Power quality and stability in oil & gas platforms: challenges with the integration of wind power

Prof. Elisabetta Tedeschi
Dept. of Electric Power Engineering, NTNU

IEEE Power & Energy Society Seminar
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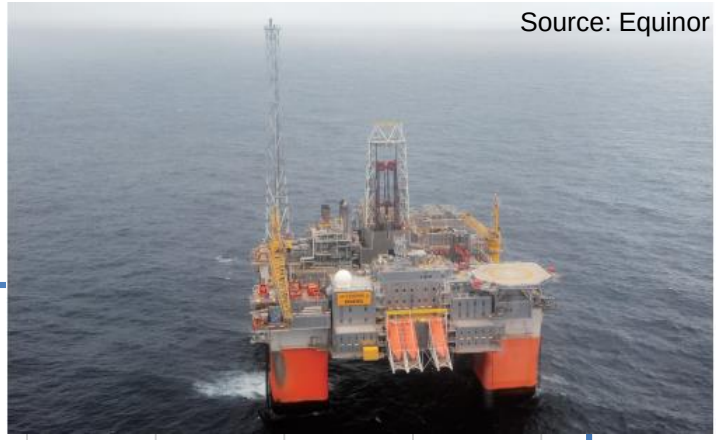
Presentation outline

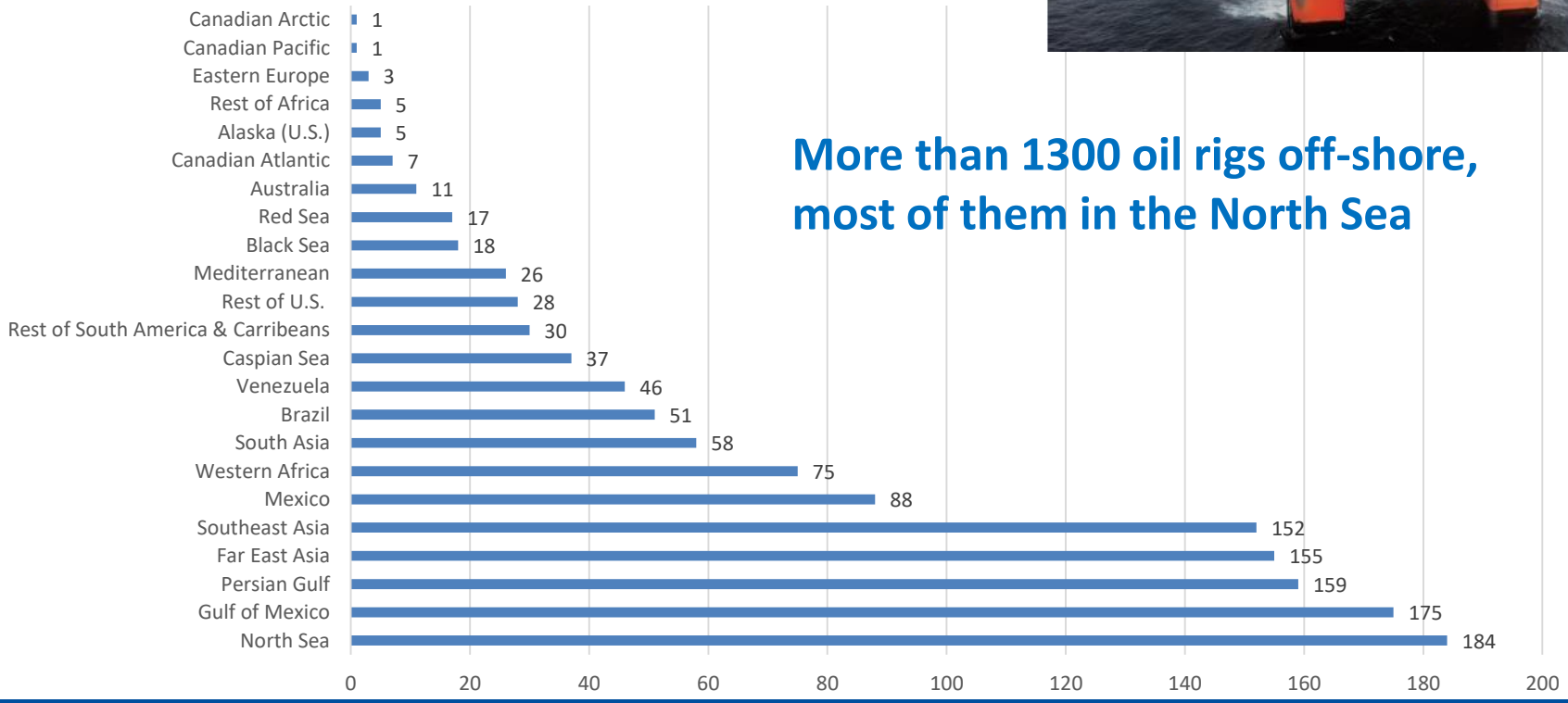
- The offshore O&G sector and its environmental impact
- Power supply alternatives to O&G platforms
- Power quality in O&G platforms
- Effect of wind integration into O&G platforms
- Perspectives for energy storage

Offshore Oil and Gas - Status

Offshore production accounts for 30% of global oil production and 27% of global gas production


Source: Equinor

Number of offshore rigs (January 2018)



More than 1300 oil rigs off-shore, most of them in the North Sea

Source: Statista (2018)

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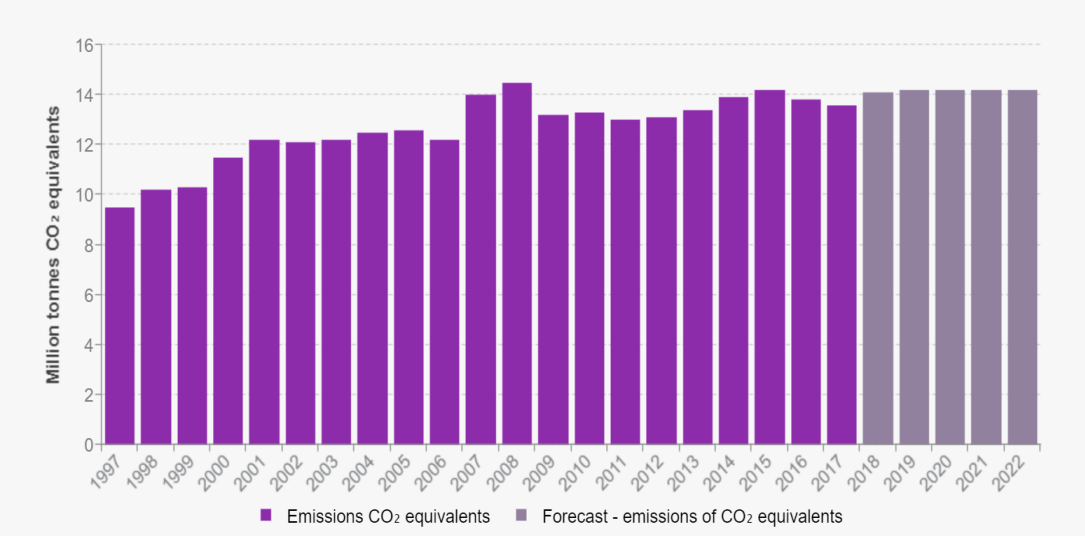
Offshore Oil and Gas - Status

Typical power consumption of oil and gas platforms in the range 5 – 100 MW

These are normally supplied by local gas turbines or diesel generators

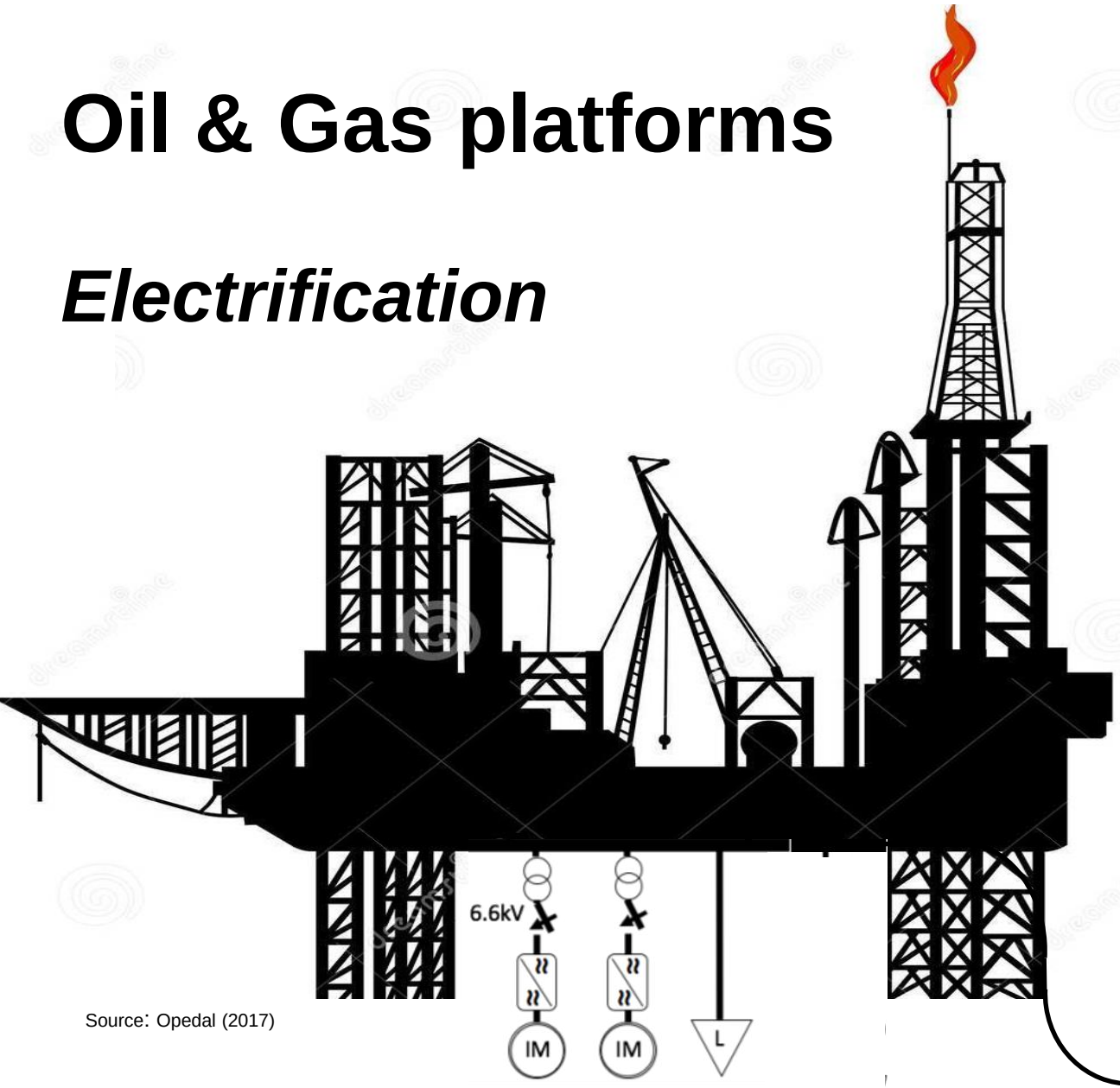
In Norway the oil and gas sector is responsible for approx. 25% of the total CO2 emissions and little less than 30% of the NOx emissions



