Ivar Aasen
11. Between submarine cable contractor 66 kV Ivar Aasen and offshore platform contractor Ivar Aasen

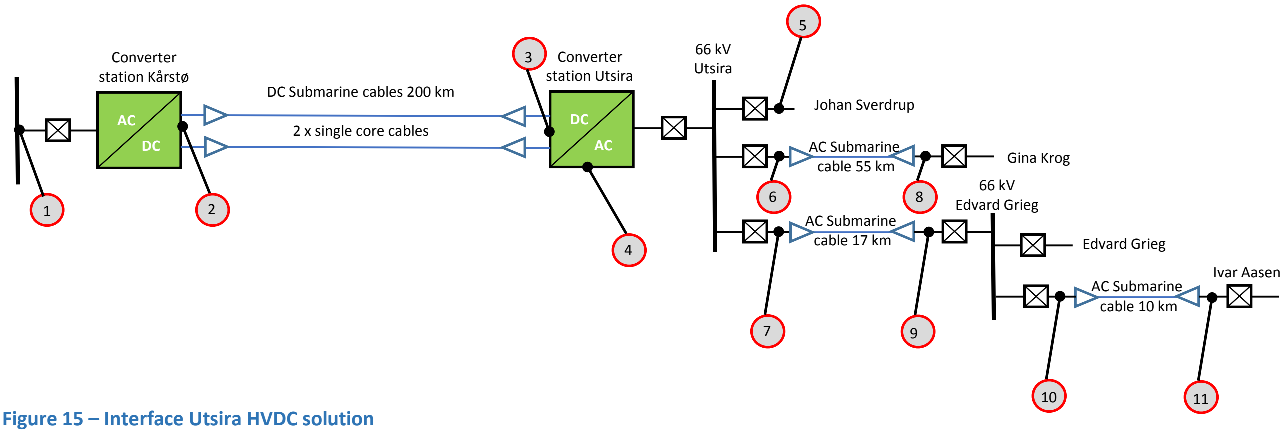


Figure 15 – Interface Utsira HVDC solution

For the HVAC solution the interfaces will be the same except that the converter will be a substation and the 200 km submarine cable will be installed as one three core cable instead of two single core cables.

If one contractor gets several lots the number of interfaces might be reduced.

4 ANALYSIS AND DISCUSSION

This chapter presents the analysis and discussion combining the theory given in chapter 2 with the contract considerations and strategy presented in chapter 3.

Project goals in a market with limited competition

The project overall goals need to be clear at an early stage and the current marked situation related to suppliers of submarine cables and converters/substations must be investigated. Procurement in a market characterized by limited competition can be challenging and more expensive than it needs to be. To avoid a situation without competition time available is a critical factor as well as taking the right decisions early in the procurement strategy phase.

PFS-solution require complex technology and requires suppliers with expert knowledge and experience. Definition of contract packages or Lots is important to stimulate competition and should be considered if newcomers can be qualified as supplier. By allowing newcomers introduces a new risk, but a mitigating action will be to select a new coming product from an experienced supplier from a multibillion USD company. Financial and technical strength are key words. Pricing and tender content committed by the newcomer a deciding factor.

Fixed price and contract standard

For the developing company the size of investment costs and predictability is important and ideally a fixed price lump sum contract is preferred. Turnkey suppliers will always price the risks high and the lump sum price might be too high for the project to be commercial viable. Sharing risks between Company and Contractor will be to select a contract standard that is balanced and a compensation format that allows for predictability for both Company and Contractor. The NSC 05 contract standard is developed for the Norwegian Continental Shelf and custom made for projects involving marine operations and installations. PFS-project is well suited for the use of the NSC 05 contract standard.

The level of technical definition must be high for the turnkey suppliers to accept a lump sum, but for a submarine cable supply the rate per meter is most common. Since the cable length is known the rate per meter times the length will give a fixed lump sum price.

Cable laying offshore can possibly be priced as a lump sum, but contractors prefers to price a day rate with the allowance for standby weather. For Company to accept a day rate for installation there must be some guaranteed operational parameters like for example that the laying vessel should be able to operate at a maximum wind speed of 10 knots and wave height 3 m, or a guaranteed installed length per day.

For cable burial and protection it is from contractor side seen as a very high risk to give a lump sum price. The established practice in the cable business is to pay a day rate (provisional sum) for protection work. This involves an increased risk for Company if more protection is needed or if the conditions appear to be more difficult and time consuming than estimated. The lump sum from contractors would still be significant higher since they have to take this risk provision for additional days into account when giving the lump sum price.

For converters and substations a lump sum price is common practise as long as the scope of work is clear and defined. Weight and size are critical and price driving factors both for the offshore converter stations (and substations), but also for the platform cost. Changes on a later stage will give additional costs.

For the onshore station a significant part of the works is civil works. Such works are ground works, concrete works, building and technical installations. If substation or converter contractors price these civil works too high there is an option to do these civil works under a separate contract. Separating civil works will give additional interfaces, but it will perhaps give a lower total price.

Success criteria

To negotiate a good contract is in many ways similar to buying and selling houses. First you need to make the house look attractive. Then you need to create a biggest possible number of people interested in buying the house (marketing). The next step will then be to make a bidding competition to bring up the price for the house as high as possible. As many buyers have experienced bitterly, the more popular and number of interested people the higher the price.

As an analogy between procurement strategy and selling a house; it is all about making the tender attractive for the contractors. It is of course easier to make a project attractive when there is lack or work and several qualified contractors, but also in a “hot” market some projects and contracts are more attractive than others. “Trust” in the developing company and previous experience is an important word. To prepare a bid for this kind of project cost a lot of money, and the contractors will always make an assessment before they decide to make a bid if:

- Who is the Company and previous experience?
- How is the contract strategy and tender content. Does it fit to core business?
- Competition with other suppliers?
- Capacity to execute project? (Spare capacity or need to increase staff and manufacturing capacity?)
- What are the chances to succeed with the bid?
- What can the profit be if the contract is secured?

