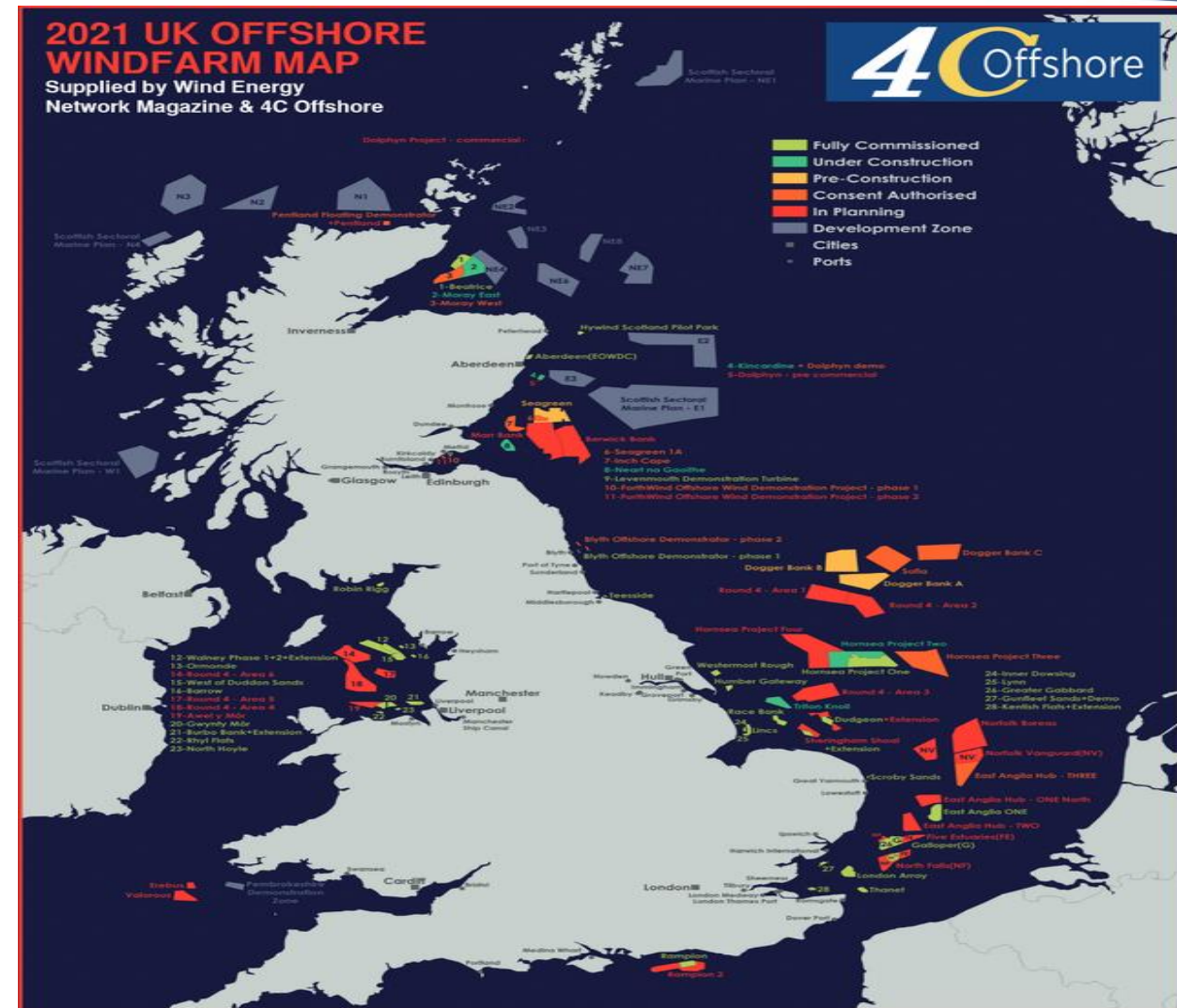
