NAE-GRP
Opportunities and Challenges in Offshore Wind

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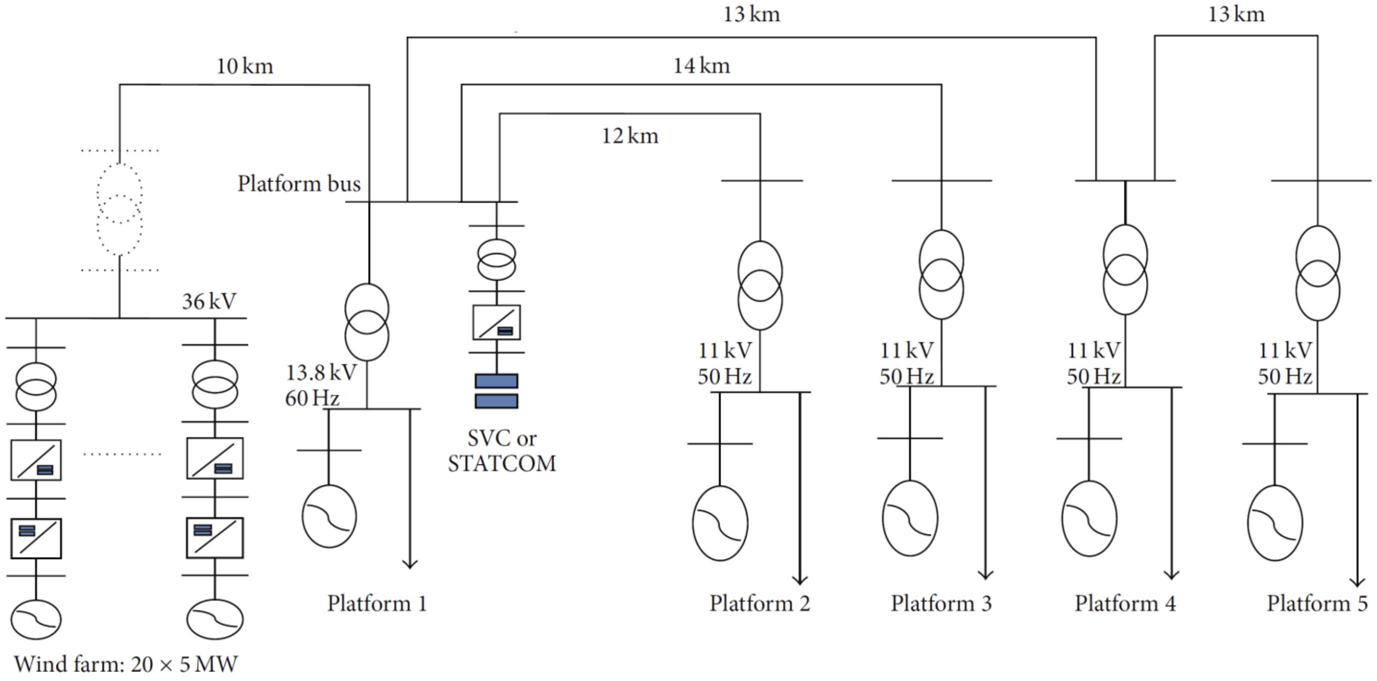
Offshore Wind Applications

1. Offshore wind for oil and gas extraction plants including Subsea systems
2. Offshore wind for Green Hydrogen
3. Offshore wind for shore power and powering the vessels
4. Offshore wind power for integrating with the onshore grid.

1A- Interconnection of Wind Farm to Offshore Grid

- Offshore deep-water Oil and Gas production systems require significantly large electrical power to drive high capacity electric submersible pumps and compressor motors located at the seabed.
- Most platforms generate their own electrical power by gas turbines. The gas turbines are also used to directly drive compressors and pumps. These gas turbines generate about 80% of the total CO_2 and NOx emissions from offshore installations. **Use of offshore wind will reduce these emissions.**