For the developing company it is important to get a reasonable number of good qualified bids. Ideal would be to have between three to six bids. This will give good competition, but also a reasonable chance for the contractor to get the job. If there is too much competition and too many bids there is a chance that the effort and quality in each bid is low.

In opposite direction to selling a house; if there are more qualified contractors to give a bid (up to a reasonable number of contractors) the lower will the cost be for the developing company.

Milestones

Milestones and progress payment is seen as the best way of measuring and achieving progress in a combination with applying liquidated damages (LD) if milestones are not achieved. The project must be divided into measurable packages that can be fulfilled and completed as a part delivery or step towards the completion of the whole project. Applying milestones and LDs can divert Contractor’s focus away from the overall targets and to focus all his attention on milestones with the highest penalty, but if the milestones are well defined and portioned out in time the achievement of milestones will secure steady progress and cash flow. Planning of implementation schedule and milestones is therefore crucial.

Government guidelines

For offshore development projects the government has to give predictable guidelines, laws and regulations when it comes to Power From Shore. Each offshore development is different from the other and some are easier and cheaper to electrify from shore than others. By for example issuing a law stating that "All new offshore platforms or installations shall be powered from shore", then the focus from project start would be to find a functional and efficient power solution instead of focusing on if the power should come from shore or not.
Statoil and partners seems to have spent the time from discovery in 2010 until 2014 to argue back and forth with the government about the issue of PFS-solution, ending up in a costly and less flexible solution [19]. Perhaps it was the short time from decision late 2014 when Statoil applied for concession for the PFS-solution to NVE until first oil production start in 2019 that forced Statoil to make the decision?

Timeframe for project

Allowing enough time for a proper tender and contract negotiation phase is crucial to achieve a best possible contract with a well-defined scope of work, technical requirements and milestone compensation format. Rushing in the tender negotiation phase can lead to important details to be left out, and it can be costly to have them implemented at a later stage.

Contractor advise

Guideline on a general basis would be to never involve only one supplier in an early phase of a PFS-project (during concept development phase, before procurement strategy phase), since suppliers target with their advices will always be to sell his specific technical solution and to avoid competition. The developing company must strive to apply standardized solutions opening up for multiple suppliers and contractors. This will give good technical solutions and cost effective prices.

AC solution most cost effective

As shown in the case example for Utsira it could have been possible with an AC solution and it could have been more cost effective compared to the DC solution. The costs calculated in this thesis is significant lower than the estimates given by Statoil in reference [13] "Power solutions for Johan Sverdrup". Prices are not checked out item by item but it appears to be a large gap between the total sums.

5 CONCLUSION

This chapter concludes the recommended procurement strategy for offshore electrification projects.

The hypothesis was that electrification projects require technology and expertise that would have limited number of suppliers and could lead to a monopoly situation or limited competition – unnecessary high prices.

As presented in the example project – Utsira – It was shown that even such a large electrification project does not lead to monopoly situation subject to having flexibility within the choice of AC or DC solution, allowing both for extruded DC cable as well as MI DC cable.
Only one supplier offers both submarine cables and converter stations, while several suppliers offers only submarine cables or converter stations. Several suppliers offer AC substations.

Recommendation is therefore to split contract packages in different lots to allow several submarine cable suppliers to tender as well as several converter contractors and AC substation contractors.

About 4 years are needed for implementation but time can be reduced if manufacturing is split on several plants and that manufacturing is started perhaps before all licensing and permits are in place. Allowing sufficient time for prequalification, tender and negotiation phase is important to secure a “well worked through” scope of work and contract document ready for signature.

Government has to give predictable guidelines, laws and regulations related to PFS-solutions for the development of offshore fields.
Developing company must not involve with only one supplier in an early phase of the development phase since this can lead to technical solution with only one supplier. One qualified supplier gives no competition.

5.1 Further work

Further work would be to execute this procurement strategy on a real project. Statoil has selected a different procurement strategy for the Utsira project, dividing the electrification in different phases [13] and selected ABB as their supplier of HVDC cables and converter stations for phase 1. (100 MW) [20] and [21]. Phase 2 will require a full new and parallel system since the phase 1 system cannot be expanded or increased capacity. Phase 1 is calculated to cost 6 billion NOK (2013) while phase 2 is estimated to be between 6 to 8 billion NOK (2013) [13].

6 REFERENCES

[1] Osmundsen, Petter. *Contract establishment.* Lecture in Contract management and execution – IND610 – UIS 2014

[2] Finansdepartementet. *Veileder nr. 7 – Kontraktstrategi*. Versjon 1.0, datert 5.5.2008

[3] Norsk Industri. *Norwegian Fabrication Contract 07 (NF 07).* 2007

[4] Norsk Industri. *Norwegian Total Contract 07 (NTK 07)*. 2007

[5] OLF. *Norwegian Subsea Contract 05 (NSC 05)*. 2005

[6] Amundsen 2015. *Implementation and Division of Operational Risk in Contracts between a Service Company and Operators.* Master Thesis UIS 2015

[7] Rudolfsen, Frode 2001. *Strømforsyning til offshoreplattformer over lange vekselstrøm sjøkabelforbindelser*. Project thesis NTNU 2001

[8] Grimm, V. Pacini, R. Spagnolo, G. Zanza. M - *Division in Lots and Competition in Procurement*. Cambridge University Press (2006)

[9] J-power.co.jp. J-*Power Systems Wins Contract with NEMO LINK for HVDC Subsea Interconnector Cable System between UK and Belgium.* Press release downloaded from www.jpowers.co.jp [Downloaded 22.05.2016]

