Variable Frequency Operation for Future Offshore Wind Farm Design: A Comparison with Conventional Wind Turbines

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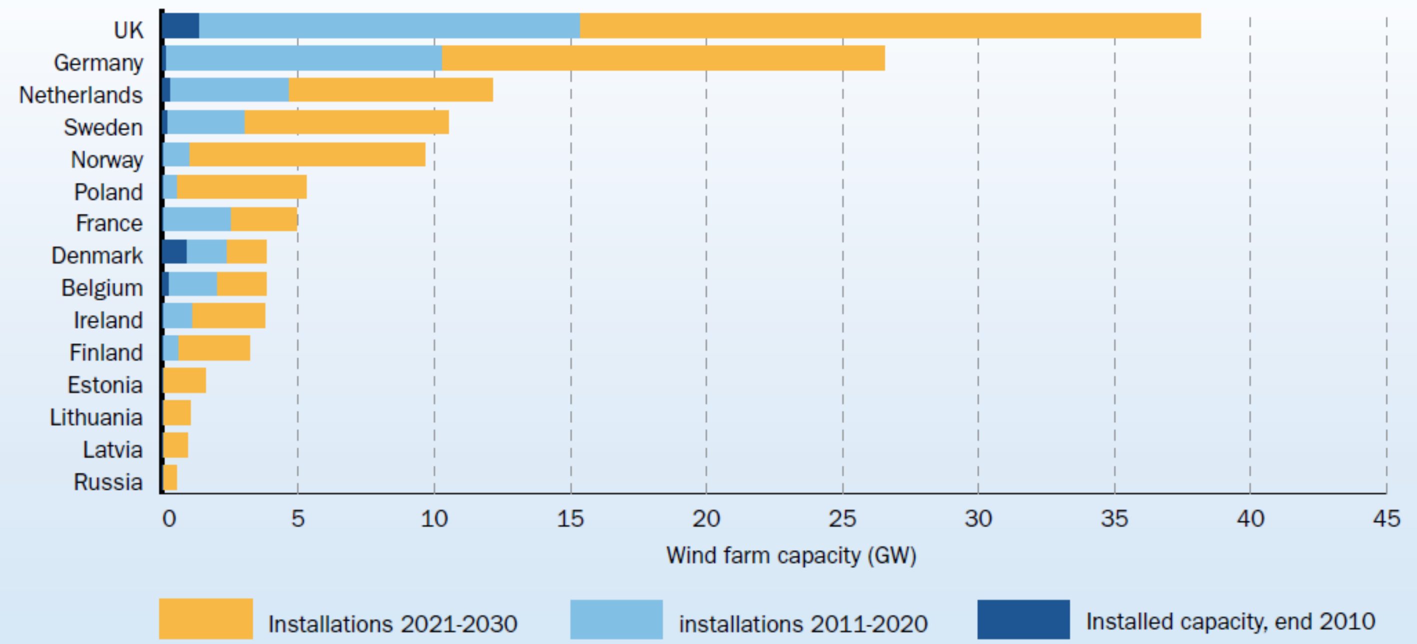
Presentation Overview

- Introduction
- Motivation
- Variable Frequency Operation
- Modelling Power Losses of Wind Farm Components
- Results
- Conclusions

Introduction : Offshore Wind

- Offshore wind expected to contribute significantly to European targets
- Currently approx. 5 GW installed, 40 GW by 2020, 150 GW by 2030

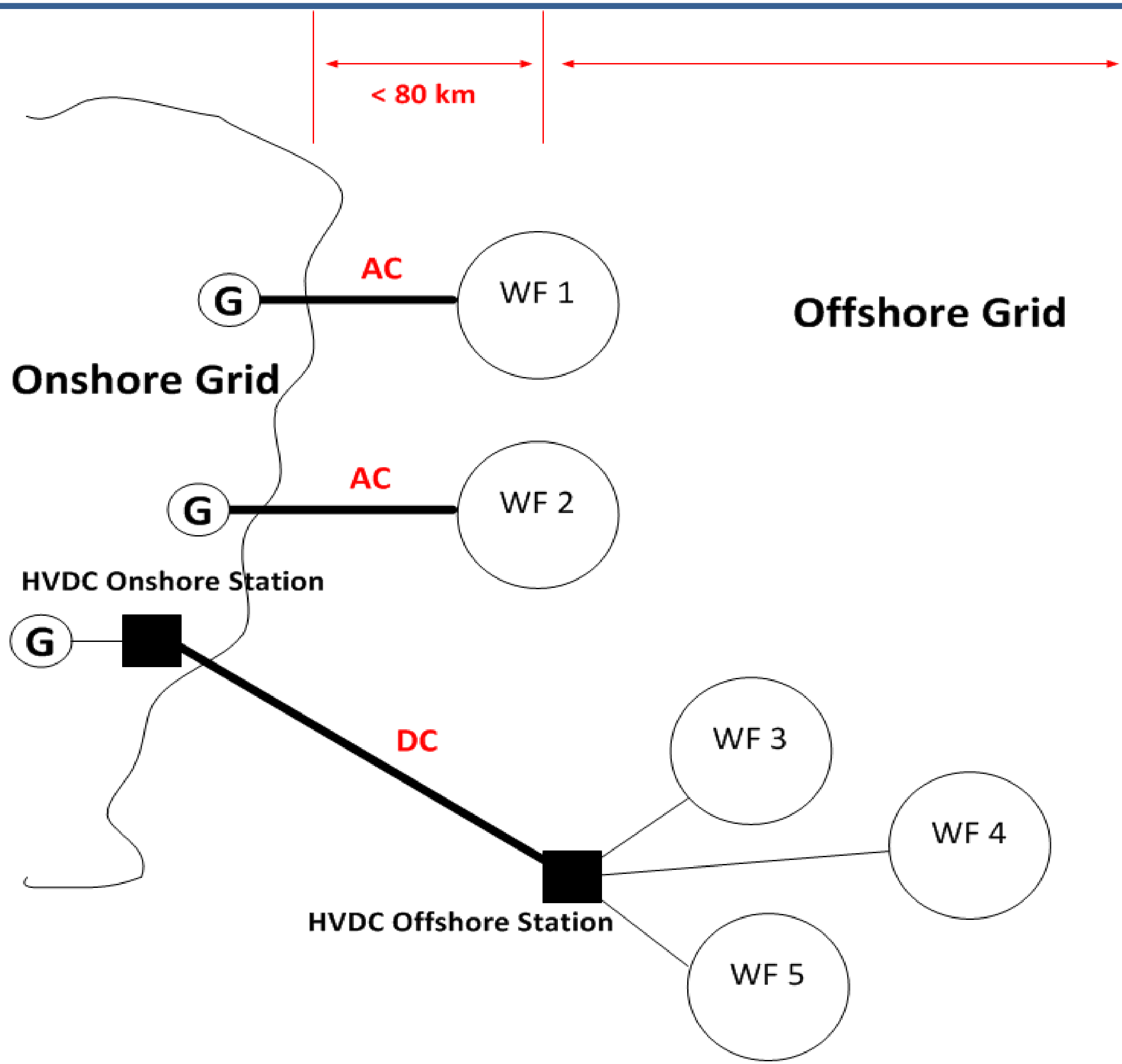
FIGURE 2.1: INSTALLED CAPACITY OF OFFSHORE WIND FARMS IN NORTHERN EUROPE TO 2030, OFFSHOREGRID SCENARIOS