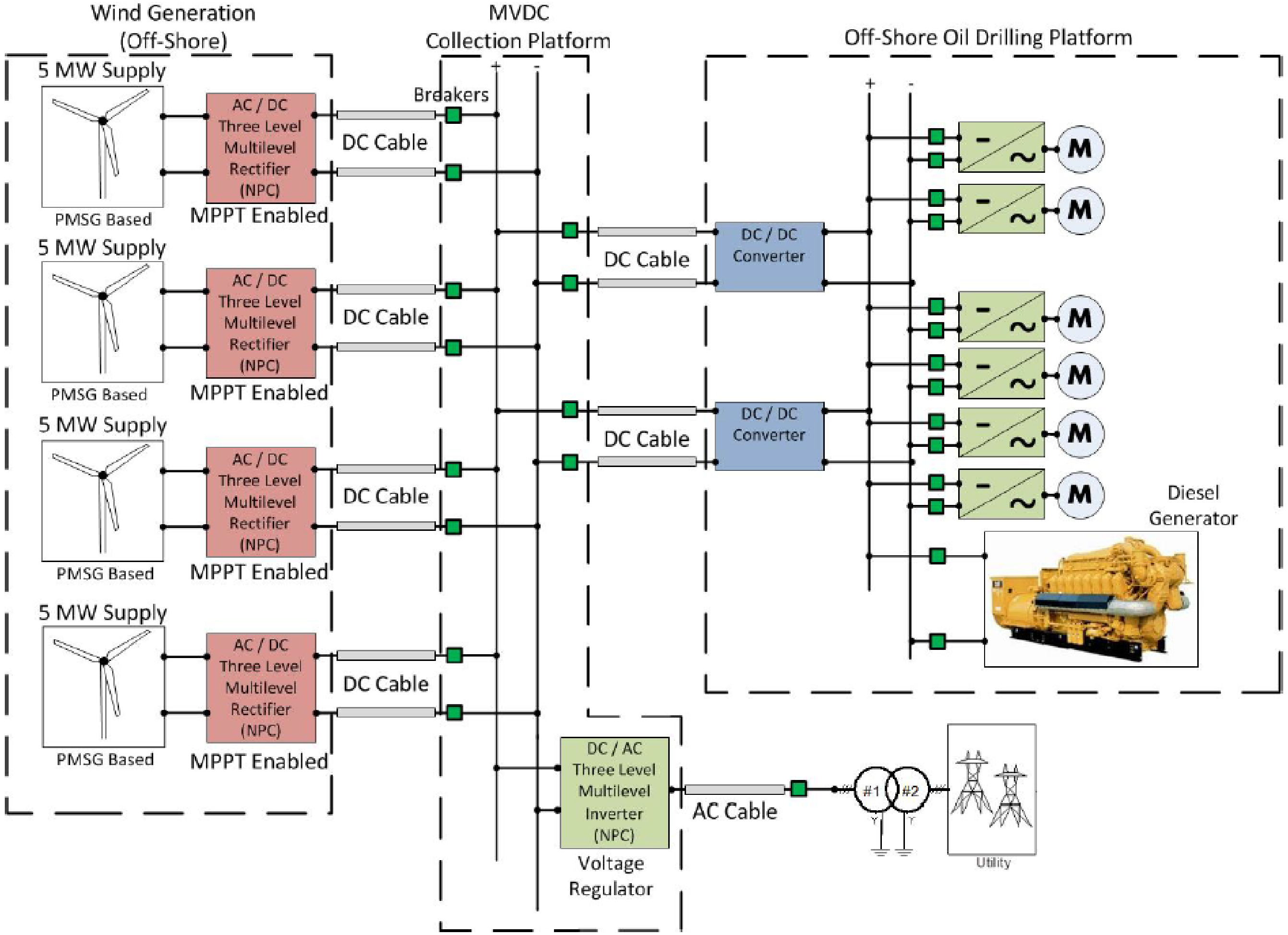
Wind farm interconnection with Platforms



Single line diagram of a typical offshore grid

Wei He, Kjetil Uhlen, Mahesh Hadiya, et al, "*Case Study of Integrating an Offshore Wind Farm with Offshore Oil and Gas Platforms and with an Onshore Electrical Grid*", *Journal of Renewable Energy*, vol. 2013,

Offshore MVDC Microgrid Supplying Power to Offshore Oil Drilling Platform



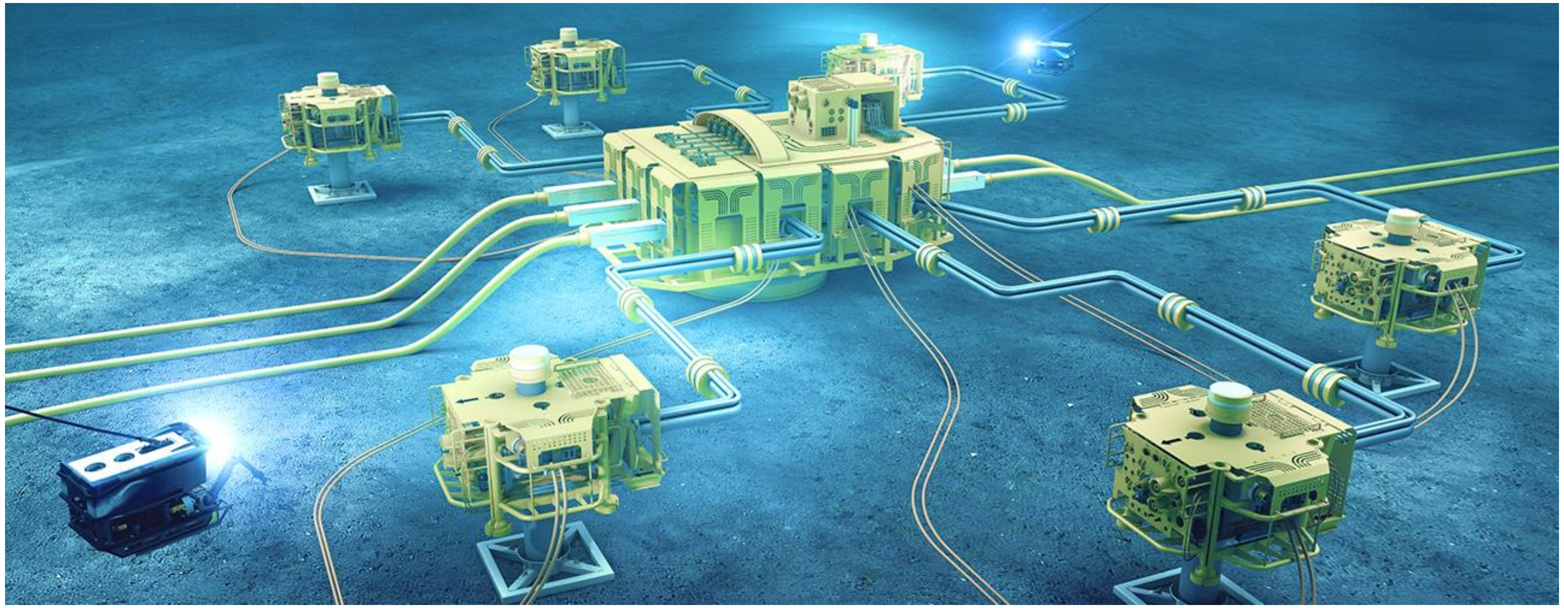
The synergy between offshore wind and offshore oil is already underway in Europe where dozens of oil, gas, and marine companies are engaged in wind energy development.