[10] Merrow, Edward W. *Industrial Megaprojects.* John Wiley & Sons. *2011*

[11] Statoil. *Utsirahøyden Elektrifiseringsprosjekt,* Statoil 2012. Available from http://www.statoil.com/no/EnvironmentSociety/Environment/impactassessments/JSutredninger/Pages/JSKraftFraLand.aspx. [Downloaded 07.02.2016]

[12] Ballari, Anders. *Electrification of the Utsira formation*. Master Thesis UIA June 2013

[13] Statoil. *Power solutions for Johan Sverdrup.* Statoil 2014. Available from http://www.statoil.com/no/EnvironmentSociety/Environment/impactassessments/JSutredninger/Downloads/Powersolutions.pdf. [Downloaded 06.04.2016]

[14] NVE. *Kraft fra land til norsk sokkel*. NVE Januar 2008

[15] Rudolfsen, F. Balog, G. Evenset, G. *Energy transmission on long three core/three foil XLPE power cables*. JICABLE 2003

[16] Rudolfsen, F. Balog, G. Evenset, G. *Power transmission over long three core submarine AC cables.* Third International Workshop on Transmission Networks for Offshore Wind Farms 11-12 April 2002

[17] Balog, G. Rudolfsen, F. Christl, N. Evenset, G. *Power transmission over long distances with cables.* B1-306, Cigré 2004

[18] McMillan, John. *Games Strategies and Managers.* Oxford University Press. 1996

[19] Statoil. *Johan Sverdrup – Kraft fra land - Søknad om anleggskonsesjon etter energiloven, og ekspropriasjonstillatelse og forhåndstiltredelse etter oreigningslova.* Statoil 2014. Available from http://www.statoil.com/no/EnvironmentSociety/Environment/impactassessments/JSutredninger/Pages/JSKraftFraLand.aspx . [Downloaded 22.05.2016]

[20] ABB.com. *ABB wins $90-million order to supply world's longest extruded 'power from shore' cable*. Press release Sept. 16, 2015 [Downloaded 10.05.2016]

[21] ABB.com. *ABB wins $155 million order to power large North Sea oilfield*. Press release March. 16, 2015 [Downloaded 10.05.2016]

[22] Osmundsen, Petter. *Optimal kontraktsdesign for offshore-prosjekter**, Økonomisk forum NR 7, 2006

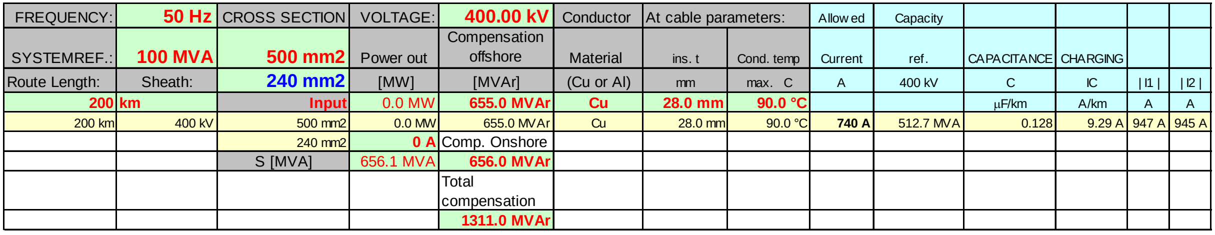
[23] Osmundsen, Petter. *Elektrifisering som klimatiltak? En samfunnsøkonomisk analyse*, Samfunnsøkonomen NR 1, 2012

[24] ZERO (Silje Lundberg og Kari Elisabeth Kaski). STRØM FRA LAND TIL OLJE- OG GASSPLATTFORMER, november 2011
[25] Aftenbladet.no. *Du betaler for elektrifisering av sokkelen*, 14. February 2014
[26] Aftenbladet.no. Lien: Johan Sverdrup skal drives med kraft fra land. 16. January 2014
[27] Dagens Næringsliv. *Elektrifisering av sokkelen*. DN 17.05.2014
[28] Aftenposten. *Ormen Lange tilpasses industrien.* Aftenposten 14.03.2003
[29] Regjeringen.no. *Fornybar energiproduksjon i Norge.* Regjeringen.no 08.12.2014
[30] Pedersen, Hildegunn Ravnås. *Regulering av The Spread i Norwegian Subsea Contract 2005*. Master Thesis UIO 2005
[31] Teknisk Ukeblad. *Goliat må granskes*. TU 03.2016
[32] Energi Norge (Add Energy). *Kraft fra land til Utsirahøyden.* 2014
[33] Rudolfsen, Frode. *Driftsforhold for lange AC sjøkabler.* Master thesis NTNU 2002
[34] Osmundsen, Petter. *Landkraft til havs: Hvem er det som spør?,* 2012-02, Universitetsforlaget.

Other references and discussion partners at Statnett:
[A] Jan Erik Skog
[B] Jan Nyborg
[C] Jørgen Thon
[D] Jan Stensrud
[E] Gunnar Evenset
[F] Rune Øverås

1. Appendix 1 – Cable calculations 400 kV

No load charging current: (400 kV)