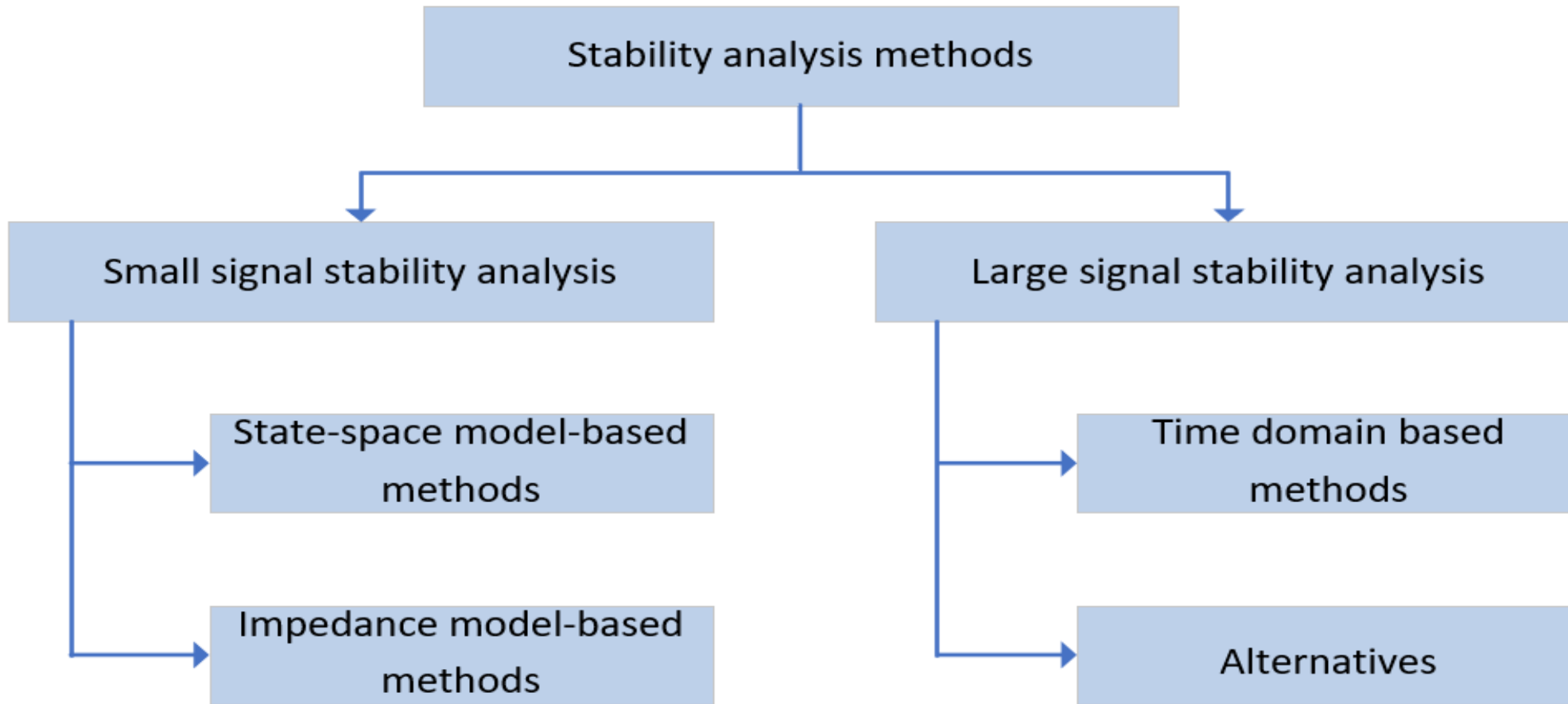