Source: Norskpetroleum.no (2018)

Oil & Gas platforms

Electrification

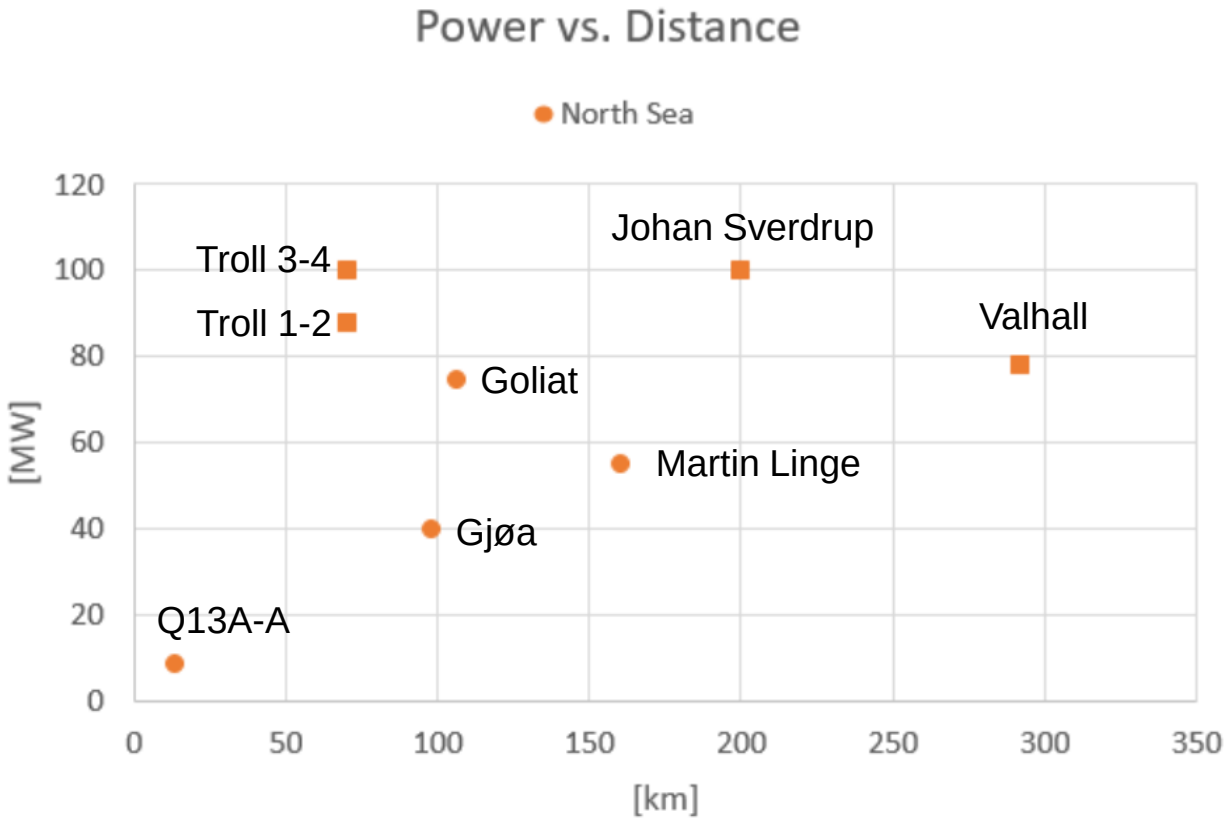


Source: Opedal (2017)

Cable to shore (AC or DC)

Oil & Gas platforms

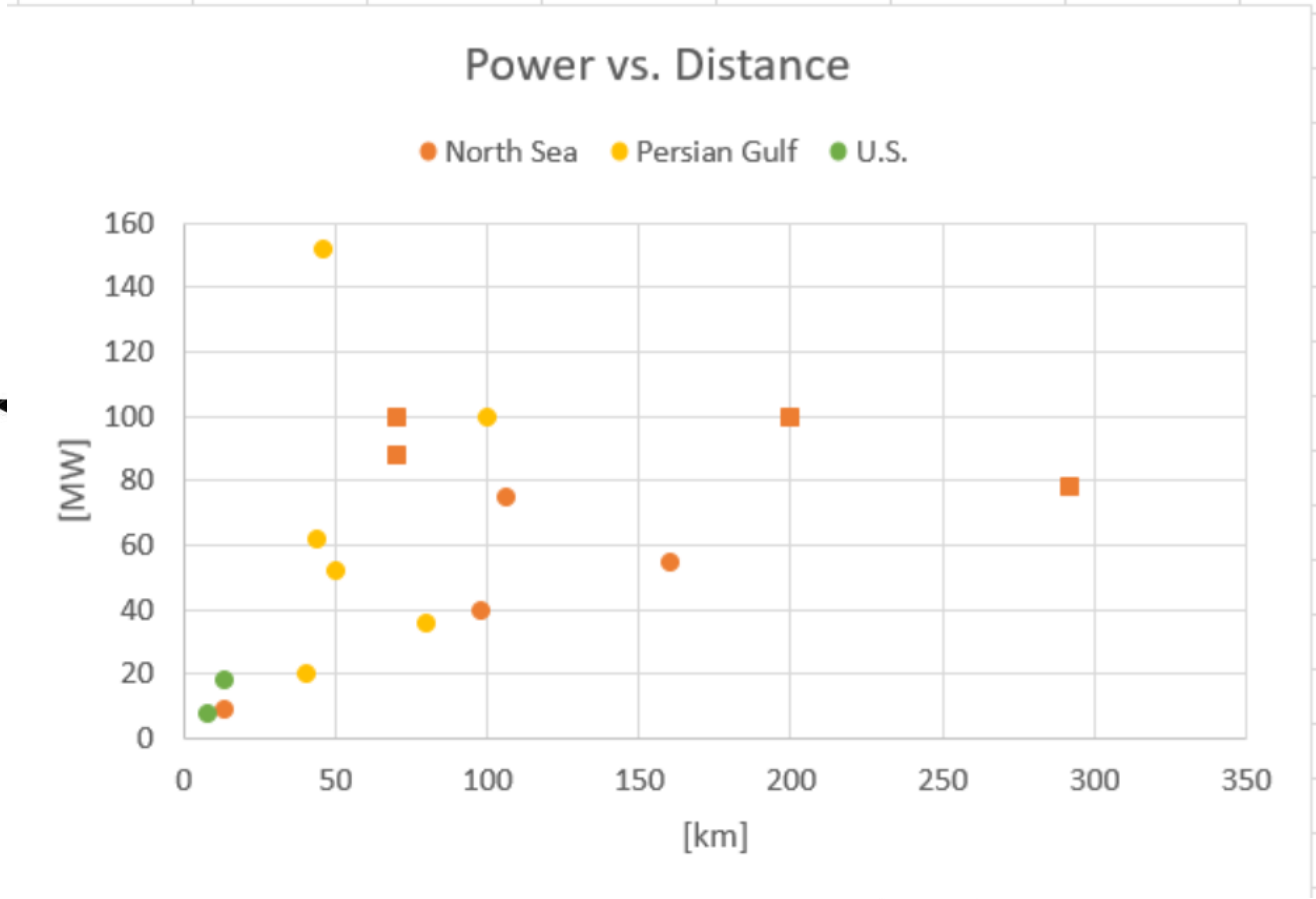
Electrification



Cable to shore (AC or DC)