Source: OffshoreGrid scenarios

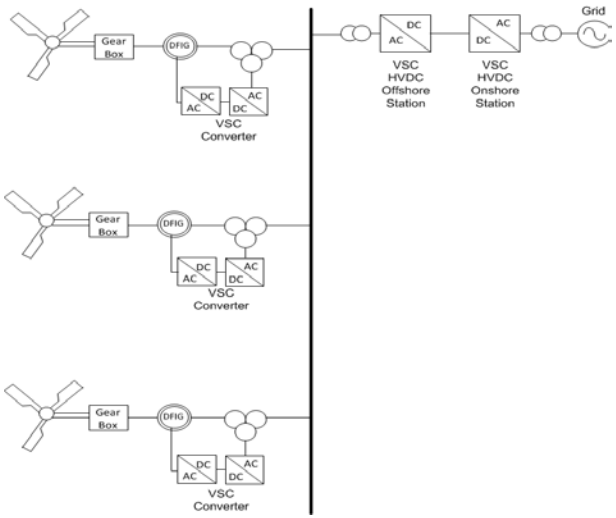
EWEA, Pure Power – Wind energy targets for 2020 and 2030, 2011 update, July 2011.

Introduction : Offshore Grid

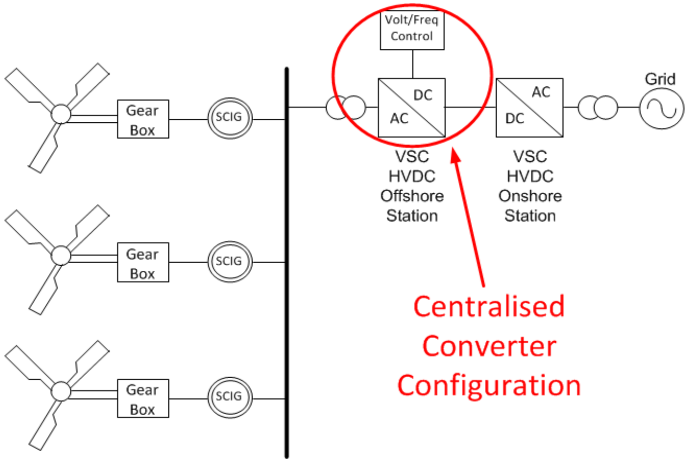


Offshore Connection Possibilities

- Converters at the turbine and at the VSC-HVDC transmission station



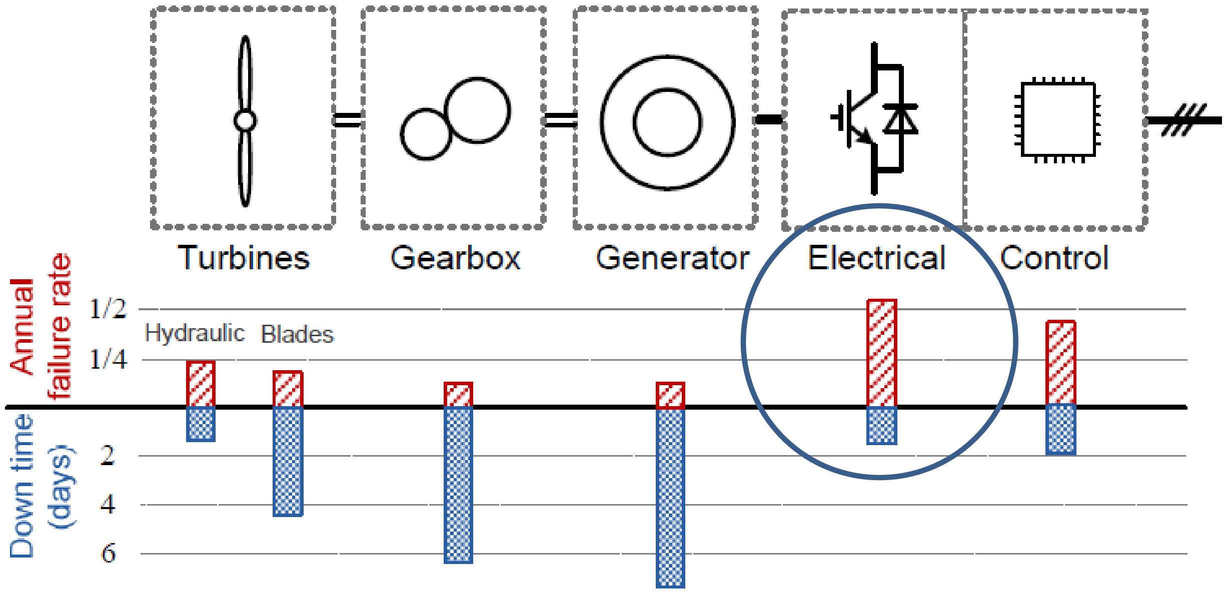
- AC to DC conversion just at the transmission converter level[1 2 3]