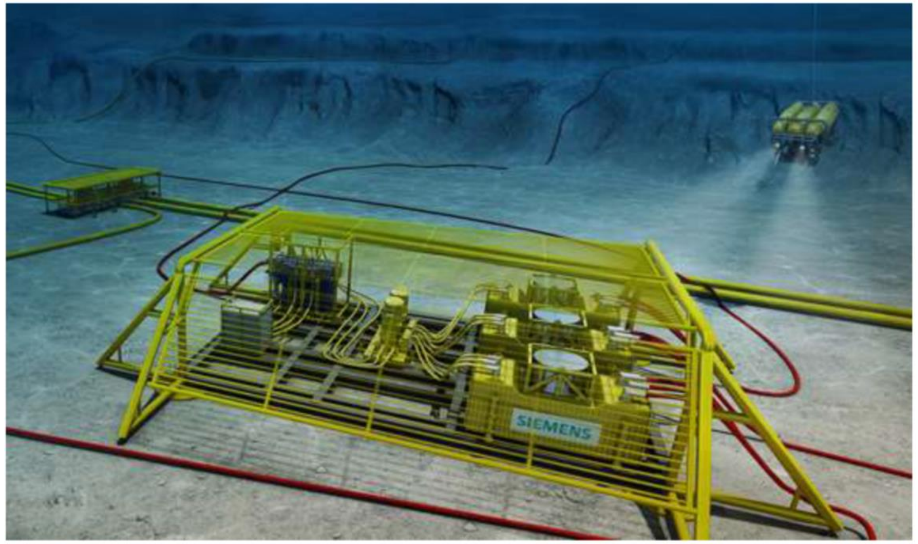
B.M. Grainger, G.F. Reed, et al, Analysis of an Offshore Medium Voltage DC Micro-grid Environment – Part I: Power Sharing Controller Design, 2014 IEEE PES T&D Exposition

1B- Subsea Oil extraction fields

Subsea developments are often the preferred solution for developing oil and gas fields in deep waters, for marginal fields, and for long step-out distances.

A subsea power grid is designed to operate at a depth of 10,000 feet and to withstand extreme pressure and harsh temperatures. It can even go to 30,000 feet depth





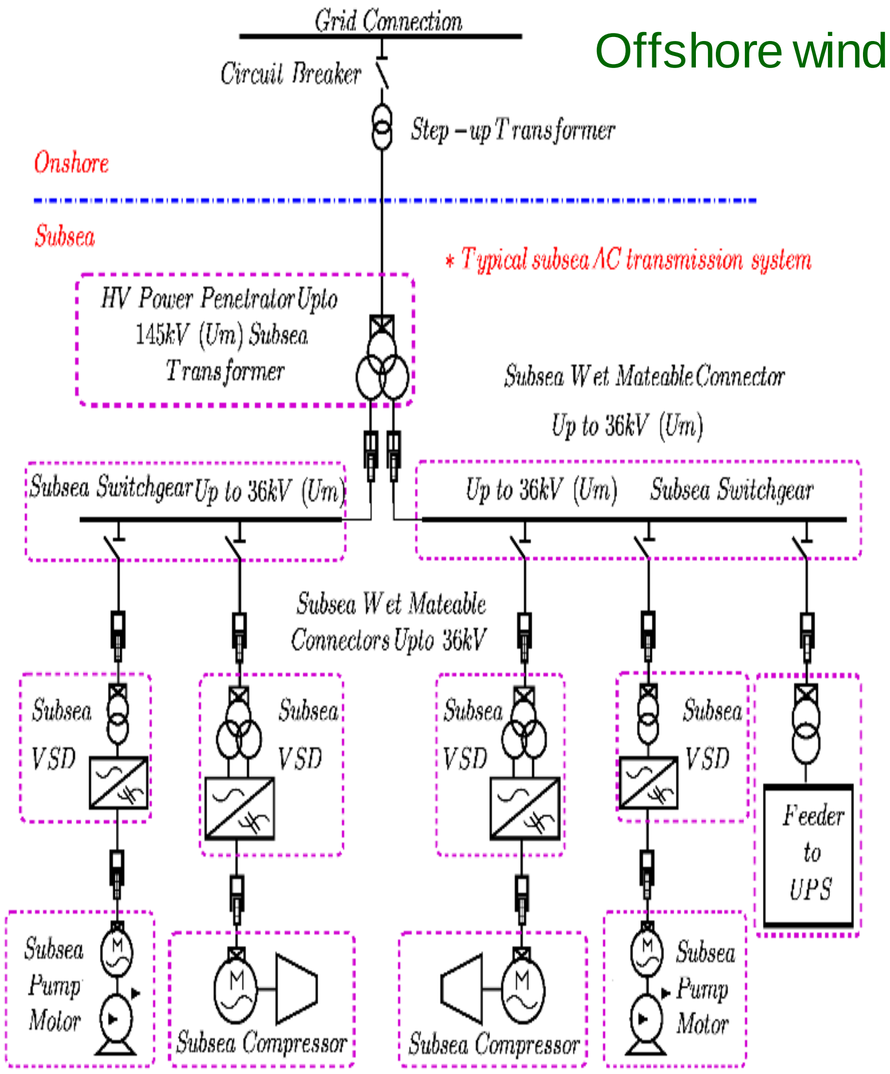
An example of a subsea power grid.