Oil & Gas platforms

Electrification



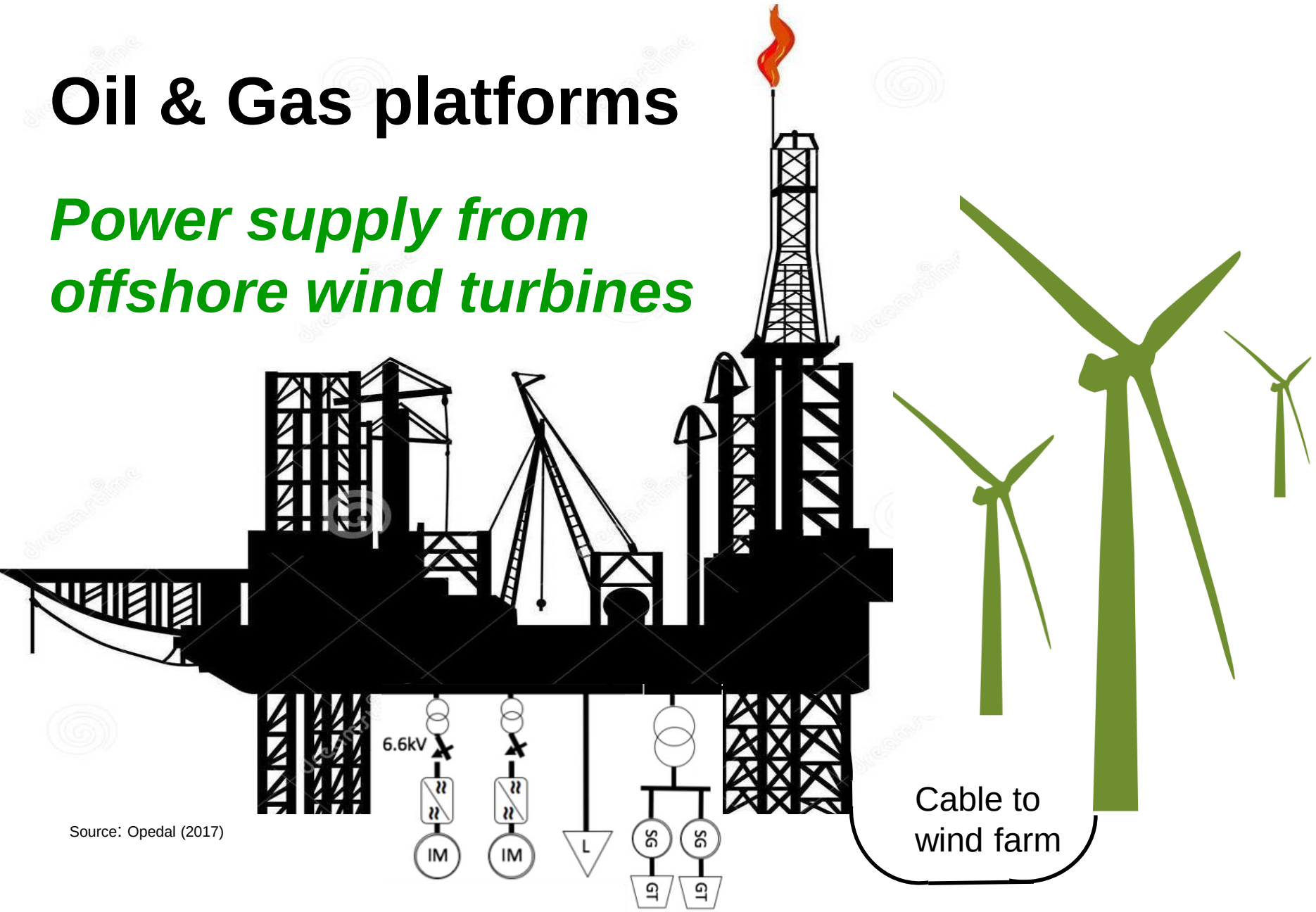
Possible showstoppers to electrification:

- **Distance from shore**
- **Limited grid access onshore**
- **Cost**

Cable to shore (AC or DC)

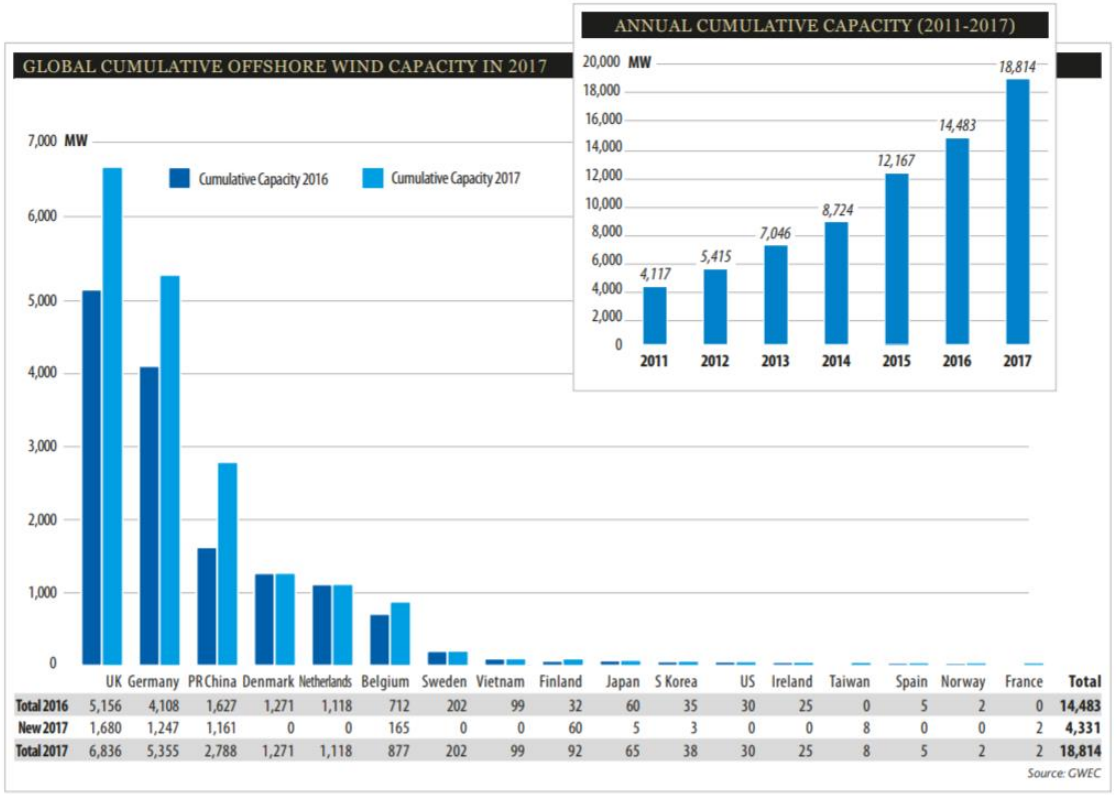
Oil & Gas platforms

Power supply from offshore wind turbines



Source: Opedal (2017)

Offshore wind - Trends



	UK	Germany	PR China	Denmark	Netherlands	Belgium	Sweden	Vietnam	Finland	Japan	S Korea	US	Ireland	Taiwan	Spain	Norway	France	Total
Total 2016	5,156	4,108	1,627	1,271	1,118	712	202	99	32	60	35	30	25	0	5	2	0	14,483
New 2017	1,680	1,247	1,161	0	0	165	0	0	60	5	3	0	0	8	0	0	2	4,331
Total 2017	6,836	5,355	2,788	1,271	1,118	877	202	99	92	65	38	30	25	8	5	2	2	18,814

Source: GWEC

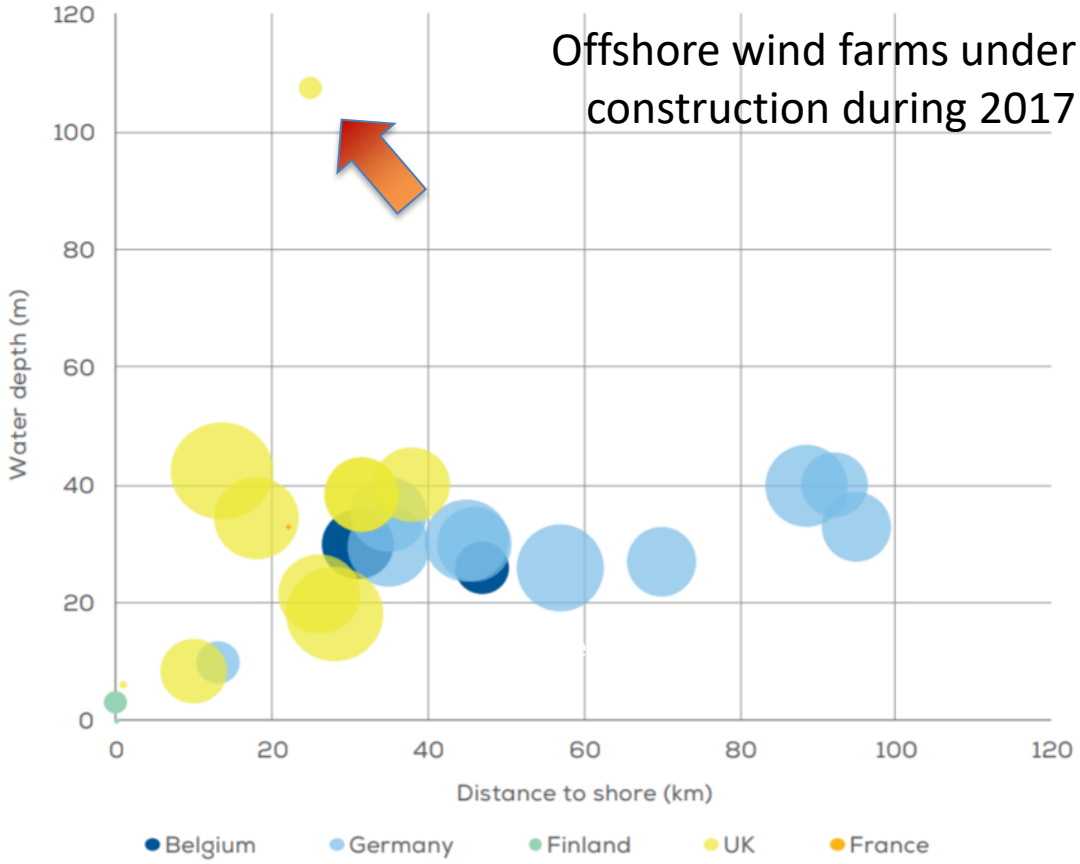
Offshore wind represents 3.5% of the global installed wind capacity

In Europe, offshore wind is expected to increase from 15.8 GW in 2017 to 66 GW in 2030

Offshore wind development

HYWIND Demo Norway

Floating wind turbine proved with capacity factor up to 50%



Wind power supply to O&G platforms

Wind farm being considered at Snorre and Gullfaks

August 28, 2018 06:45 CEST | Last modified August 28, 2018 08:33 CEST

equinor

Illustration of the Hywind Tampen project. Dimensions and distances are not realistic.

Equinor and partners at Gullfaks and Snorre have decided to explore the possibilities of supplying the Gullfaks and Snorre fields with power from floating offshore wind. This could be the first time an offshore wind farm is directly connected to oil and gas platforms.