[1] R. Meere, M. O'Malley, A. Keane "*VSC-HVDC Link to Support Voltage/Frequency Fluctuations for Variable Speed Wind Turbines for Grid Connection*" IEEE PES Innovative Smart Grid Technologies (ISGT) Europe Conference, Berlin, Germany, October 14 – 17, 2012.
[2] V. Gevorgian et al. "*Variable Frequency Operation of a HVDC-VSC Interconnected Type 1 Offshore Wind Power Plant*" IEEE Power and Energy Society General Meeting July 22-26, pp 1-8, 2012.
[3] L. Trilla et al. "*Control of SCIG wind farm using a single VSC*" in Proc. 14th European Conference on Power Electronics and Applications, Aug. 30 -Sept. 1, 2011.

Motivation

- Power electronics has the highest failure rate for the wind turbine system



- Less power electronic converters results in greater wind farm reliability[4].

[4] B. Hahn, M. Durstewitz, K. Rohrig "*Reliability of wind turbines –Experience of 15 years with 1500 WTs*", Wind Energy: Proceedings of the Euromech Colloquium, S. 329–332, Springer-Verlag, Berlin.

Objective of the Study

- Type 4 Turbines optimise individual machines for maximum wind capture
- Variable Frequency Scheme : cluster of turbines are centrally controlled – lose up to 2% annual energy capture[2]

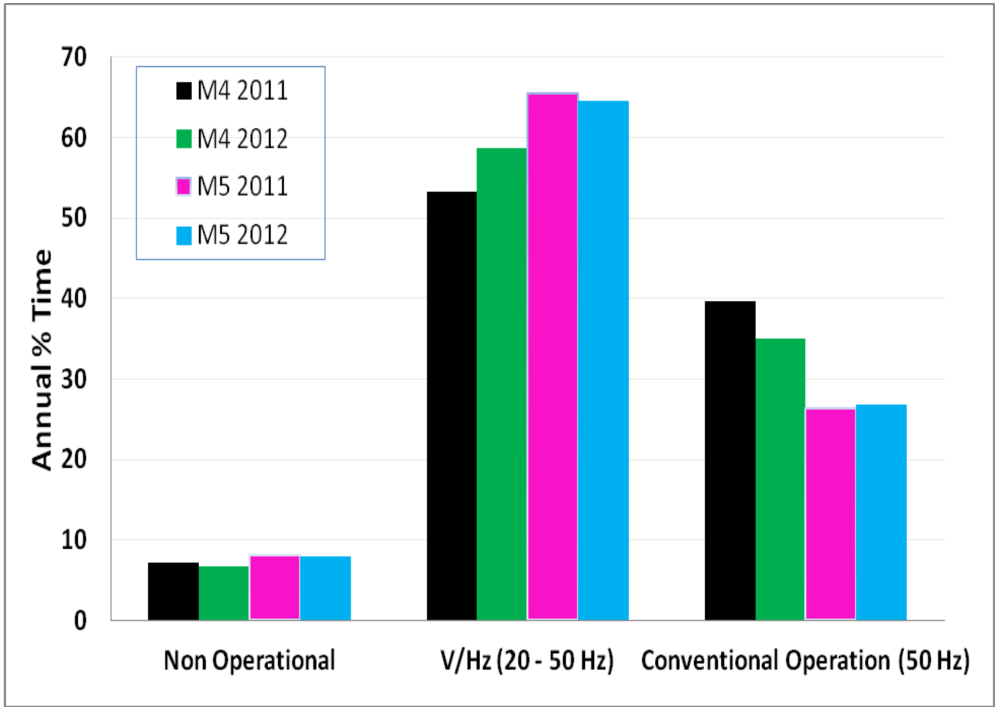
But.....

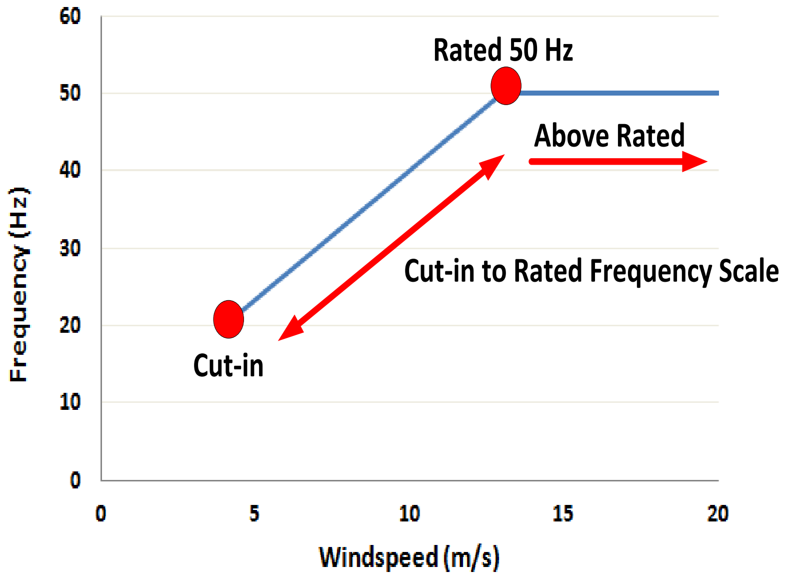
- Can you save with reduced power losses for variable/lower frequency operation in the wind farm ?
- Compare both variable and fixed frequency designs to see is there a difference in power loss