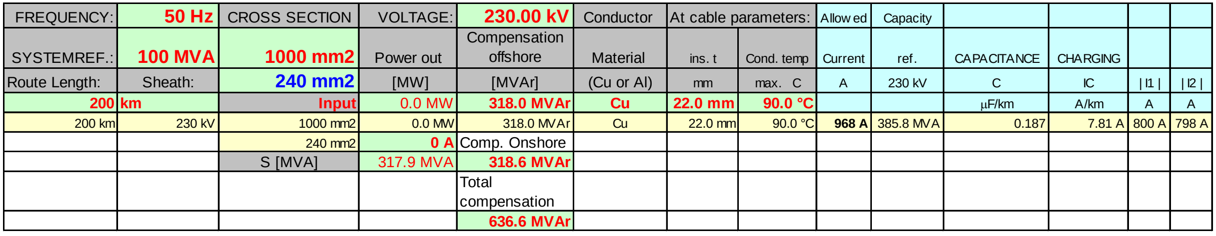


FREQUENCY:	50 Hz	CROSS SECTION	VOLTAGE:	400.00 kV	Conductor	At cable parameters:		Allowed	Capacity				
SYSTEMREF.:	100 MVA	500 mm2	Power out	Compensation offshore	Material	ins. t	Cond. temp	Current	ref.	CAPACITANCE	CHARGING		
Route Length:	Sheath:	240 mm2	[MW]	[MVAr]	(Cu or Al)	mm	max. C	A	400 kV	C	IC	| I1 |	| I2 |
200	km	Input	0.0 MW	655.0 MVAr	Cu	28.0 mm	90.0 °C			µF/km	A/km	A	A
200 km	400 kV	500 mm2	0.0 MW	655.0 MVAr	Cu	28.0 mm	90.0 °C	**740 A**	512.7 MVA	0.128	9.29 A	947 A	945 A
		240 mm2	0 A	Comp. Onshore									
		S [MVA]	656.1 MVA	656.0 MVAr									
				Total compensation									
				1311.0 MVAr									

As can be seen in the calculation the charging current is higher that the allowed current capacity. 400 kV HVAC solution for 200 km length is therefore not feasible even if the charging current is compensated half from both side.

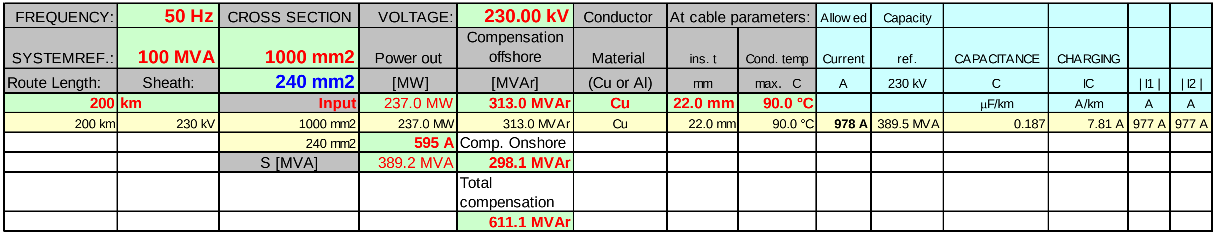
2. Appendix 2 – Cable calculations 230 kV

No load charging current: (230 kV)



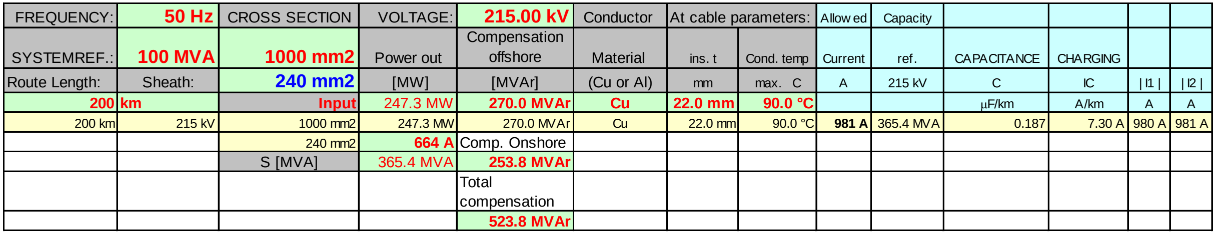
FREQUENCY:	50 Hz	CROSS SECTION	VOLTAGE:	230.00 kV	Conductor	At cable parameters:		Allowed	Capacity				
SYSTEMREF.:	100 MVA	1000 mm2	Power out	Compensation offshore	Material	ins. t	Cond. temp	Current	ref.	CAPACITANCE	CHARGING		
Route Length:	Sheath:	240 mm2	[MW]	[MVAr]	(Cu or Al)	mm	max. C	A	230 kV	C	IC	| I1 |	| I2 |
200	km	Input	0.0 MW	318.0 MVAr	Cu	22.0 mm	90.0 °C			µF/km	A/km	A	A
200 km	230 kV	1000 mm2	0.0 MW	318.0 MVAr	Cu	22.0 mm	90.0 °C	**968 A**	385.8 MVA	0.187	7.81 A	800 A	798 A
		240 mm2	0 A	Comp. Onshore									
		S [MVA]	317.9 MVA	318.6 MVAr									
				Total compensation									
				636.6 MVAr									

Max power: (230 kV)



FREQUENCY:	50 Hz	CROSS SECTION	VOLTAGE:	230.00 kV	Conductor	At cable parameters:		Allowed	Capacity				
SYSTEMREF.:	100 MVA	1000 mm2	Power out	Compensation offshore	Material	ins. t	Cond. temp	Current	ref.	CAPACITANCE	CHARGING		
Route Length:	Sheath:	240 mm2	[MW]	[MVAr]	(Cu or Al)	mm	max. C	A	230 kV	C	IC	| I1 |	| I2 |
200	km	Input	237.0 MW	313.0 MVAr	Cu	22.0 mm	90.0 °C			µF/km	A/km	A	A
200 km	230 kV	1000 mm2	237.0 MW	313.0 MVAr	Cu	22.0 mm	90.0 °C	**978 A**	389.5 MVA	0.187	7.81 A	977 A	977 A
		240 mm2	595 A	Comp. Onshore									
		S [MVA]	389.2 MVA	298.1 MVAr									
				Total compensation									
				611.1 MVAr									

Max power: (Lower the feeding voltage to 215 kV)