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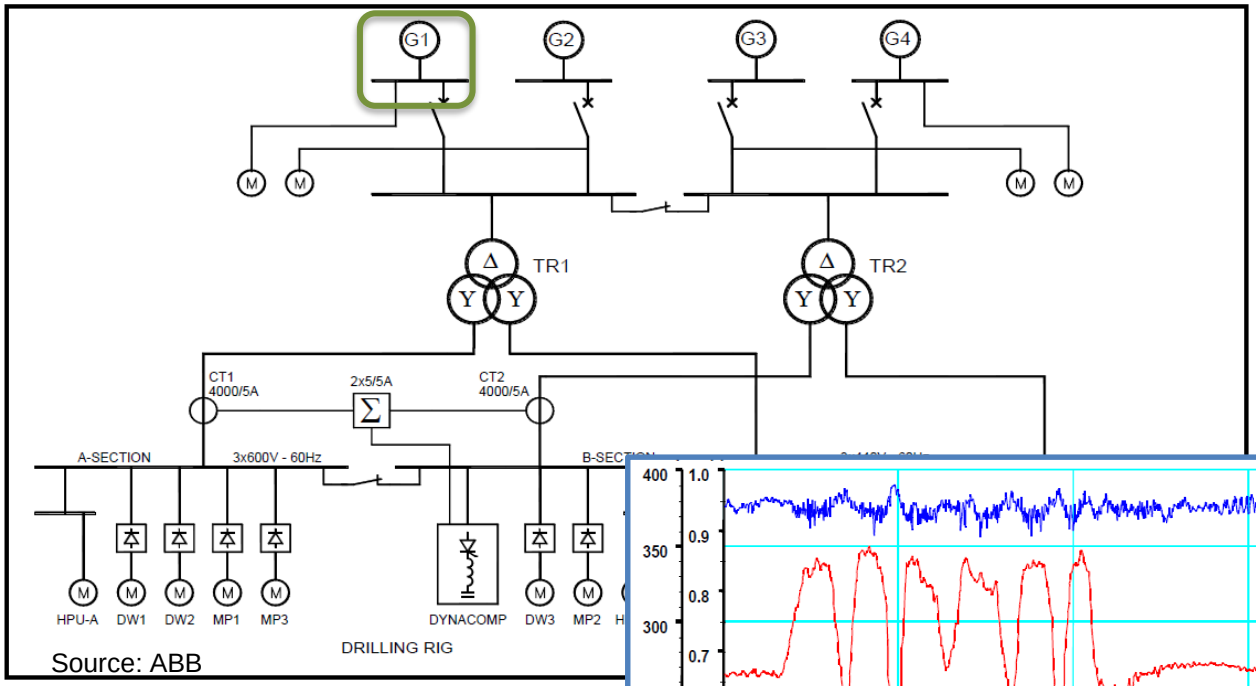
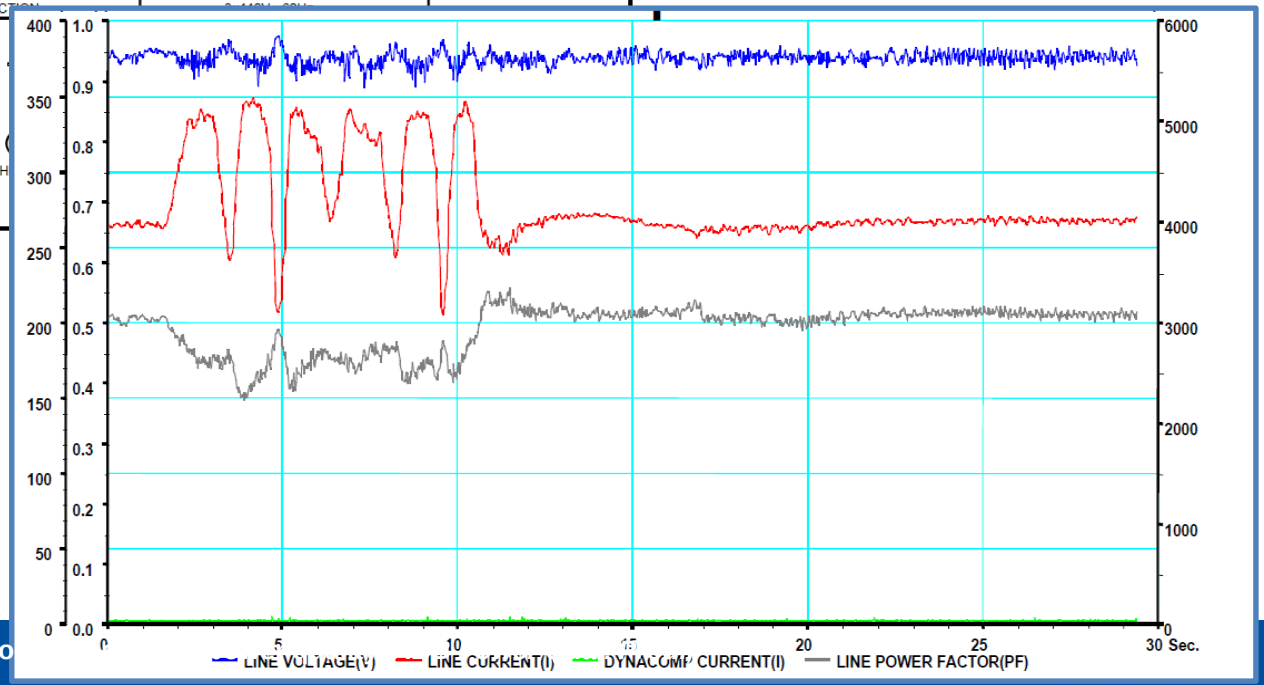
Electrical power system on O&G rigs



Source: ABB

O&G platforms can be classified as electrically «weak grids»

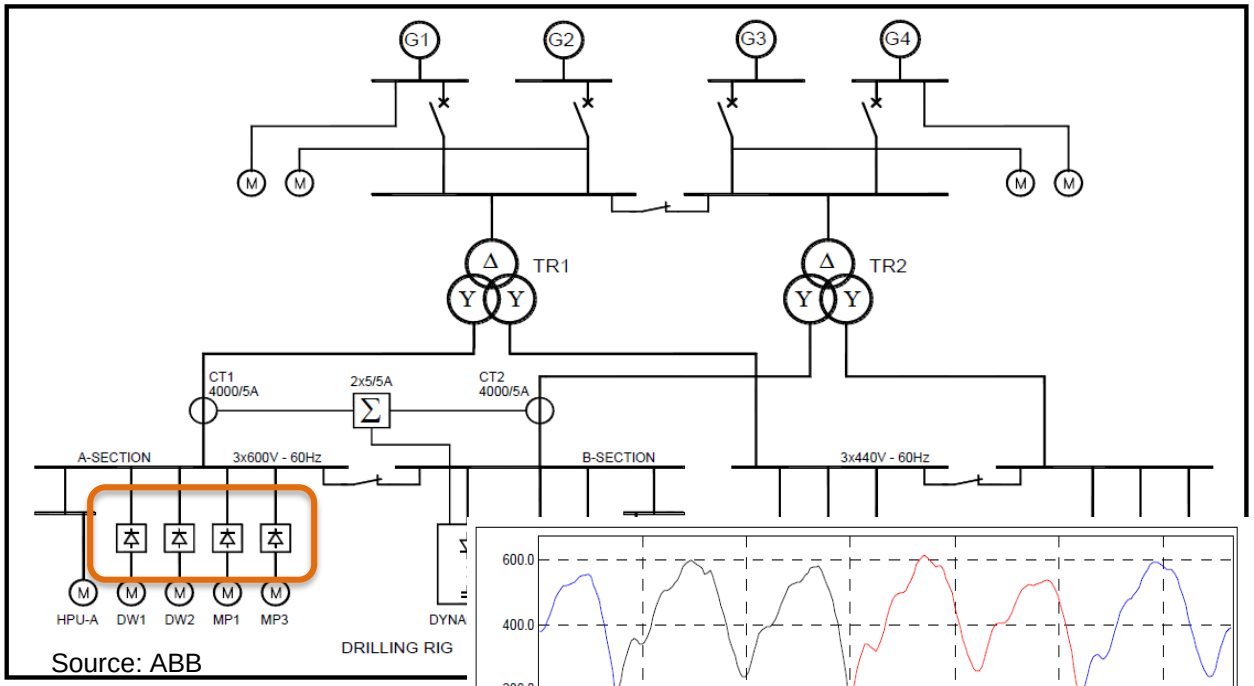
Power quality is low



- High reactive power demand/low power factor

Schipman, K., & Delincé, F. (2010). The impo
Charleroi, Belgium, ABB Review

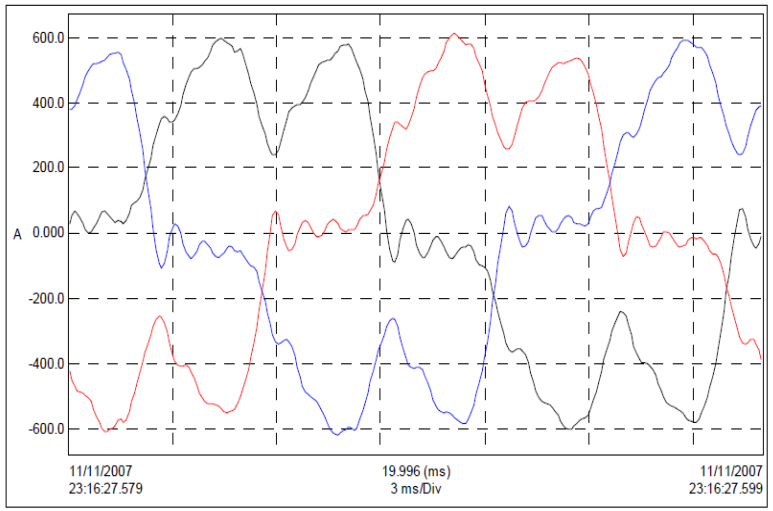
Electrical power system on O&G rigs

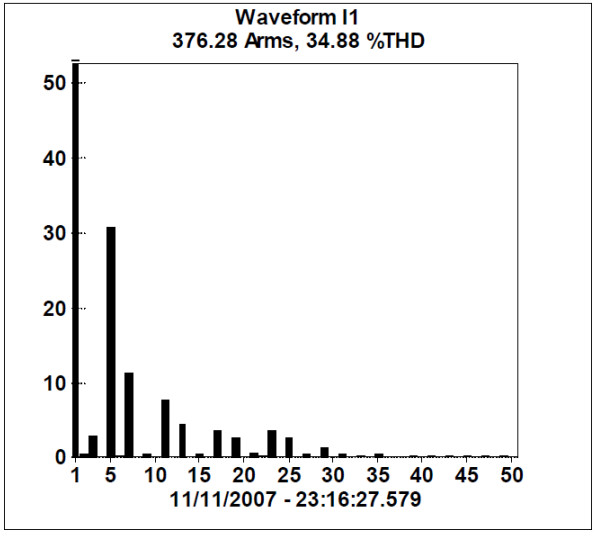


Source: ABB

O&G platforms can be classified as electrically «weak grids»