[2] V. Gevorgian et al. "*Variable Frequency Operation of a HVDC-VSC Interconnected Type 1 Offshore Wind Power Plant*" IEEE Power and Energy Society General Meeting July 22-26, pp 1-8, 2012

Offshore Wind and Variable Frequency

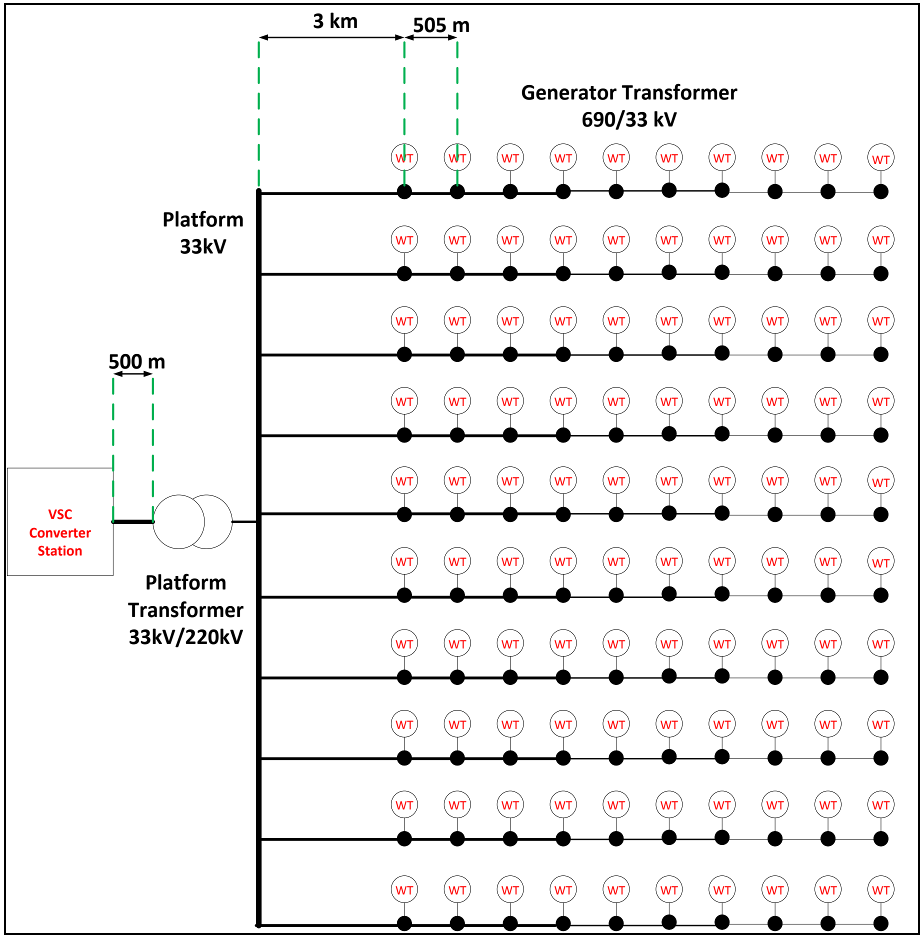
- Wind speed data is utilised to demonstrate the potential of the variable frequency approach
- Focus on wind speeds for turbine operational range at 2 sites off the west Irish coast for the years 2011/2012





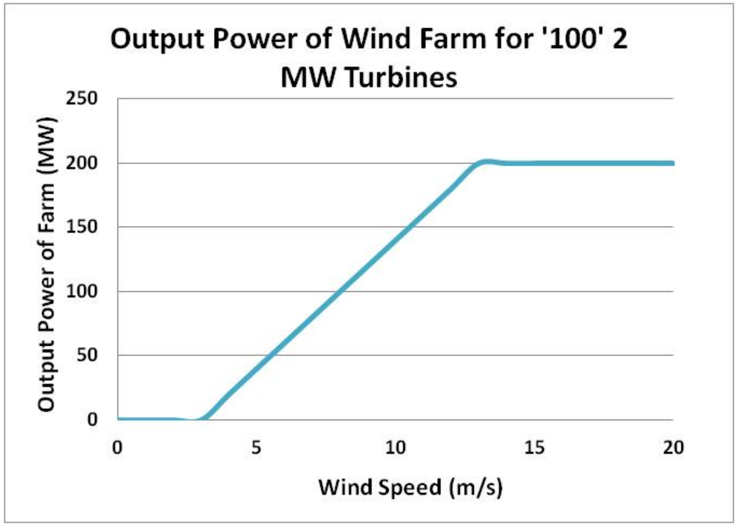
< 50 Hz Operation Impact at Farm

- The lower than rated frequency operation of the system may result in potentially lower power loss for the wind farm components - the **cables** and **transformers**



Key Losses for Wind Farm [100 (2MW)] :