Offshore Wind Farm Interaction Studies

- Large number of MMC based HVDC systems for interconnection or offshore wind farm integration are already in operation and many more will be installed in the coming years.
- Due to the presence of Type 3 and Type 4 Wind turbines, OWF has multiple internal harmonics, which causes complex internal dynamics and multifrequency response.
- With high penetration of converter interfaced renewable energy and distributed generation, and increased use of HVDC interconnections, the characteristics of power systems is undergoing significantly changes.
- Interaction between grid-connected converters and networks is likely to increase, which may lead to stability and resonance problems, and in particular, when the grid is “weak” as the relatively high system impedance.





State space model-based methods

- State space model can be derived by linearising the targeted system's behaviours at the operating point.
- With the system's state space matrix provided, the system stability can be evaluated with different analysis methods.

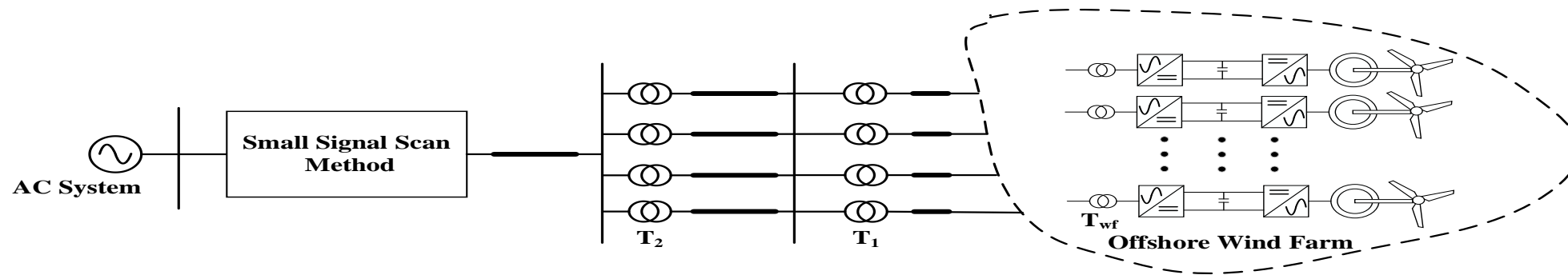
Impedance model-based methods

- The impedance model-based method has also been widely practiced to study stability issues with the following advantages:
 - Simplification of the computation process
 - Capable of accessing black-boxed systems
- The studied system is divided as a source equivalent and a load equivalent, and system stability can be determined by various further analysis methods.

Time Domain Analysis Method

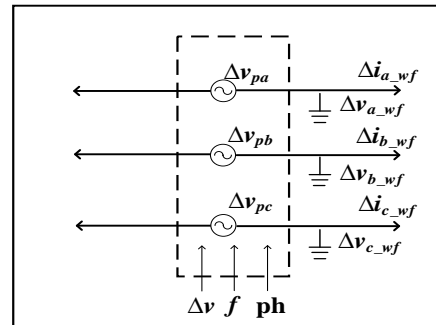
- The time domain analysis approach is frequently used to examine the large-signal stability of a system, online and offline EMT simulation tools have been created to study the behaviour of systems under various disturbances. EMT models with correct parameters provided can deliver the most reliable results. EMT based simulation are also commonly practiced to validate the developed small signal models.

- Type IV wind turbines based on power electronics are prone to subsynchronous as well as super-synchronous resonance when connected to AC Grid.
- Reason for same being voltage source converters in design, these voltage sources are current controlled, and the nature of any such closed-loop control will lend to a tuned resonant impedance and associate small-signal modes being unavoidably present in a given design.
- In order to understand these resonance Frequencies and interaction with AC system we performed small signal studies on an OWF model integrated with AC Source.