- High voltage and current harmonics





Evans, I. C., & Richards, M. J. (2011, April). The price of poor power quality. In 2011 AADE National Technical Conference (pp. 1-17).
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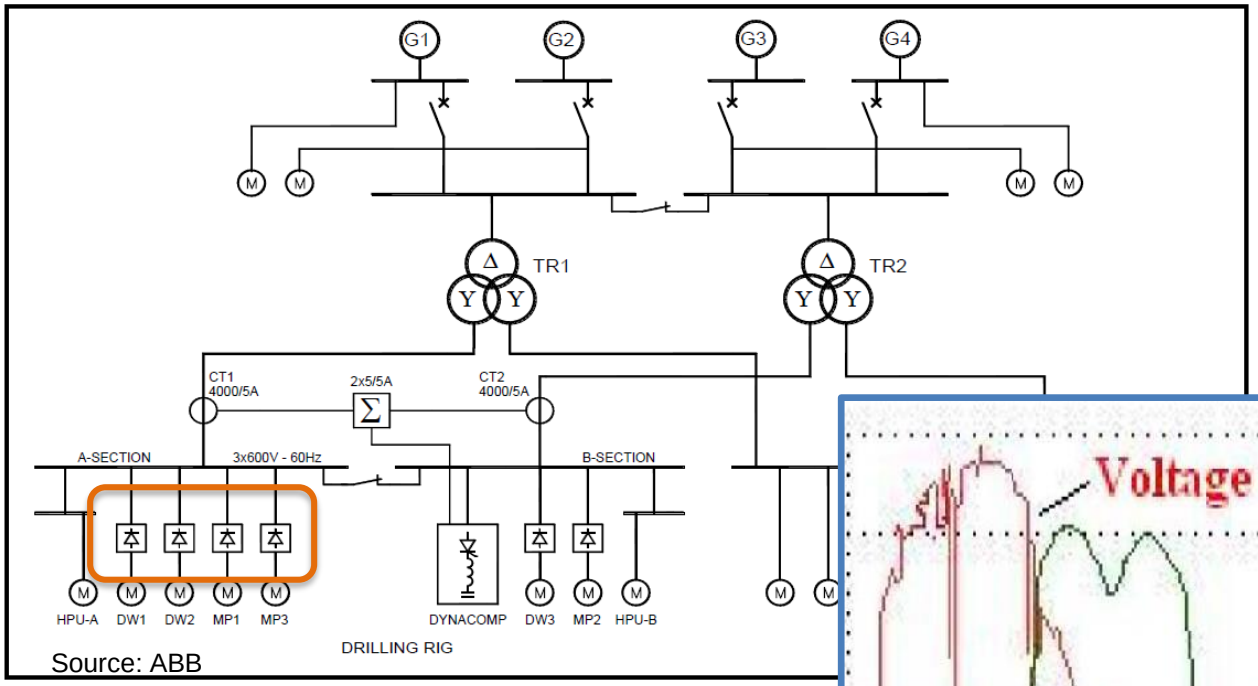
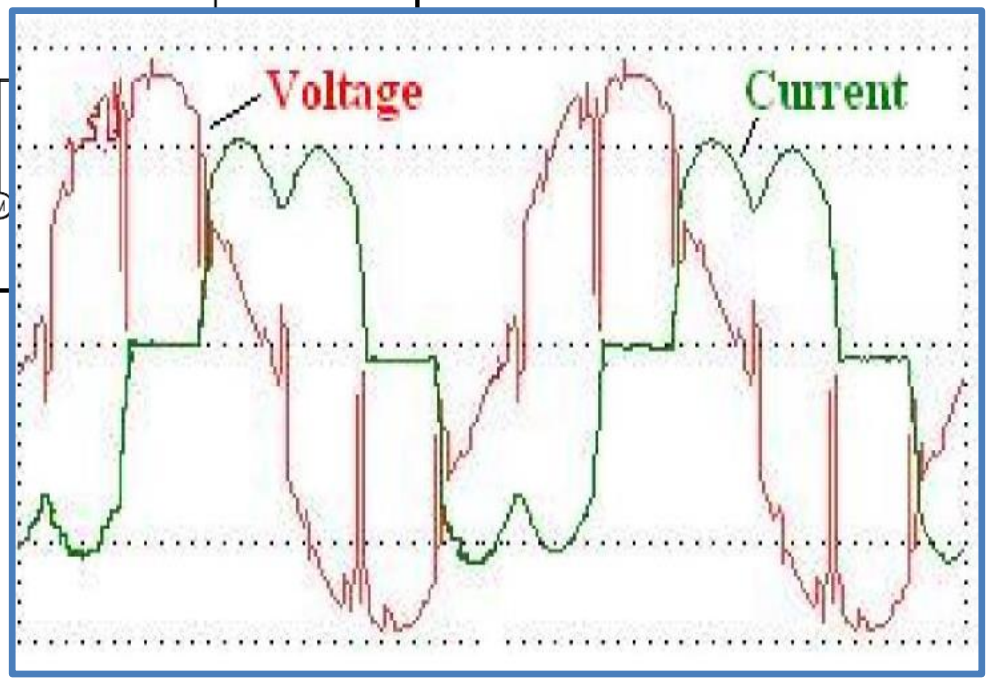


Source: ABB

O&G platforms can be classified as electrically «weak grids»

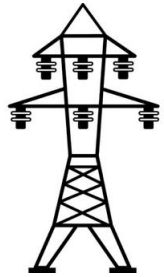


- **Voltage notching and induced common mode disturbances**

Estimated financial loss (2010) for incidents due to poor power quality in O&G is 250-750 KEUR/day

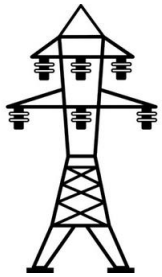
Evans, I. C., & Richards, M. J. (2011, April). The price of poor power quality. In 2011 AADE National Technical Conference (pp. 1-17).

Wind power integration into O&G rigs



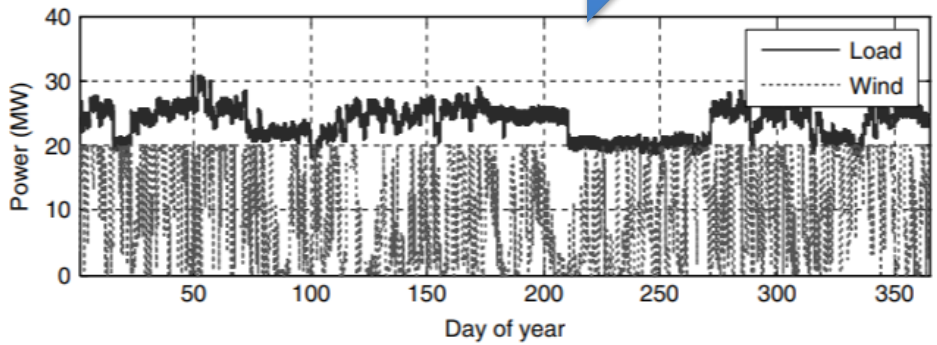
What is the impact of connecting intermittent energy sources, potentially with significant penetration, to an isolated power system?

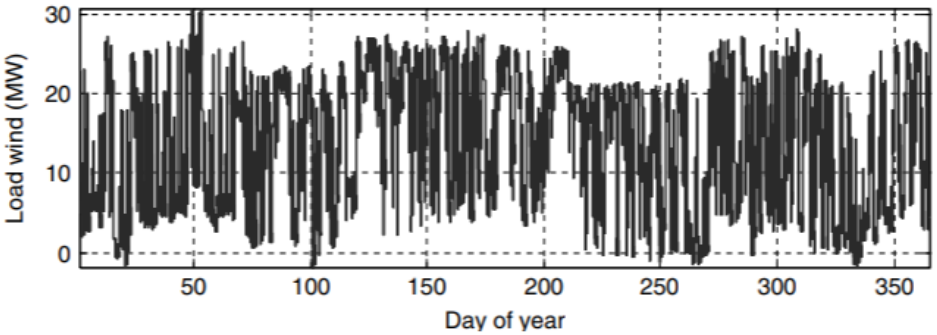
Effect of the wind variability



Energy analysis, oriented to system planning

- **How much of the yearly electrical energy consumption can be covered with wind power?**
- **How much greenhouse gas emissions can be saved?**