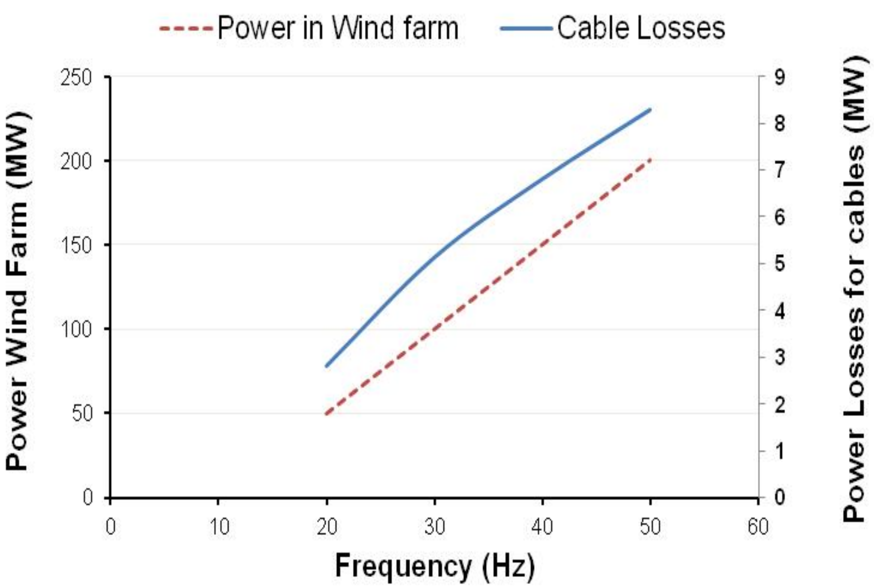
- Cables
- Transformers
- Converters

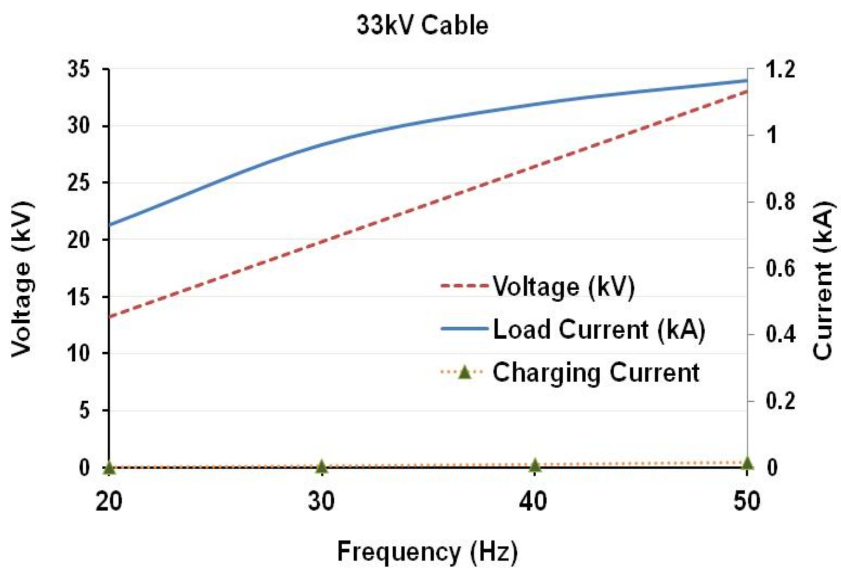


Impact: Cables

Cables:

- Charging current reduces with decreasing frequency: $I_C = 2\pi f C l V$
- Decreasing V/Hz – Load current does not reduce at the same rate