https://www.dnv.com/oilgas/subsea-facilities/index.html

A Typical Subsea Power System

❖ A fully integrated electrical system built on the seabed consists of
  - Motors,
  - Converters,
  - Transformers,
  - Switchgear,
  - Uninterruptable Power Supply (UPS),
  - electric submersible pump (ESP)
  - Power management systems

Offshore wind



Power is supplied from an onshore substation through an HV power umbilical to a subsea stepdown transformer

A typical length of the subsea power cable can be up to 100 km, and

❖ The voltage used for the high voltage umbilical is typically over 100 kV, whereas the subsea distribution voltage is up to 36 kV.

❖ The typical rating for the motocompressor is 10–15 MW, and the pump is 400 kW. The motocompressor and the pump are powered by subsea variable frequency drives (VFDs)

]. K. Ho, P.E ,``PDHonline Course E443 (4 PDH) Introduction to Subsea Engineering for Electrical Engineers",. 2017, PDH Online | PDH Center

Typical Loads and Ratings in Subsea Application

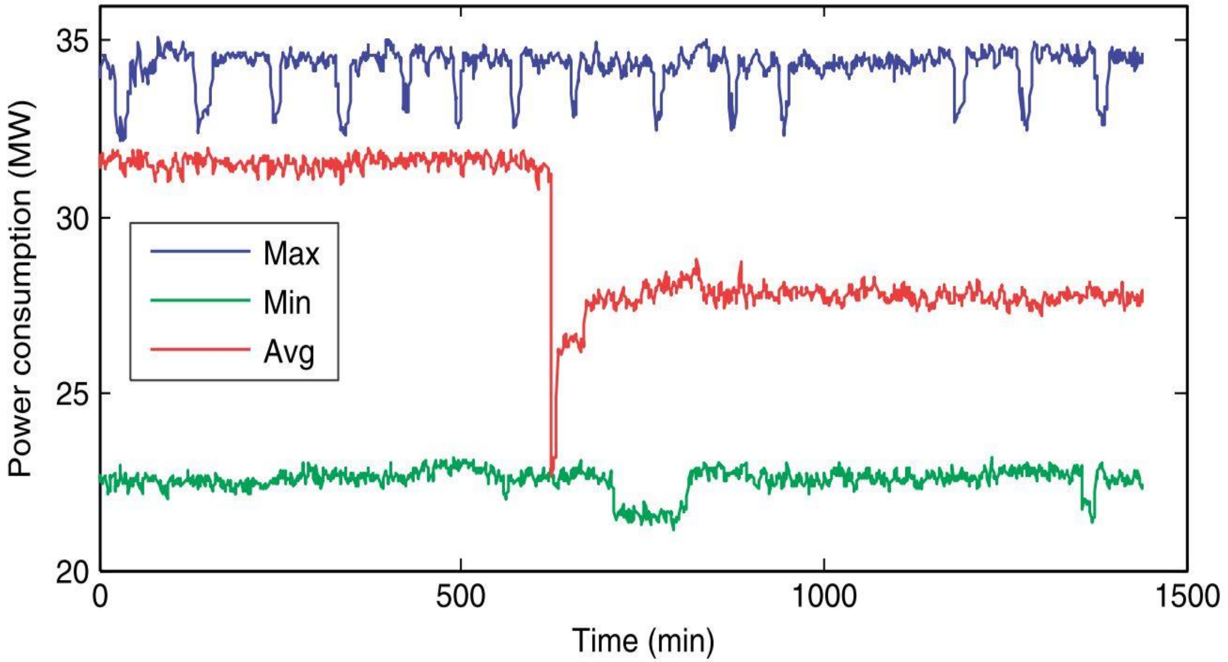
No.	Electrical Loads	Power ratings
1	**Electrical pumps and Oil Compressors**	up to 10-15MW
	➢ Electrical Pumps	up to 2.5MW
	➢ Compressors	up to 12.5MW
2	**Electrical Heating**	up to 3-4kW/m
3	**All-Electric Production System**	
	➢ Single valve actuation (Momentary operation)	3-5kW
	➢ Single valve normal operation	20-50W
	➢ Choke valve actuation	1-2kW(momentary), 60W(continuous)
	➢ Subsea electronic module	up to 80W
	➢ Sensors	up to 50W
4	**Electro-Hydraulic Production System**	
	➢ Hydraulic power unit	up to 11kW/pump (momentary)
	➢ Single valve actuation (Momentary operation)	10W
	➢ Choke valve actuation (Momentary operation)	10W
	➢ Subsea electronic module	up to 80W
	➢ Sensors	up to 50W