FREQUENCY:	50 Hz	CROSS SECTION	VOLTAGE:	215.00 kV	Conductor	At cable parameters:		Allowed	Capacity				
SYSTEMREF.:	100 MVA	1000 mm2	Power out	Compensation offshore	Material	ins. t	Cond. temp	Current	ref.	CAPACITANCE	CHARGING		
Route Length:	Sheath:	240 mm2	[MW]	[MVAr]	(Cu or Al)	mm	max. C	A	215 kV	C	IC	| I1 |	| I2 |
200	km	Input	247.3 MW	270.0 MVAr	Cu	22.0 mm	90.0 °C			µF/km	A/km	A	A
200 km	215 kV	1000 mm2	247.3 MW	270.0 MVAr	Cu	22.0 mm	90.0 °C	**981 A**	365.4 MVA	0.187	7.30 A	980 A	981 A
		240 mm2	664 A	Comp. Onshore									
		S [MVA]	365.4 MVA	253.8 MVAr									
				Total compensation									
				523.8 MVAr									

Lowering the feeding voltage will reduce the charging current allowing more active current to flow through the link increasing the active power output at Utsira from 237 MW to 247 MW. Transmission losses will be about 5.1 to 5.5 % of transmitted power.

3. Appendix 3 – Cable calculations 66 kV

No load charging current: (66 kV and 17+10 km)

FREQUENCY:	**50 Hz**	CROSS SECTION	VOLTAGE:	**66.00 kV**	Conductor	Ambient	At cable parameters:		Allowed	Capacity				
SYSTEMREF.:	**100 MVA**	**400 mm2**	Power out	Compensation	Material	temperature	ins. t	Cond. temp	Current	ref.	CAPACITANCE	CHARGING		
Route Length:	Sheath:	**50 mm2**	[MW]	[MVAr]	(Cu or Al)		mm	max. C	A	66 kV	C	IC	| I1 |	| I2 |
27	**km**	**Input**	0.0 MW	**3.4 MVAr**	**Cu**	**15.0 °C**	**14.0 mm**	**90.0 °C**			µF/km	A/km	A	A
27 km	66 kV	400 mm2	0.0 MW	3.4 MVAr	Cu	15.0 °C	14.0 mm	90.0 °C	**658 A**	75.2 MVA	0.188	2.25 A	31 A	30 A
		50 mm2	**0 A**	Comp. Onshore										
		S [MVA]	0.0 MVA	**3.6 MVAr**										
				Total compensation										
				7.0 MVAr										

Max power: (66 kV and 17+10 km)

FREQUENCY:	**50 Hz**	CROSS SECTION	VOLTAGE:	**66.00 kV**	Conductor	Ambient	At cable parameters:		Allowed	Capacity				
SYSTEMREF.:	**100 MVA**	**400 mm2**	Power out	Compensation	Material	temperature	ins. t	Cond. temp	Current	ref.	CAPACITANCE	CHARGING		
Route Length:	Sheath:	**50 mm2**	[MW]	[MVAr]	(Cu or Al)		mm	max. C	A	66 kV	C	IC	| I1 |	| I2 |
27	**km**	**Input**	68.6 MW	**1.5 MVAr**	**Cu**	**15.0 °C**	**14.0 mm**	**90.0 °C**			µF/km	A/km	A	A
27 km	66 kV	400 mm2	68.6 MW	1.5 MVAr	Cu	15.0 °C	14.0 mm	90.0 °C	**669 A**	76.5 MVA	0.188	2.25 A	621 A	621 A
		50 mm2	**600 A**	Comp. Onshore										
		S [MVA]	68.6 MVA	**1.7 MVAr**										
				Total compensation										
				3.2 MVAr										

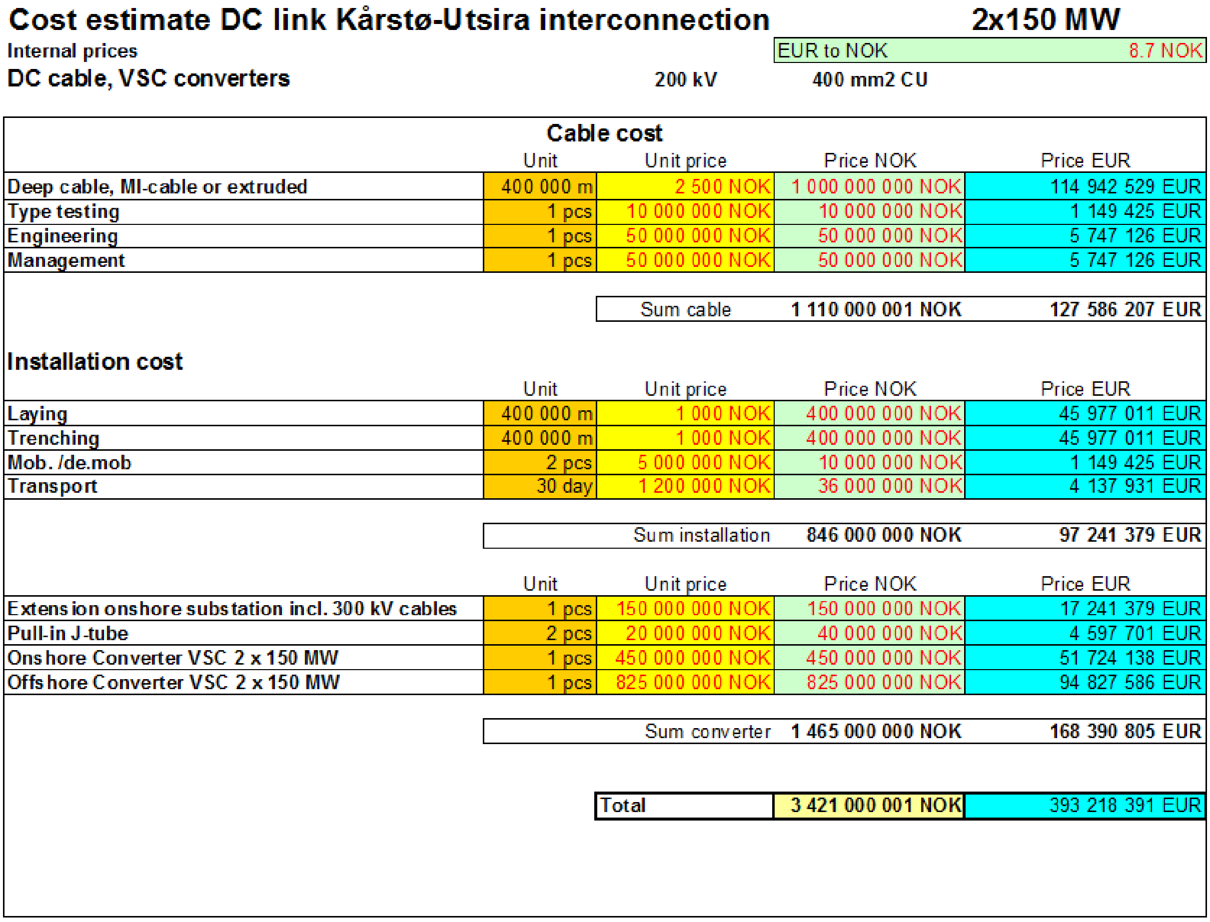
No load charging current: (66 kV and 55 km)