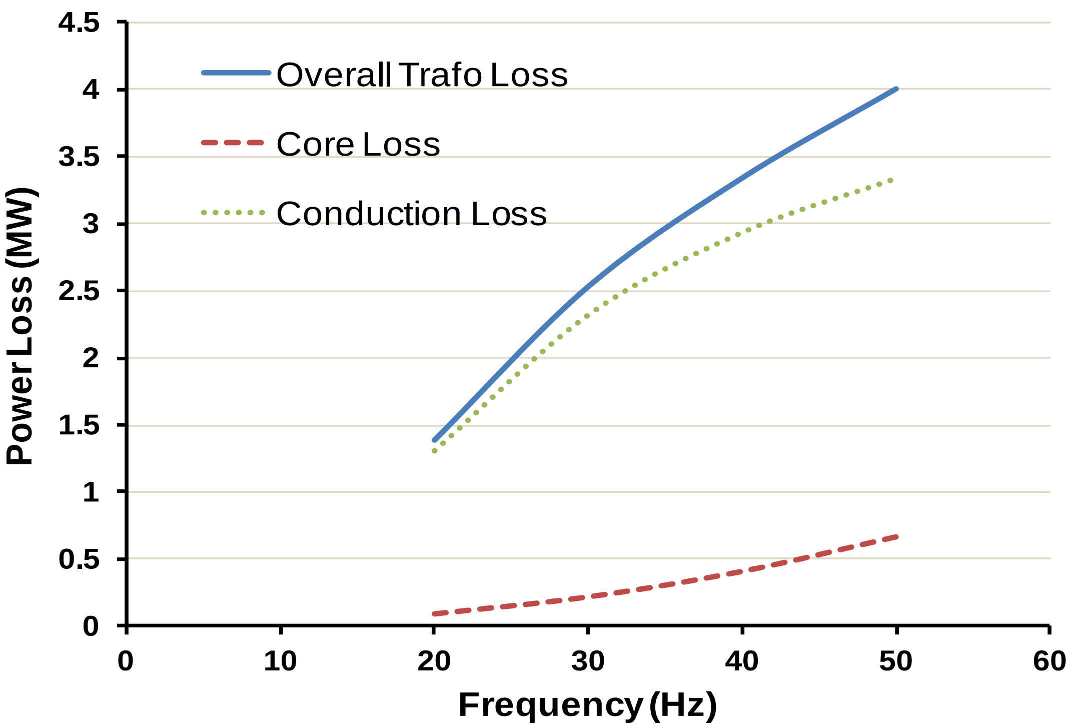




Impact: Transformers

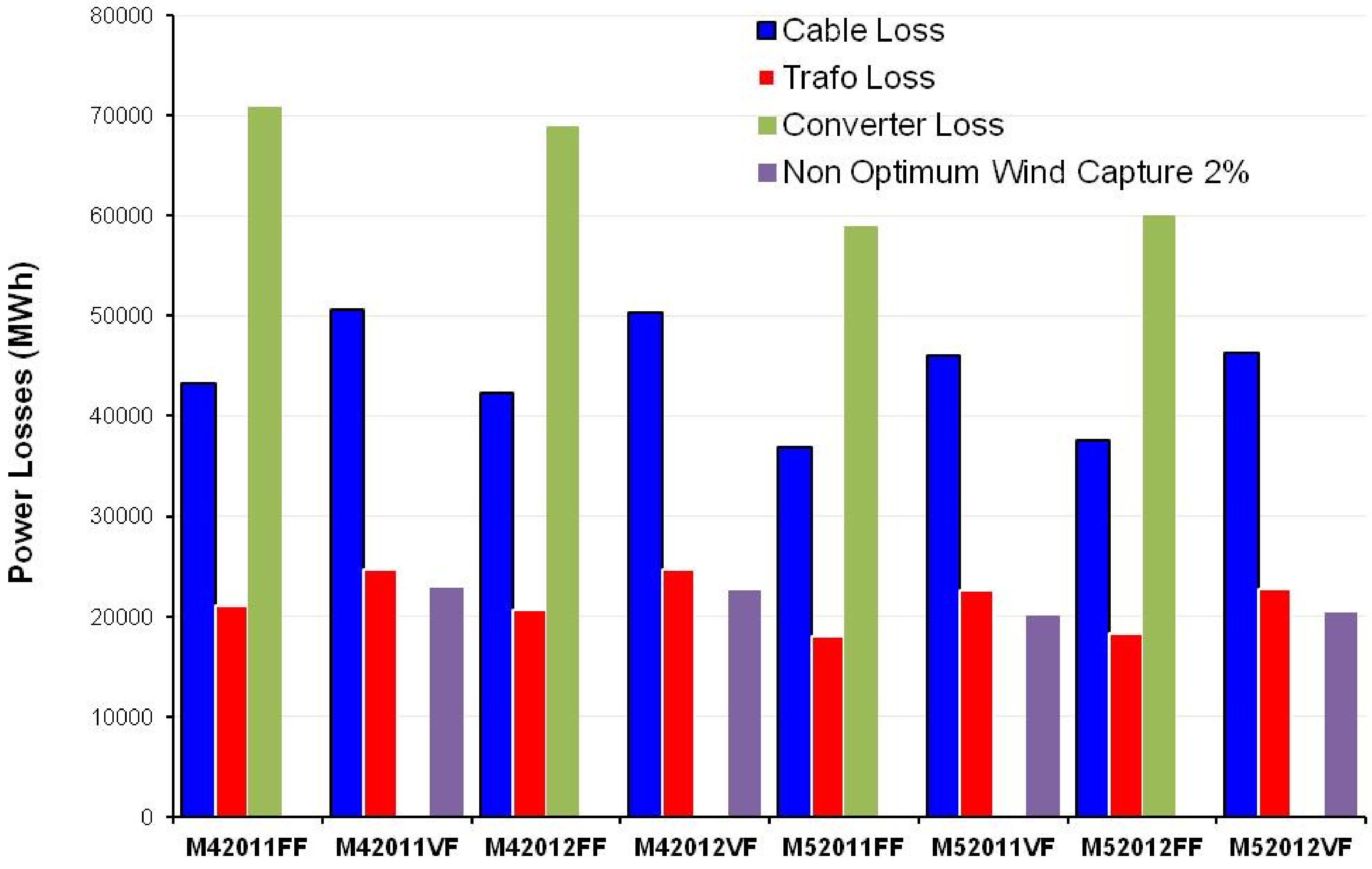
Transformer:

- Core Losses – based on the Steinmetz Equation : $P_{core} = Kf^{\alpha} B_{pk}^{\beta}$
- Conduction Losses - I^2R winding losses (excludes AC resistance loss)