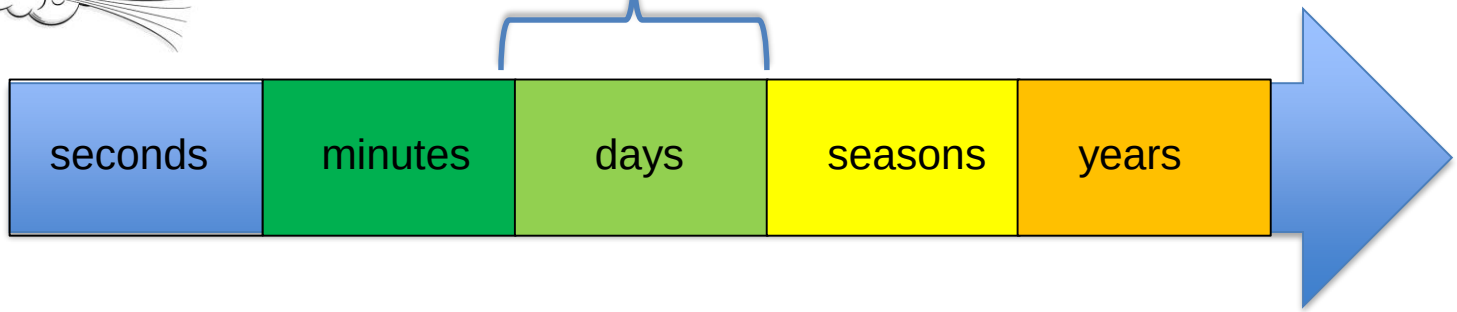


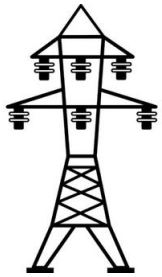


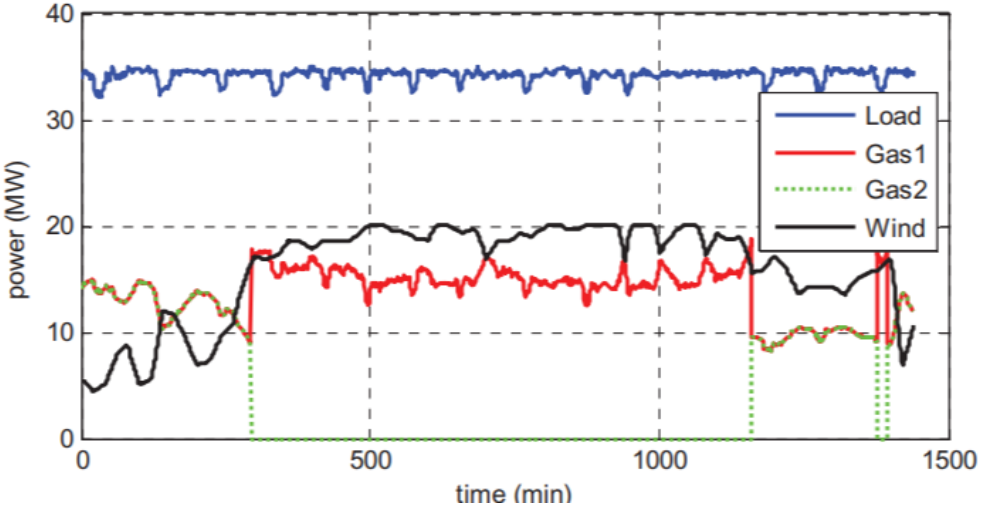
W. He, J. Gunnar, A. Tiit, O. Freydar, H. Tor D, M. Korpas, T Trond, E. Jale, k. Uhlen, and J. Emil, “The potential of integrating wind power with offshore oil and gas platforms.” inWind Engineering 34, 2010, pp. 125–137

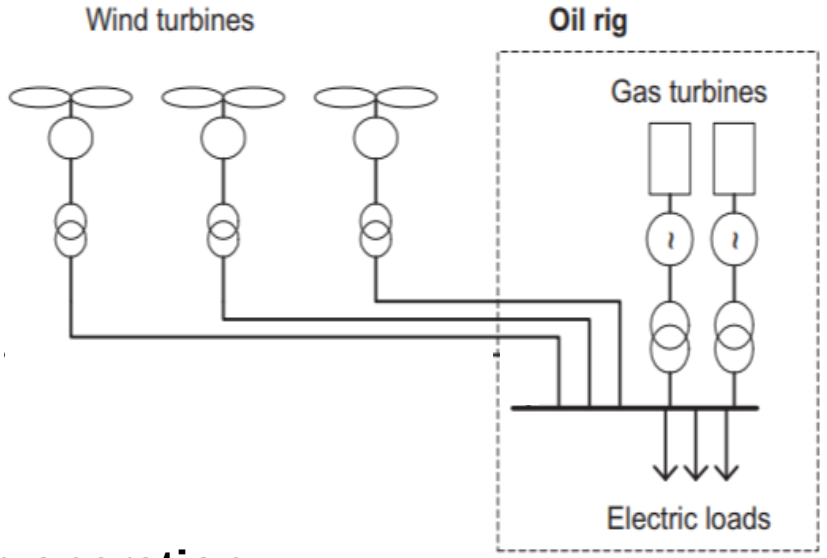
Effect of the wind variability

Medium term variability







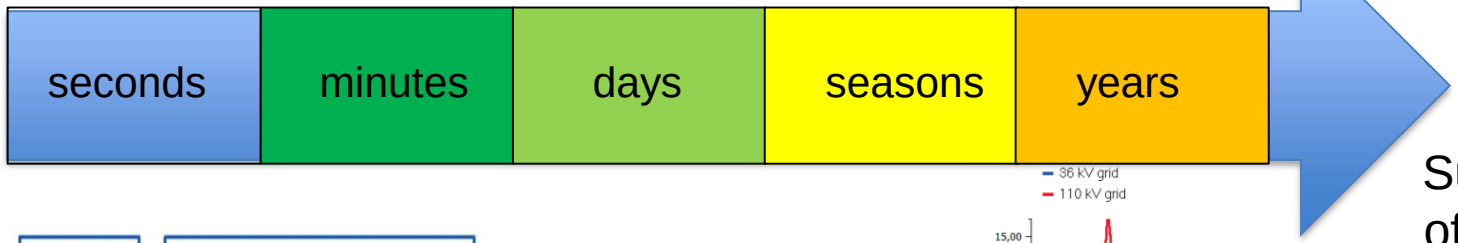


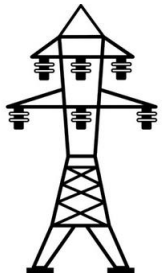
Quasi-stationary analysis, oriented to system operation
- How can the operational strategy of gas turbines be optimized?

M.Korpas, L. Warland, W. He, and J. O. Tande, “A case-stdy on offshore wind power supply to oil and gas rigs.” Energy Procedia no. 24, pp. 18–26, 2012

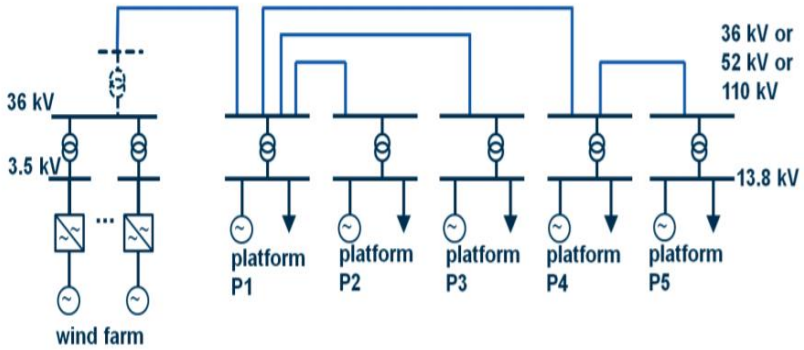
Effect of the wind variability

Short term variability

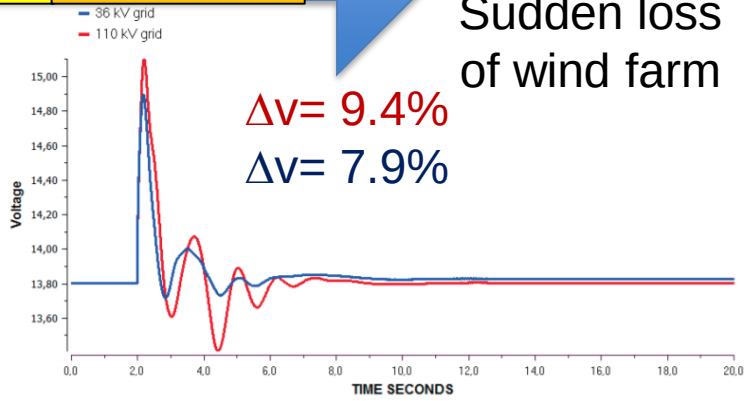


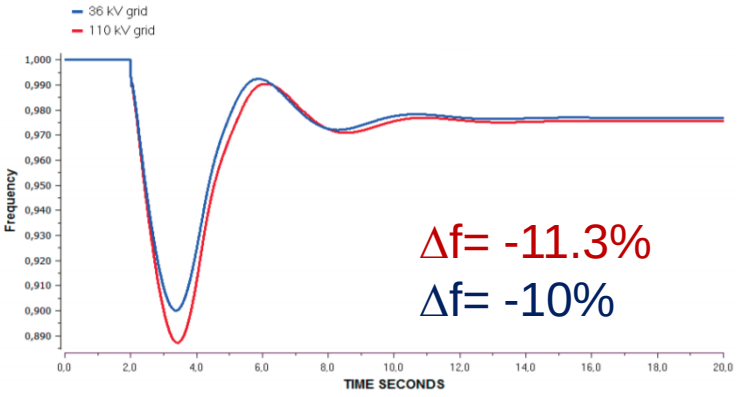


Sudden loss of wind farm



100 MW O&G + 100 MW WF

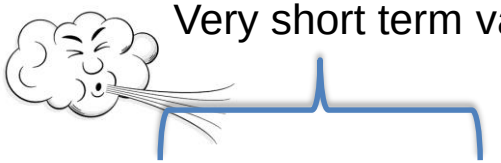




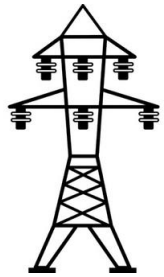
- **Does the installation operate within the allowed voltage limits under steady state and normal operating transients?**
- **Does the installation operate within the allowed frequency limits under steady state and normal operating transients?**

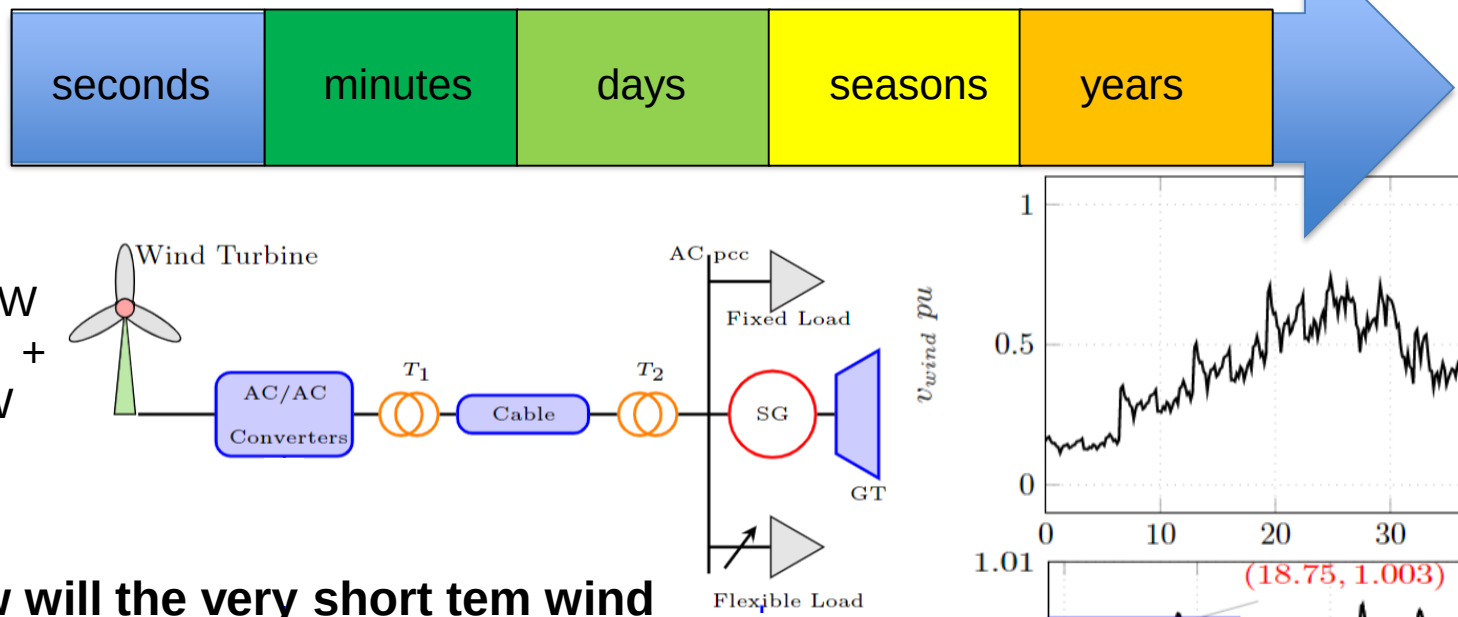
H. G. Svendsen, M. Hadiya, E. V. Øyslebø and K. Uhlen, "Integration of offshore wind farm with multiple oil and gas platforms," 2011 IEEE Trondheim PowerTech, Trondheim, 2011, pp. 1-3