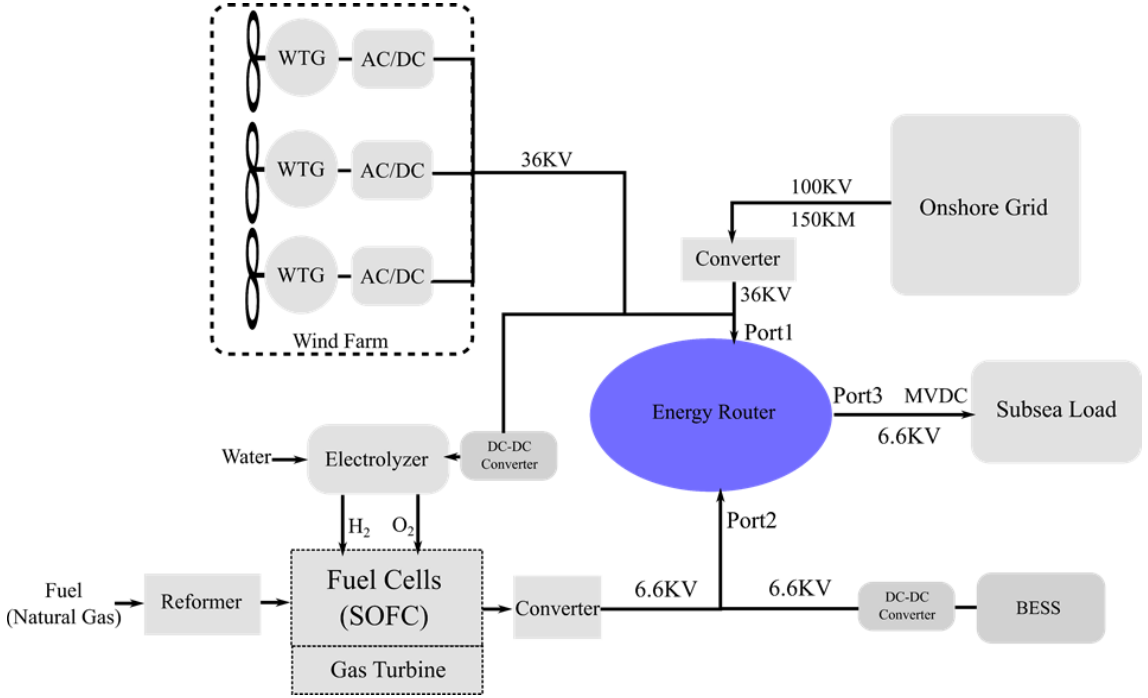
The total electrical load could be up to 100-MW range, and thus, high-voltage power distribution is required.

[1].K. Rajashekara, H. S. Krishnamoorthy, and B. S. Naik, "Electrification of subsea systems: requirements and challenges in power distribution and conversion", *CPSS Transactions on Power Electronics and Applications*, vol. 2, no. 4, pp. 259–266, December 2017.

[2].Midttveit, Steinar, Monsen, Bjarne, Frydenlund, Snorre, and Karl Stenevik. "SS on Implications of Subsea Processing power Distribution - Subsea Power Systems - a Key Enabler for Subsea Processing." *Paper presented at the Offshore Technology Conference*, Houston, Texas, USA, May 2010.