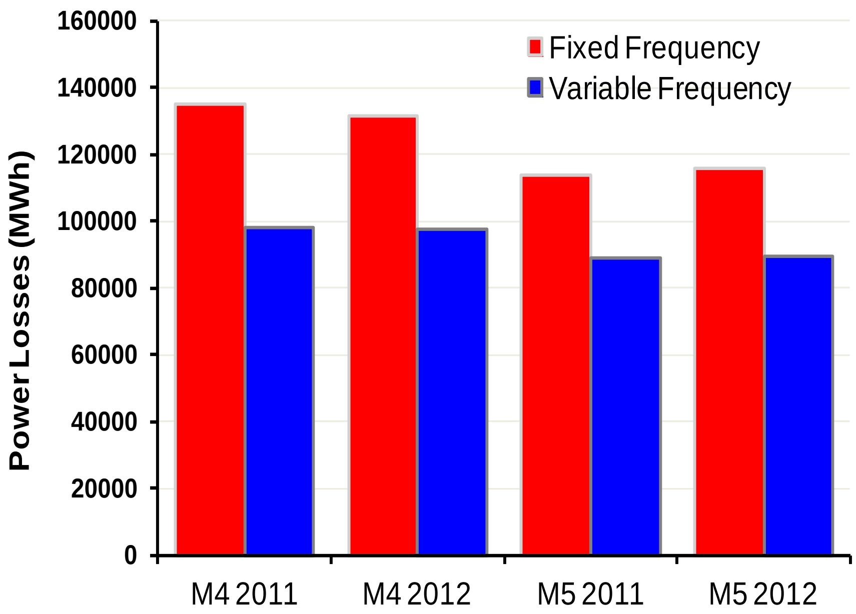
Variable vs. Fixed Frequency: Losses

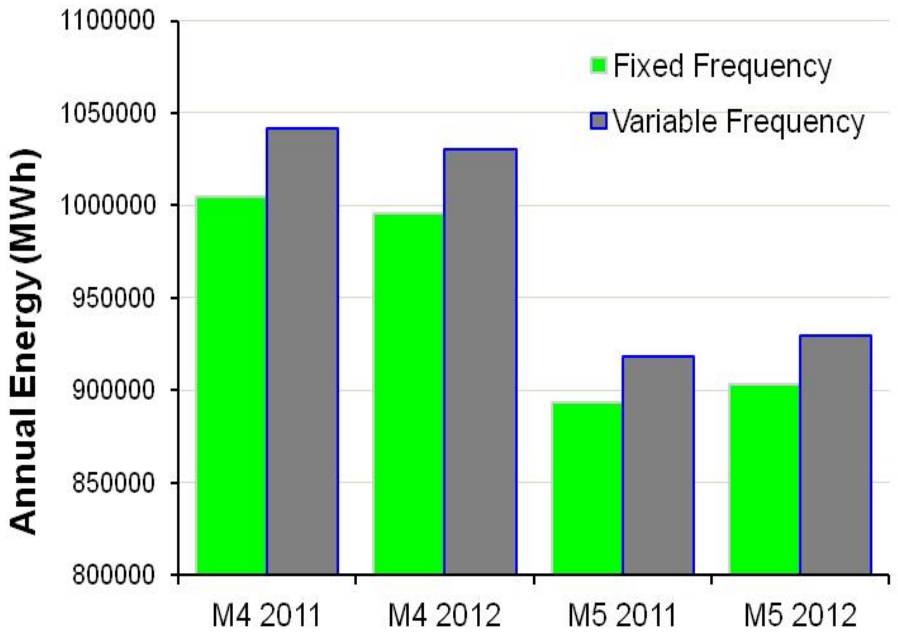
FF : Fixed Frequency **VF : Variable Frequency**



Variable vs. Fixed Frequency Results

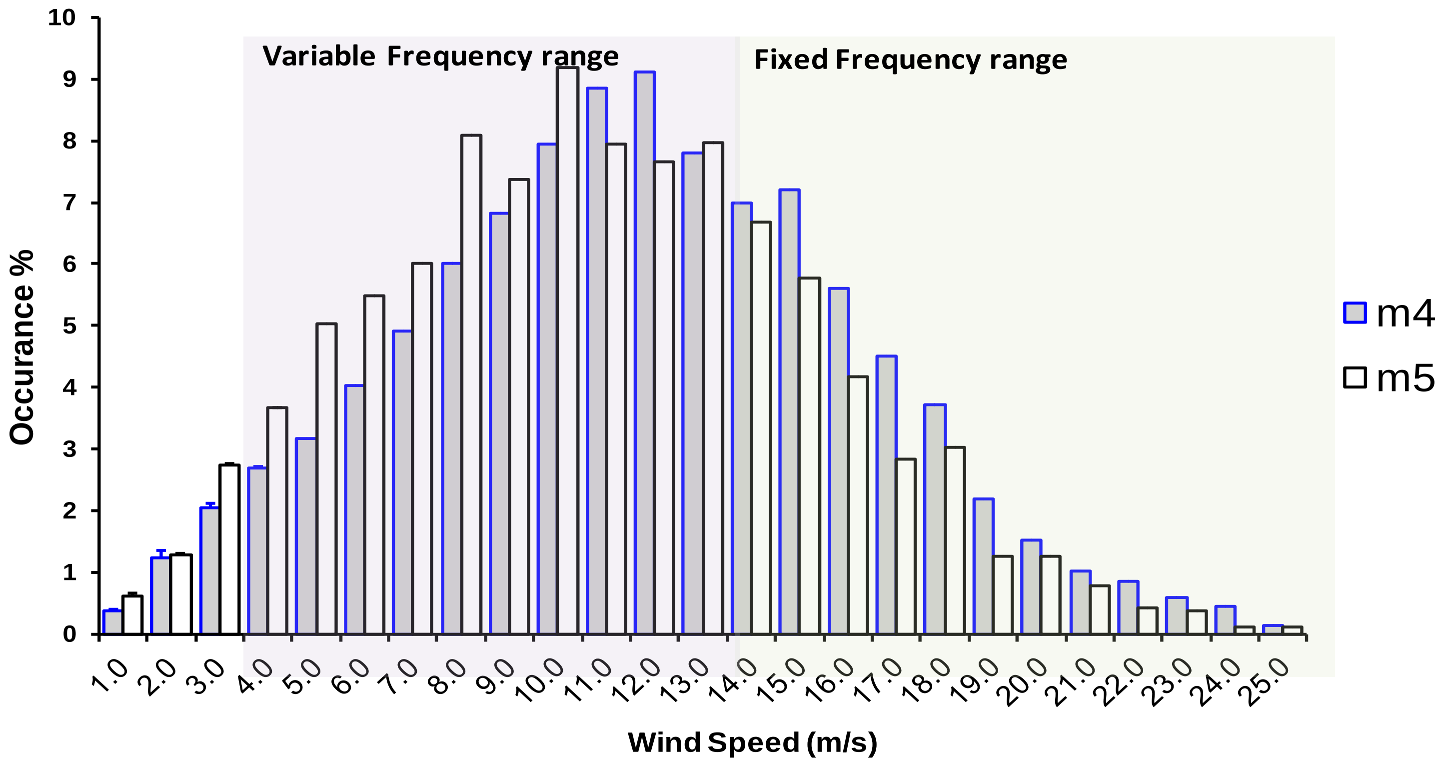
- 2012/2011 Wind Data for 2 Irish Offshore Sites
- Variable Frequency 2.7-3.5 % **greater** total annual energy return