Effect of the wind variability

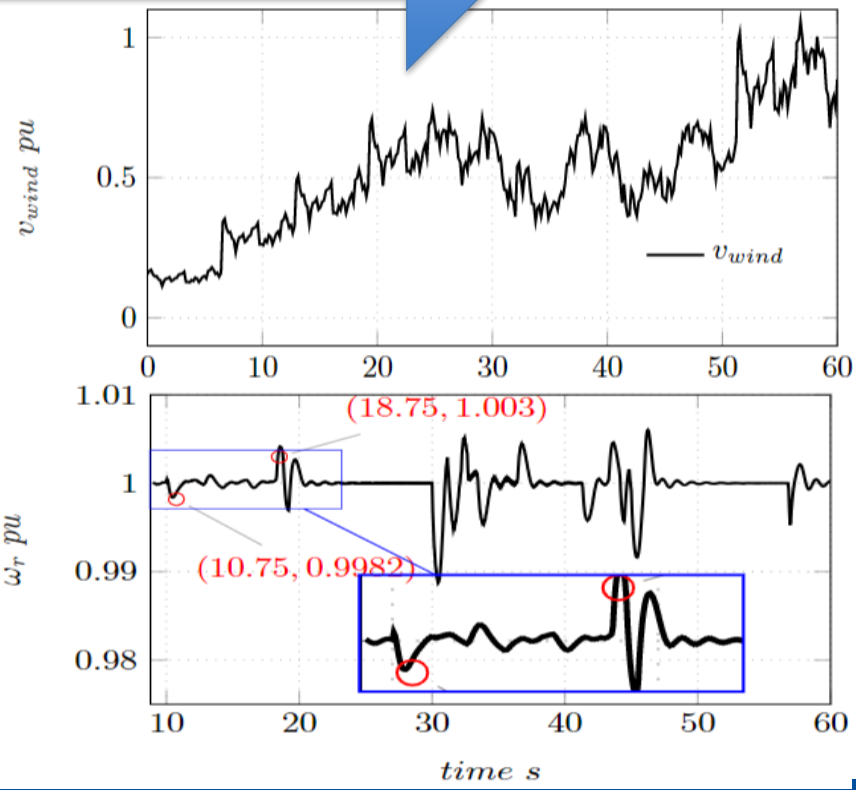


Very short term variability





25 MW O&G + 6 MW WF

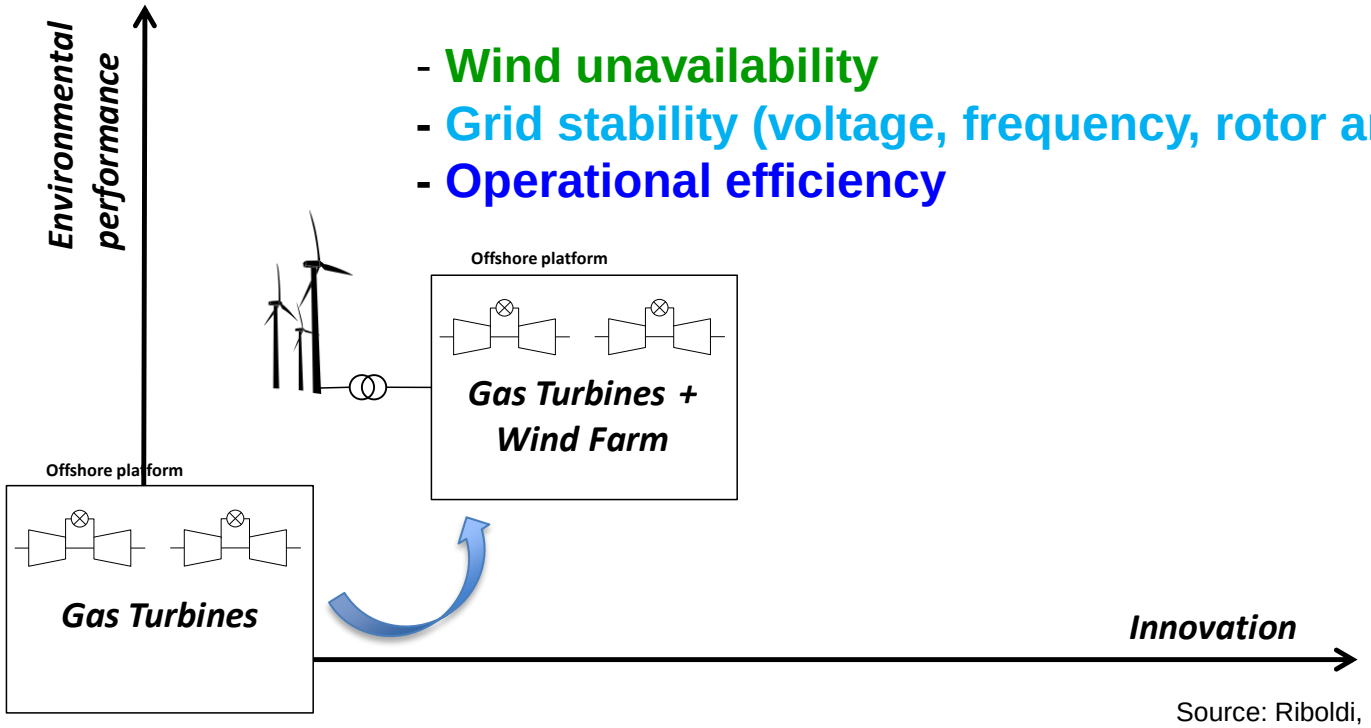


- How will the very short tem wind variability affect the rotor angle stability of electrical machines directly connected to the grid?

- Which countermeasures can be taken to mitigate such problems?

S. Sanchez, E. Tedeschi, J. Silva, M. Jafar and A. Marichalar, "Smart load management of water injection systems in offshore oil and gas platforms integrating wind power," in *IET Renewable Power Generation*, vol. 11, no. 9, pp. 1153-1162, 12 7 2017.

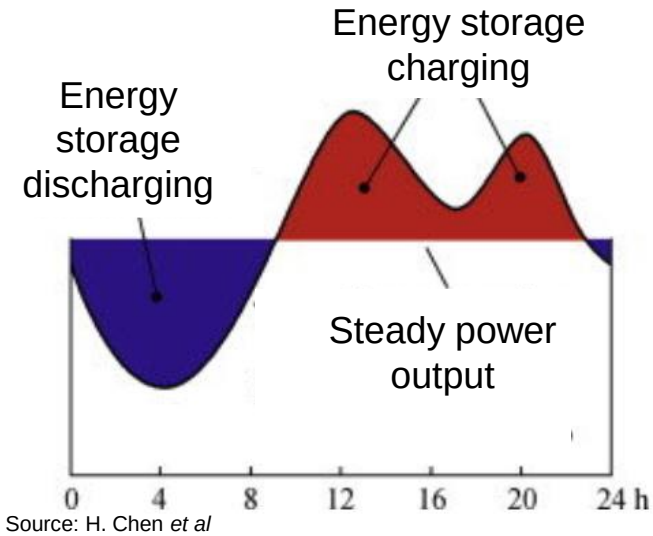
Progress in energy supply to O&G rigs



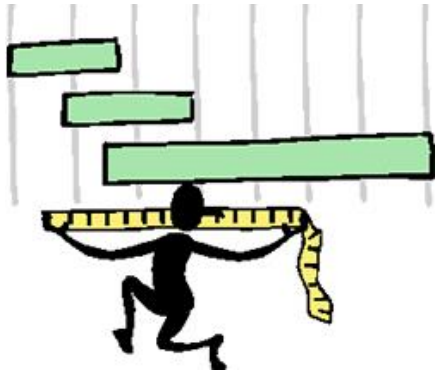
Source: Riboldi, Nord

Energy storage in O&G platforms

Energy storage: sizing



Source: H. Chen *et al*



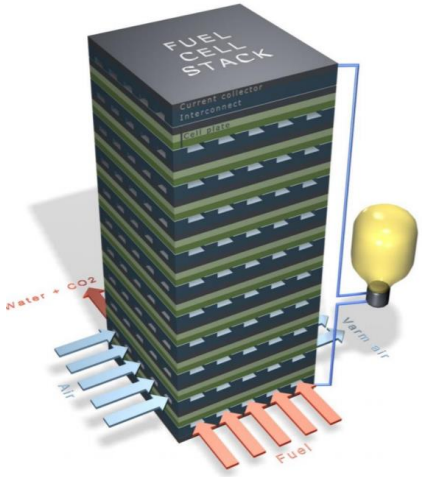
Sizing based on energy requirements?

Sizing based on stability/power quality requirements?