FREQUENCY:	**50 Hz**	CROSS SECTION	VOLTAGE:	**66.00 kV**	Conductor	Ambient	At cable parameters:		Allowed	Capacity				
SYSTEMREF.:	**100 MVA**	**400 mm2**	Power out	Compensation	Material	temperature	ins. t	Cond. temp	Current	ref.	CAPACITANCE	CHARGING		
Route Length:	Sheath:	**50 mm2**	[MW]	[MVAr]	(Cu or Al)		mm	max. C	A	66 kV	C	IC	| I1 |	| I2 |
55	**km**	**Input**	0.0 MW	**7.1 MVAr**	**Cu**	**15.0 °C**	**14.0 mm**	**90.0 °C**			µF/km	A/km	A	A
55 km	66 kV	400 mm2	0.0 MW	7.1 MVAr	Cu	15.0 °C	14.0 mm	90.0 °C	**658 A**	75.2 MVA	0.188	2.25 A	62 A	62 A
		50 mm2	**0 A**	Comp. Onshore										
		S [MVA]	0.0 MVA	**7.1 MVAr**										
				Total compensation										
				14.2 MVAr										

Max power: (66 kV and 55 km)

FREQUENCY:	**50 Hz**	CROSS SECTION	VOLTAGE:	**66.00 kV**	Conductor	Ambient	At cable parameters:		Allowed	Capacity				
SYSTEMREF.:	**100 MVA**	**400 mm2**	Power out	Compensation	Material	temperature	ins. t	Cond. temp	Current	ref.	CAPACITANCE	CHARGING		
Route Length:	Sheath:	**50 mm2**	[MW]	[MVAr]	(Cu or Al)		mm	max. C	A	66 kV	C	IC	| I1 |	| I2 |
55	**km**	**Input**	45.7 MW	**5.0 MVAr**	**Cu**	**15.0 °C**	**14.0 mm**	**90.0 °C**			µF/km	A/km	A	A
55 km	66 kV	400 mm2	45.7 MW	5.0 MVAr	Cu	15.0 °C	14.0 mm	90.0 °C	**663 A**	75.8 MVA	0.188	2.25 A	421 A	419 A
		50 mm2	**400 A**	Comp. Onshore										
		S [MVA]	45.7 MVA	**5.7 MVAr**										
				Total compensation										
				10.7 MVAr										