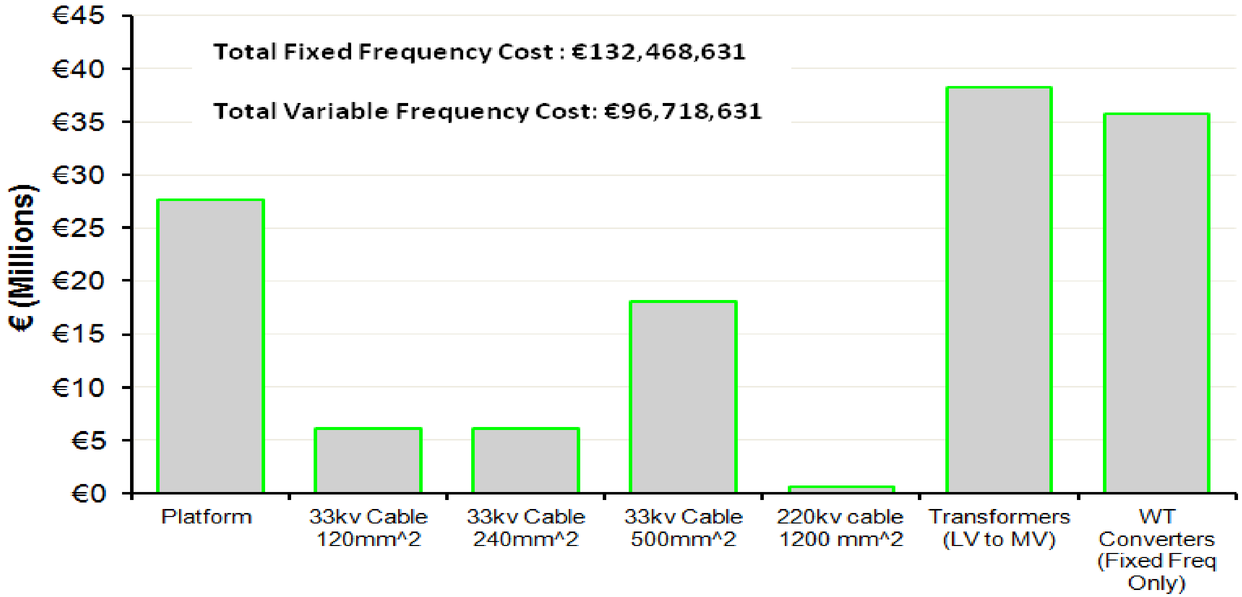
Variable vs. Fixed Frequency Results

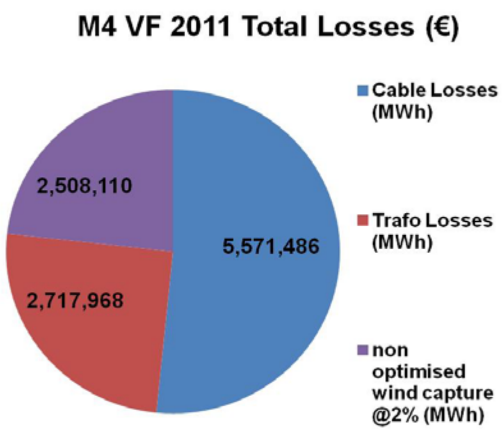
- 2012 Mean Wind Speed Distribution for both sites
- Site specific – Site M5 is more favorable for variable frequency

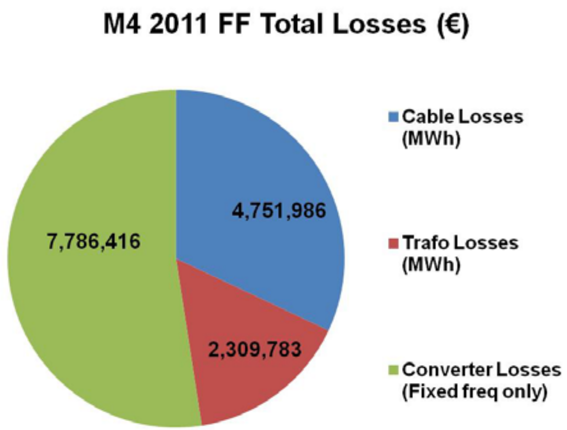


Variable vs. Fixed Frequency Results

- **FF approach has 27% greater losses in terms of power loss (€) than VF**







Total VF €10,797,564

Total FF €14,817,185

Conclusions and Future Work

- Question: Can you gain what you lost (2% Energy Capture with Variable Freq)

Yes : Lower power loss, greater annual energy, less maintenance and lower cost

But, ……..

- Further work is needed to fully understand the non-optimum power capture calculation and also examine the impacts of wind farm layout on energy capture variation

- Reliability of power electronics will improve and costs will reduce

- This study is only opening the discussion – more detailed analysis and models are needed to further understand the potential of the approach

Thanks for your attention

Questions ?