Load Profile in a Subsea System



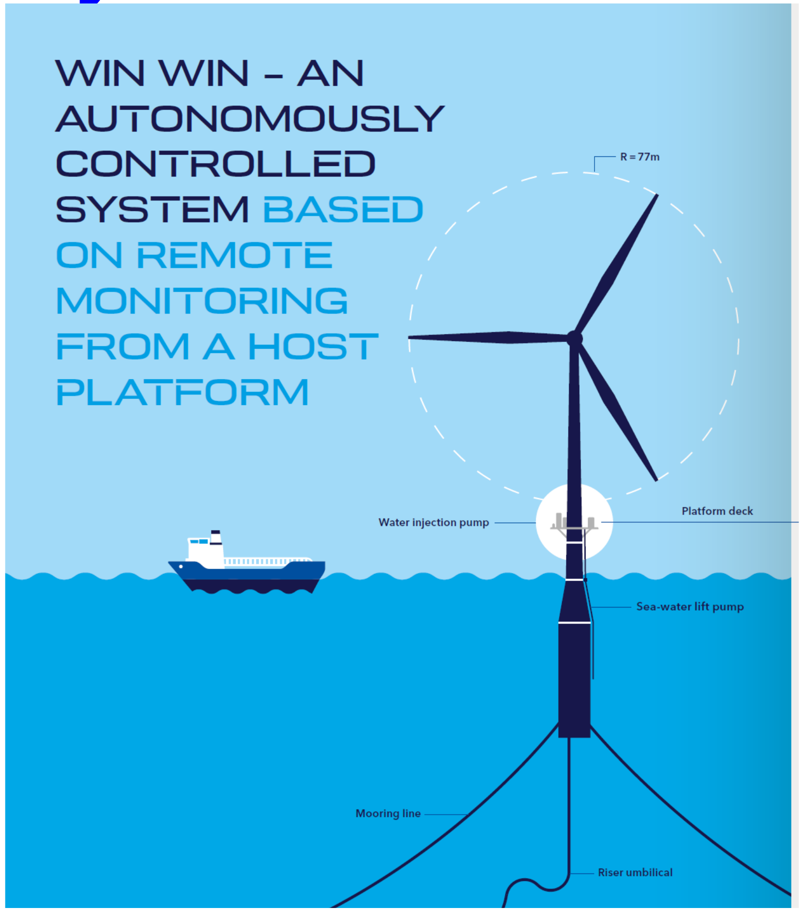


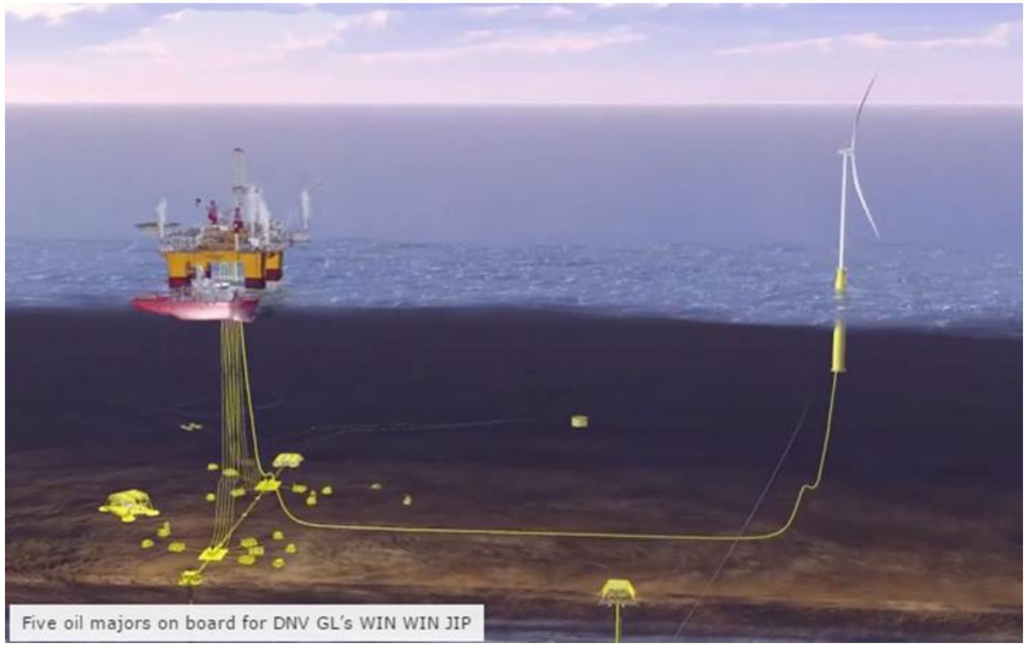
- The load is fairly constant but can change quickly due to different motor start ups and shutdowns. But, wind power availability varies
- The power being used in a year varies typically between 20 MW and 35 MW.
- The average power is about 30MW

Integration of other power generation systems with offshore wind to achieve stable power. The three ports of the Energy Router to integrate wind energy, backup energy storages, on-shore DC grid, and the subsea load. (UH – Subsea Systems Institute and PEMSEC)

1C- Enhancing Oil Recovery

- A new DNV joint industry project plans to harness wind-power to inject water into mature fields and enhance oil recovery
- DNV has proposed a new concept called WIN WIN (WINd powered Water INjection) that will use floating wind turbines to power water injection at offshore fields
- The technology integrates compressor and water treatment equipment into the substructure of a floating wind turbine, which is connected to a subsea well
- The use of wind power has been investigated to inject water through a riser into the reservoir to help lift additional oil





Eight companies including Exxon Mobil, ENI Norge, Nexen Petroleum, Equinor, etc. are working with DNV.
The base case for DNV's pilot project is a 6 MW wind turbine that would power both an injection pump and a desalination system inside the foundation