Energy storage in O&G platforms

Energy storage: choice of technology

Source: PBES



Source: Prototech

Source: Uwira

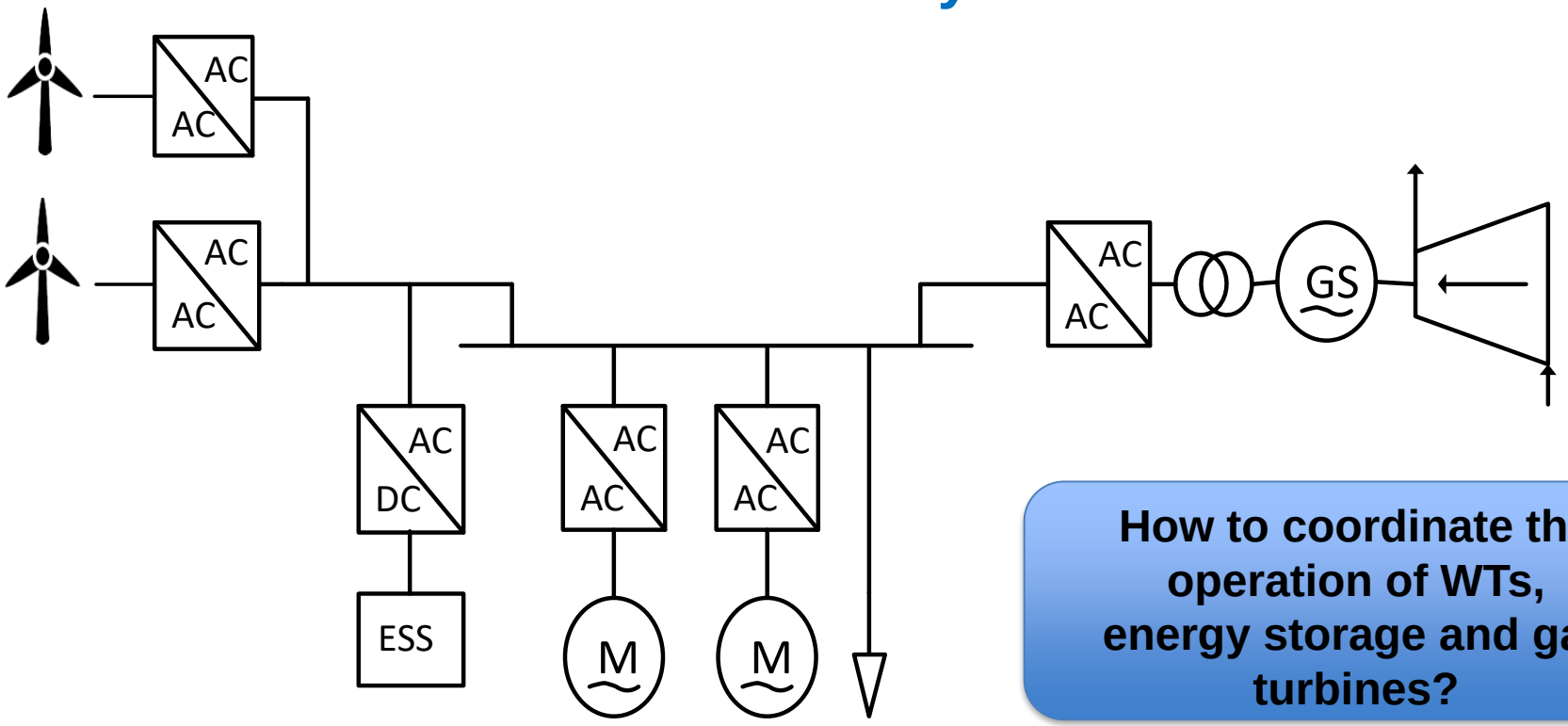
Source: Maxwell technologies

Technology suitability based on required depth of discharge, response time, size/weight, etc.

Opportunity for hybrid energy storage solutions

Energy storage in O&G platforms

Energy storage: operation within the isolated systems



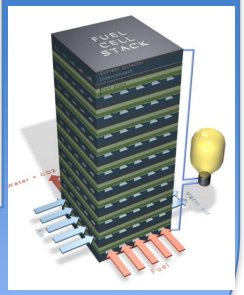
How to coordinate the operation of WTs, energy storage and gas turbines?

Future perspectives

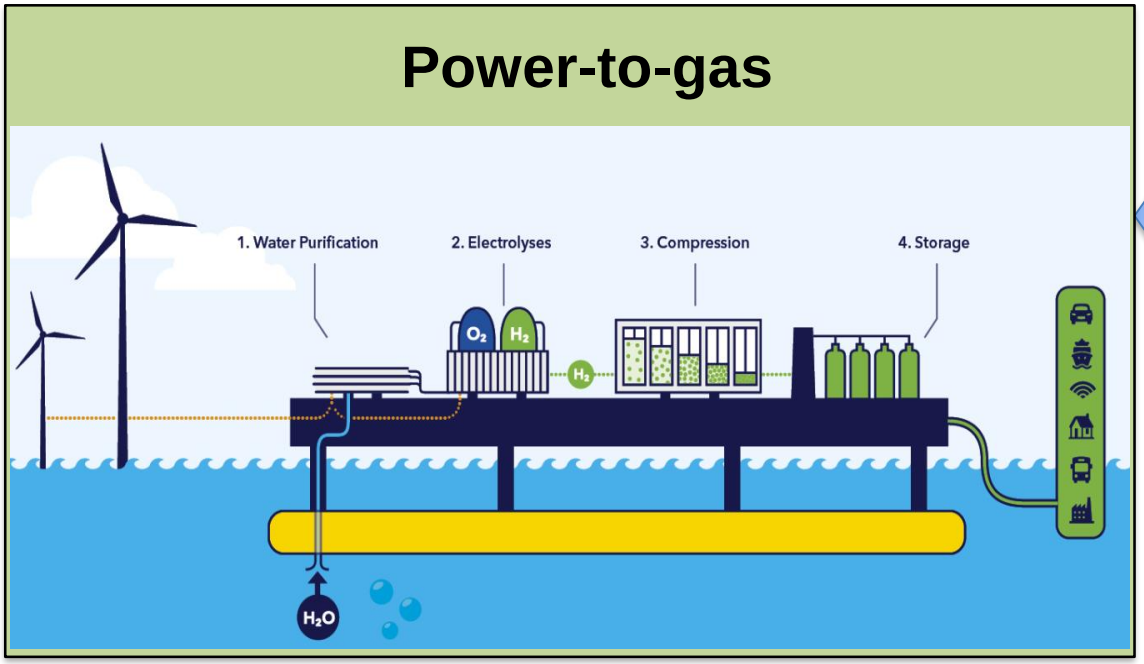
Renewables

En. management

Energy storage



Power-to-gas



Source: DNV GL

Future perspectives

Renewables

En. management

Energy storage

100% renewable O&G platforms

Future perspectives

Renewables

En. management

Energy storage

Offshore energy hubs

Source: Energinet

Oil & Gas platforms – Activity @NTNU-IEL

Specialization projects/MSc Theses:

2018: Systematikk for planlegging av mikronett
2017: Electrical Grid Study of Using Offshore Wind Power for Oil & Gas Offshore Installations
2017: Power quality studies of a Stand-alone Wind-powered Water Injection System without Physical Inertia
2016: Wind Powered Water Injection Systems for Oil and Gas Applications
2016: Use of Hywind in Oil and Gas Platforms to Reduce CO2 and NOx Gas Emissions […]

Experts in teamwork projects:

1) Synthetic Diesel production using renewable energy resources on a decommissioned offshore platform
2) Wind Powered Water Injection

Active and granted research projects:

Innovative Hybrid Energy System for Stable Power and Heat Supply in Offshore Oil & Gas Installation (HES-OFF 2018/22)

N. 1 PhD position at the Dept. of Electric Power Engineering

Energy management and control of offshore platforms integrating renewable energy (2019/22)

N. 1 PhD position at the Dept. of Electric Power Engineering

Research project: *"Sustainable Energy Solutions for Powering Offshore Oil and Gas Installations*"- Research contract with Statoil A.S.

LowEmission

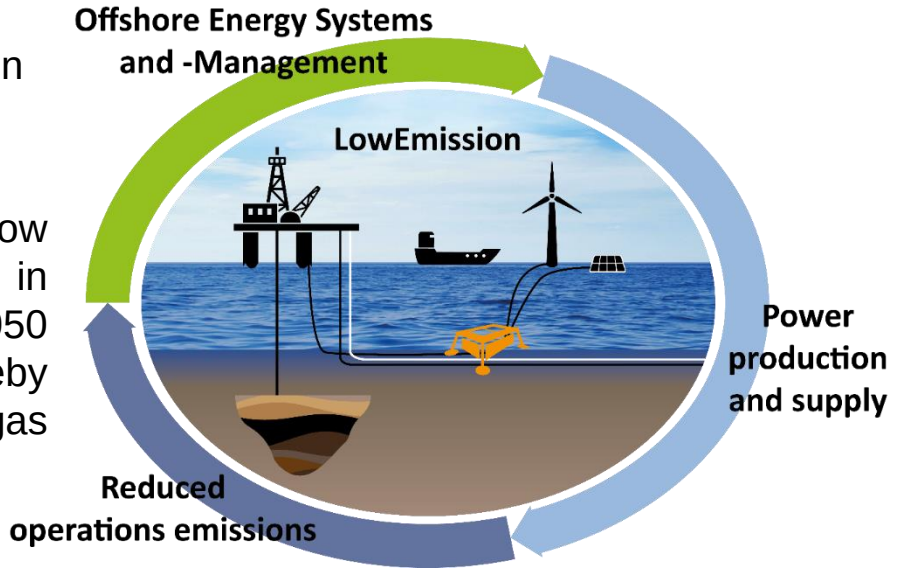
Research Centre for a Low Emission Petroleum Industry on the NCS

Vision

Move towards Zero Emission Oil and Gas Production

Mission

Promote development and implementation of low emissions technologies with 40 % reduction in emissions for existing fields & move towards 2050 goal of zero emissions for future fields, and thereby improve Competitiveness of Norwegian oil & gas industry



About the Centre

- Led by SINTEF, NTNU strategic partner
- Petrocentre (funded by RCN and Industry)
- Budget 30 M/year for 8 years:
  - 15 MNOK/year from RCN
  - 7.5 MNOK /year from partners
- Time period: 2019-2027

Thanks for your attention!

elisabetta.tedeschi@ntnu.no