4. Appendix 4 – Cost estimate HVDC



Cost estimate DC link Kårstø-Utsira interconnection **2x150 MW**

Internal prices

EUR to NOK 8.7 NOK

DC cable, VSC converters 200 kV 400 mm2 CU

Cable cost

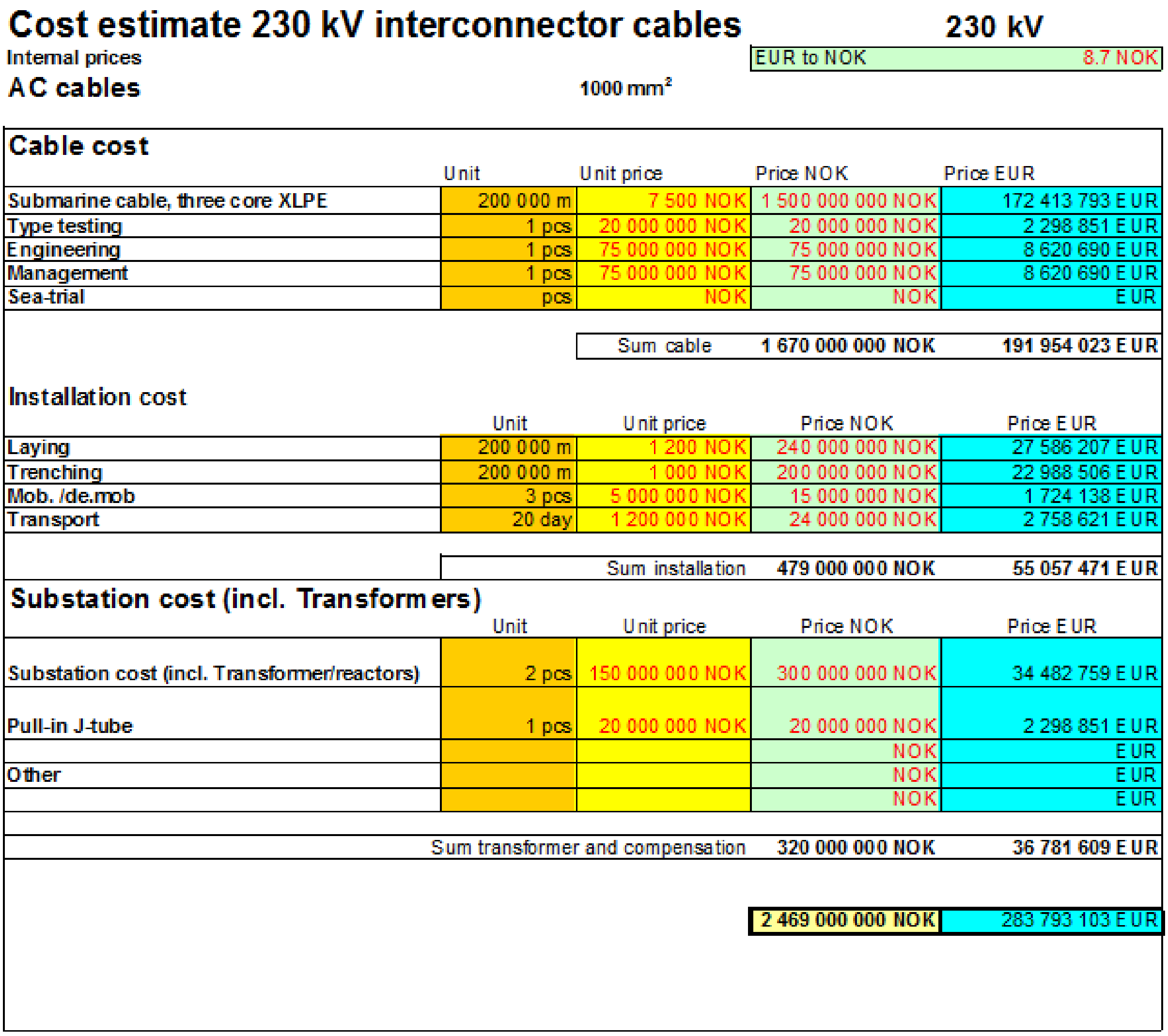
	Unit	Unit price	Price NOK	Price EUR
Deep cable, MI-cable or extruded	400 000 m	2 500 NOK	1 000 000 000 NOK	114 942 529 EUR
Type testing	1 pcs	10 000 000 NOK	10 000 000 NOK	1 149 425 EUR
Engineering	1 pcs	50 000 000 NOK	50 000 000 NOK	5 747 126 EUR
Management	1 pcs	50 000 000 NOK	50 000 000 NOK	5 747 126 EUR
		Sum cable	1 110 000 001 NOK	127 586 207 EUR

Installation cost

	Unit	Unit price	Price NOK	Price EUR
Laying	400 000 m	1 000 NOK	400 000 000 NOK	45 977 011 EUR
Trenching	400 000 m	1 000 NOK	400 000 000 NOK	45 977 011 EUR
Mob. /de.mob	2 pcs	5 000 000 NOK	10 000 000 NOK	1 149 425 EUR
Transport	30 day	1 200 000 NOK	36 000 000 NOK	4 137 931 EUR
		Sum installation	846 000 000 NOK	97 241 379 EUR

	Unit	Unit price	Price NOK	Price EUR
Extension onshore substation incl. 300 kV cables	1 pcs	150 000 000 NOK	150 000 000 NOK	17 241 379 EUR
Pull-in J-tube	2 pcs	20 000 000 NOK	40 000 000 NOK	4 597 701 EUR
Onshore Converter VSC 2 x 150 MW	1 pcs	450 000 000 NOK	450 000 000 NOK	51 724 138 EUR
Offshore Converter VSC 2 x 150 MW	1 pcs	825 000 000 NOK	825 000 000 NOK	94 827 586 EUR
		Sum converter	1 465 000 000 NOK	168 390 805 EUR
		Total	3 421 000 001 NOK	393 218 391 EUR