https://www.dnv.com/feature/wind-powered-oil-recovery.html

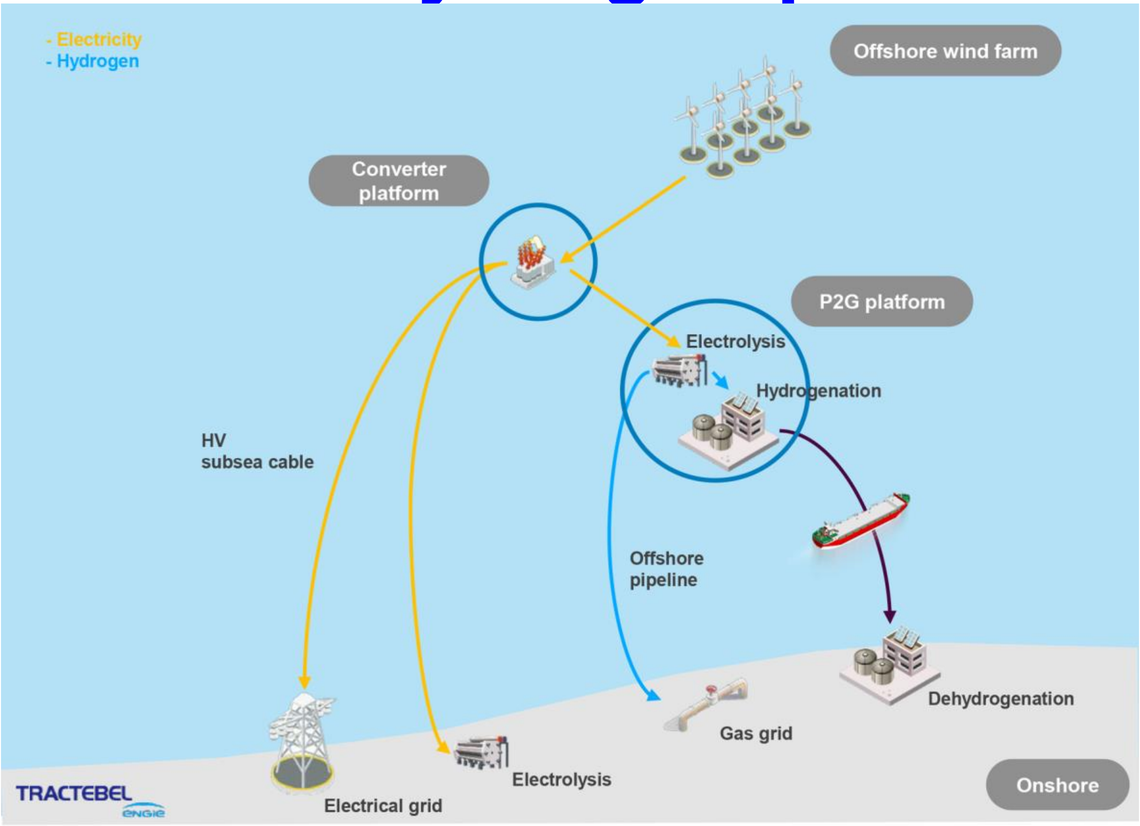
2-Green Hydrogen Production

Governments, energy companies, and end users (chemical companies, steel producers, and so on) are increasingly looking at offshore wind as a power source to produce green hydrogen that can be used in other sectors of the economy (e.g., transportation, heating, industry, grid storage) as a zero-emission fuel. Several global projects have either been proposed or are in early stages of development including:

- **Shell, RWE, Gasunie, Gascade, Equinor, Ørsted, and Boskalis.** These developers plan to use 10 GW of offshore wind energy to produce hydrogen and pipe it to Europe as part of the quaVentus/AquaDuctus project. The goal of these efforts is to produce up to 1 million tons of hydrogen from 2035 onward.
- **Ørsted and POSCO form South Korean Hydrogen Pact.** POSCO, one of South Korea's largest industrial and steel conglomerates, plans to use 1.6 GW of Ørsted's offshore wind capacity off the coast of Incheon to power its hydrogen production requirements.
- **Neptune Energy's PosHydon.** This project will integrate offshore wind, offshore gas, and offshore hydrogen for Dutch utilities Eneco, Gasunie, Noordgastransport, and Northern Offshore Gas Transfer.
- **Ørsted's H2RES.** The 2-MW wind-to-hydrogen project will use the company's two 3.6-MW offshore wind turbines at Avedøre Holme to produce 1,000 kilograms of hydrogen per day and power zero-emission road transport in the greater Copenhagen area . Danish energy major (Ørsted) has set out to develop a 1-GW electrolyzer plant powered by offshore wind as part of the SeaH2Land industrial green hydrogen project on the Dutch-Belgian border.

US Dept. of Energy: Offshore Wind Market Report: 2021 Edition

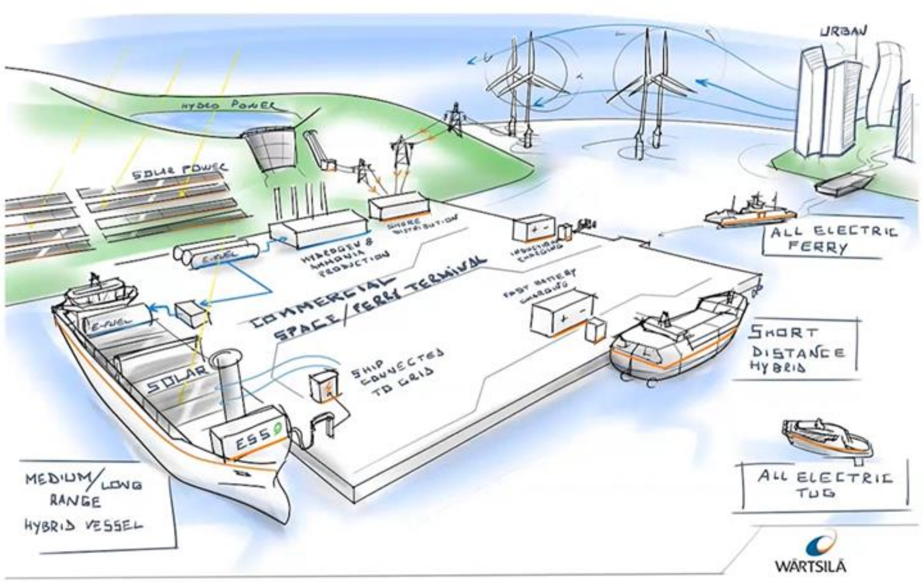
Hydrogen production from offshore wind



Tractebel has been involved to produce an estimated 15 tons of green hydrogen per day via a 400MW electrolyzer from offshore wind energy at an industrial scale using electrolysis

In large-scale offshore wind farms, Tractebel sees enormous potential for CO2-neutral production of “green” hydrogen
https://tractebel-engie.com/en/news/2019/400-mw-offshore-hydrogen-production-takes-system-to-new-levels