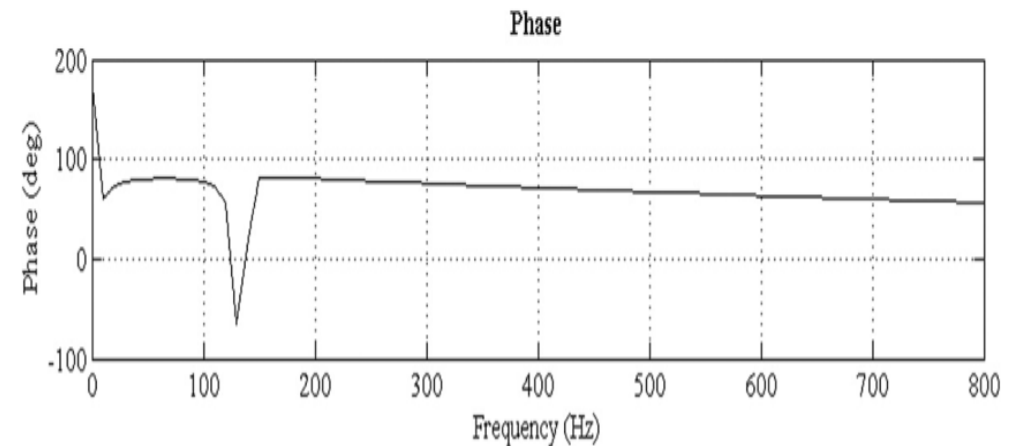
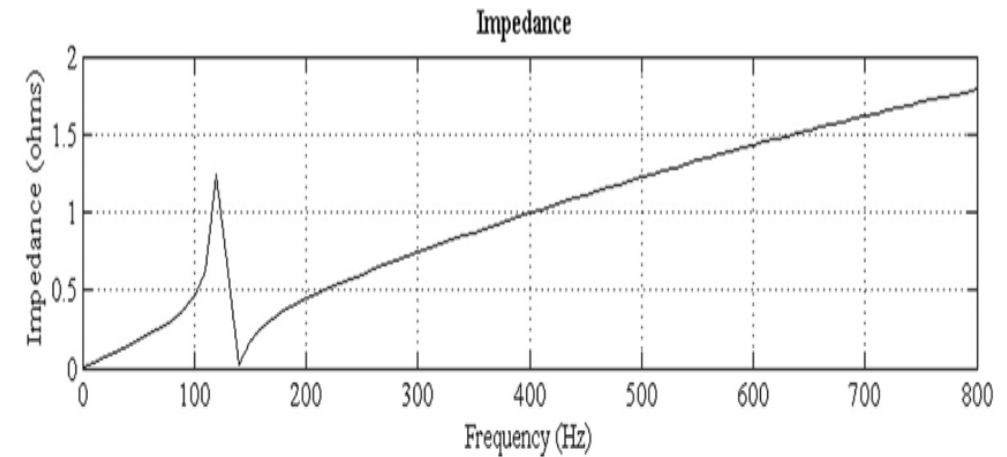
- A time-domain simulation model of a grid connected OWF is established in PSCAD to verify the small-signal admittance of EMT Model in pn frame.
- Strathclyde and HVDC Centre developed Small Signal Model was integrated with our OWF Model and AC Model to carry out Small Signal Studies.
- In order to extract the admittance in the time-domain simulation, a series of small-perturbation voltages (Δv_{pa} , Δv_{pb} , Δv_{pc}) (1 -2 at different frequencies are injected to the system at the point of common coupling (PCC)

Small Signal Scan Method



- By measuring the voltages (Δv_a , Δv_b , Δv_c) and response currents (Δi_a , Δi_b , Δi_c) the admittance of the converter in time-domain can be derived.

- In OWF Model we have performed different cases by including/excluding the Statcom, Cables and Wind Farms by analysing different permutations possible .
- Impedance Plots(Z-plots) for the frequency were plotted for all the cases for the Positive Phase Sequence (PPS) and Negative Phase Sequence Injection(NPS).
- A simplified 2 by 2 admittance matrix in PN frame is extracted from the OWF embedded small-signal model for ease of system stability analysis.
- Admittance graphs from EMT Model results using MATLAB/SIMULINK are prepared for stability analysis.



Thanks for listening.
Any questions, please?

□ For further information, please visit www.hvdccentre.com ; OR email: [info@hvdccentre.com/](mailto:info@hvdccentre.com)



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