5. Appendix 5 – Cost estimate 230 kV HVAC 200 km



Cost estimate 230 kV interconnector cables **230 kV**

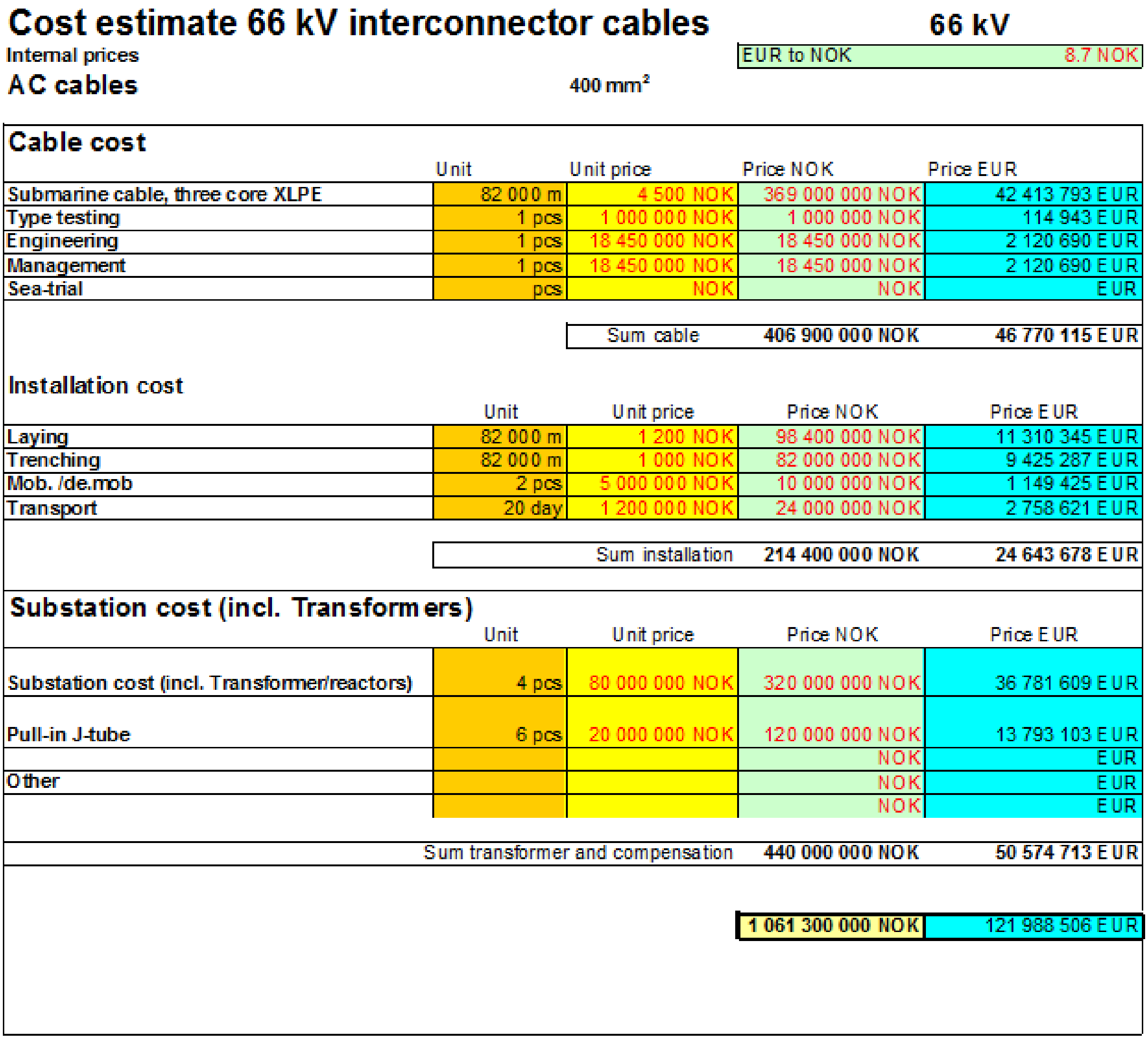
Internal prices

EUR to NOK 8.7 NOK

AC cables 1000 mm^2

Cable cost	Unit	Unit price	Price NOK	Price EUR
Submarine cable, three core XLPE	200 000 m	7 500 NOK	1 500 000 000 NOK	172 413 793 EUR
Type testing	1 pcs	20 000 000 NOK	20 000 000 NOK	2 298 851 EUR
Engineering	1 pcs	75 000 000 NOK	75 000 000 NOK	8 620 690 EUR
Management	1 pcs	75 000 000 NOK	75 000 000 NOK	8 620 690 EUR
Sea-trial	pcs	NOK	NOK	EUR
		Sum cable	**1 670 000 000 NOK**	**191 954 023 EUR**
Installation cost	Unit	Unit price	Price NOK	Price EUR
Laying	200 000 m	1 200 NOK	240 000 000 NOK	27 586 207 EUR
Trenching	200 000 m	1 000 NOK	200 000 000 NOK	22 988 506 EUR
Mob. /de.mob	3 pcs	5 000 000 NOK	15 000 000 NOK	1 724 138 EUR
Transport	20 day	1 200 000 NOK	24 000 000 NOK	2 758 621 EUR
		Sum installation	**479 000 000 NOK**	**55 057 471 EUR**
Substation cost (incl. Transformers)	Unit	Unit price	Price NOK	Price EUR
Substation cost (incl. Transformer/reactors)	2 pcs	150 000 000 NOK	300 000 000 NOK	34 482 759 EUR
Pull-in J-tube	1 pcs	20 000 000 NOK	20 000 000 NOK	2 298 851 EUR
			NOK	EUR
Other			NOK	EUR
			NOK	EUR
		Sum transformer and compensation	**320 000 000 NOK**	**36 781 609 EUR**
			2 469 000 000 NOK	283 793 103 EUR

6. Appendix 6 – Cost estimate 66 kV HVAC



Cost estimate 66 kV interconnector cables **66 kV**

Internal prices

EUR to NOK	8.7 NOK

AC cables 400 mm²

Cable cost

	Unit	Unit price	Price NOK	Price EUR
Submarine cable, three core XLPE	82 000 m	4 500 NOK	369 000 000 NOK	42 413 793 EUR
Type testing	1 pcs	1 000 000 NOK	1 000 000 NOK	114 943 EUR
Engineering	1 pcs	18 450 000 NOK	18 450 000 NOK	2 120 690 EUR
Management	1 pcs	18 450 000 NOK	18 450 000 NOK	2 120 690 EUR
Sea-trial	pcs	NOK	NOK	EUR
		Sum cable	406 900 000 NOK	46 770 115 EUR

Installation cost

	Unit	Unit price	Price NOK	Price EUR
Laying	82 000 m	1 200 NOK	98 400 000 NOK	11 310 345 EUR
Trenching	82 000 m	1 000 NOK	82 000 000 NOK	9 425 287 EUR
Mob. /de.mob	2 pcs	5 000 000 NOK	10 000 000 NOK	1 149 425 EUR
Transport	20 day	1 200 000 NOK	24 000 000 NOK	2 758 621 EUR
		Sum installation	214 400 000 NOK	24 643 678 EUR

Substation cost (incl. Transformers)

	Unit	Unit price	Price NOK	Price EUR
Substation cost (incl. Transformer/reactors)	4 pcs	80 000 000 NOK	320 000 000 NOK	36 781 609 EUR
Pull-in J-tube	6 pcs	20 000 000 NOK	120 000 000 NOK	13 793 103 EUR
			NOK	EUR
Other			NOK	EUR
			NOK	EUR
		Sum transformer and compensation	440 000 000 NOK	50 574 713 EUR
			1 061 300 000 NOK	121 988 506 EUR