3- Offshore wind for shore power for powering the vessels



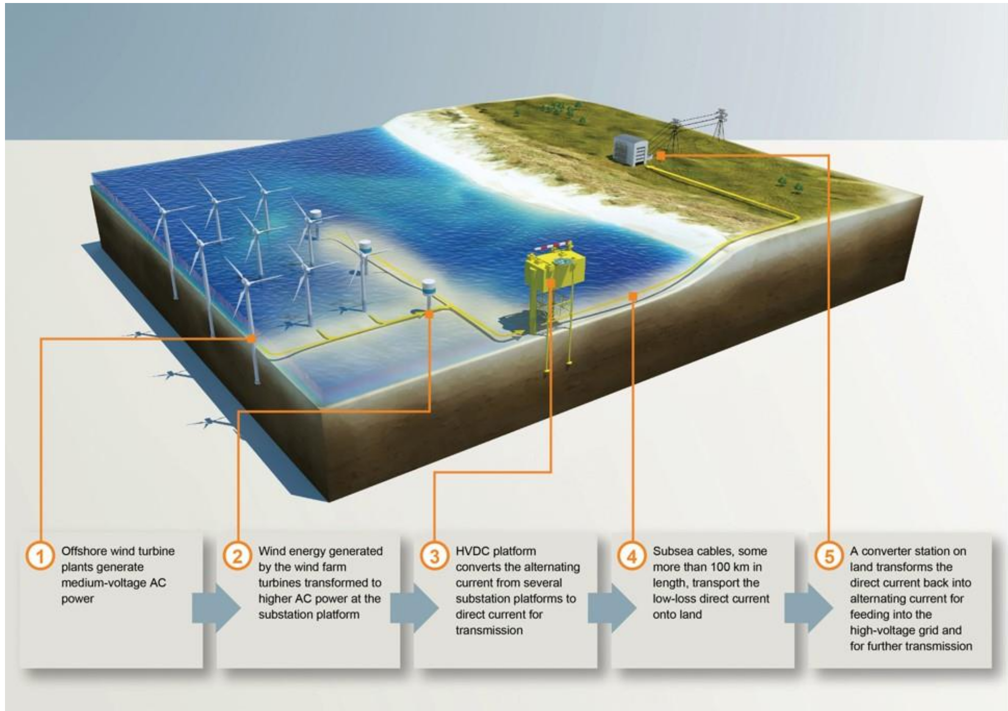
Use of Offshore wind for shore power helps decarbonization. Whenever a vessel is using and fueling, use of offshore wind energy reduces CO_2

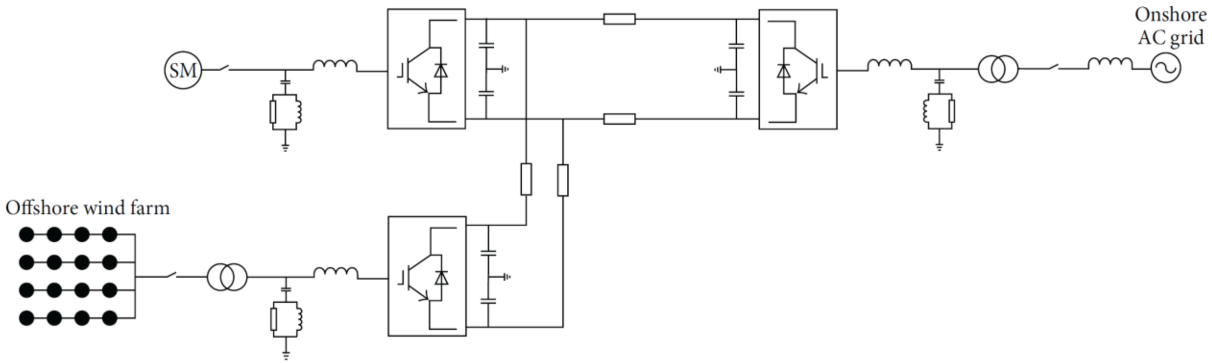
There are a number of proposals to develop offshore wind in California coast, including floating wind farms.

In 2017, California mandated that at least half of all container ships run on shore-side electricity at berth.

https://www.wartsila.com/

4- Offshore wind power integration to onshore grid





- HVDC transmission is the most optimal solution from offshore wind farm to onshore grid.
- Voltage Source Converter (VSC) based systems have emerged as best possible option for HVDC transmission, but reliability remains an issue.
- No need for reactive power compensation, and lower losses

Principal Challenges of HVDC

- Absence of natural zero crossing of fault current
- Very small network inductance compared to ac systems which means fault current rises very fast
- Steady state fault current is limited only by the series resistance of the network, so fault level is much higher compared to ac systems
- Above challenges require very fast fault isolation rendering existing mechanical (SF6/Vacuum) circuit breakers obsolete
- Several power electronic circuits have been investigated for dc circuit breakers

http://breakingenergy.com/2015/02/06/new-technology-critical-to-future-of-offshore-wind-power/

Challenges to Integrate Wind Power to Offshore Grid

- **Intermittency of wind power**
  - Due to intermittency of the wind velocity, the generated wind power also varies from one hour to another over a day. So, for stable operation, higher penetration level of wind power is not possible in the offshore grid .
  - To reduce the intermittency, high-capacity backup energy sources (e.g., battery) are required, which increase the cost of the overall system.

- **Lack of short-circuit capacity**
  - The short-circuit capacity (SCC) in a power system is an indicator of its robustness. Since wind turbines are interfaced with frequency converters, their contribution is limited to SCC.

- **Negative damping**
  - Wind turbines are interfaced through power electronics converters, and can give negative damping, and makes system unstable.

- **Harmonics instability**
  - Due to presence of inverter at the output of the wind turbine, it emits harmonics and hence can affect the offshore grid by the reflection components or by oscillating the system at resonance frequency.

- **Reliability**
  - Integration of different energy sources may also affect reliability of the overall system

Summary

- Integration of offshore wind power with offshore oil & gas installations are feasible with positive impact on reducing greenhouse gas emissions from the oil & gas platforms. It considerably saves the use of fuel, when wind power is integrated with other conventional sources.
- Offshore wind power also can be used for generating Hydrogen and can be transported to shore for various applications
- Offshore wind energy can be for shore power for powering the vessels and also for grid integration
- Operation and maintenance costs of the offshore wind power are higher compared to other conventional power sources.
- Due to intermittency of the wind power, higher penetration in the offshore grid is not possible for stable grid operation.
- Integration of wind energy in offshore grid requires large backup battery storage for stable grid operation, which further increase the cost of the system.