Impedance Assessment of Offshore Wind Farm

Nikhil Sharma, Shangen Tian, Dong Chen, Ben Gomersall, Benjamin Marshall

The National HVDC Centre, Glasgow, UK

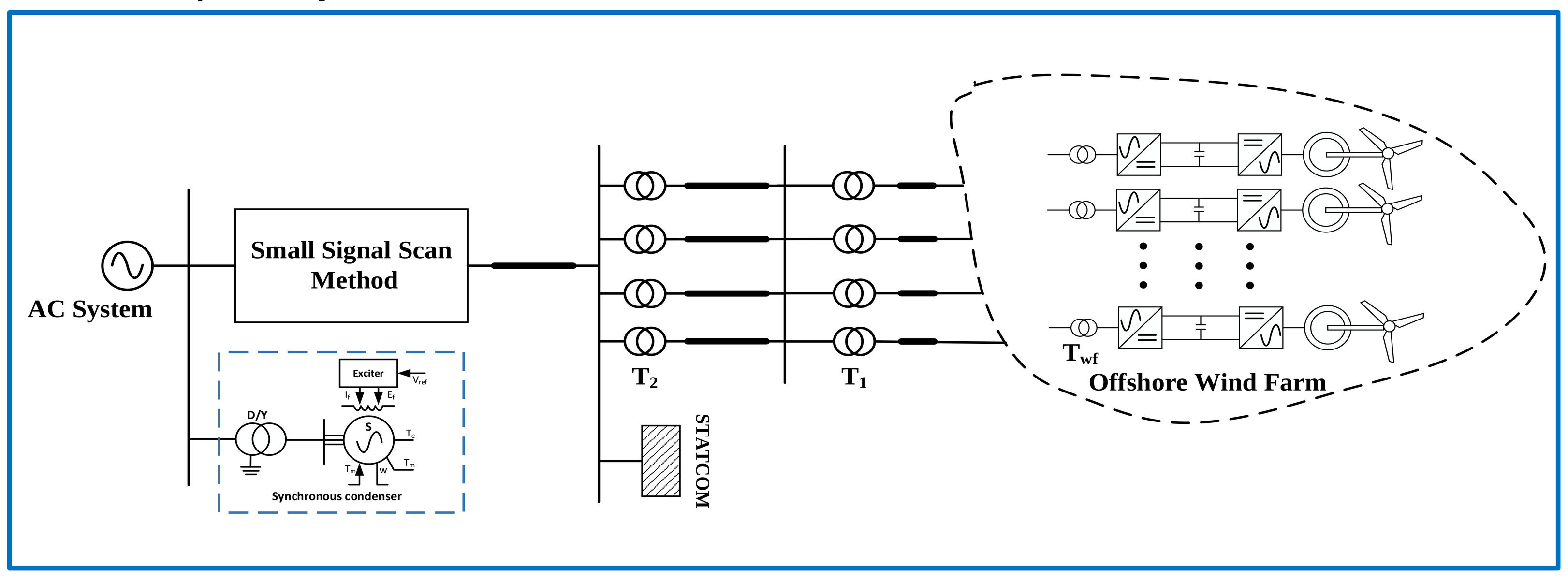
nikhil.sharma@sse.com

ACDC® 2023
AC and DC Power Transmission
1 – 3 March 2023
University of Strathclyde | Glasgow | UK

The National HVDC Centre

Introduction

Resonance between wind turbines and the grid is a practical problem that has gained much attention in recent years. The unstable resonances between the wind turbines in offshore wind farm and the weak grid within a wide frequency band have been frequently reported. In this paper we are performing the impedance assessment of an illustrative offshore wind farm arrangement using small signal injection approach in PSCAD Electro Magnetic Transients (EMT) Generic Model as represented in the Figure in order to quantify such modes.



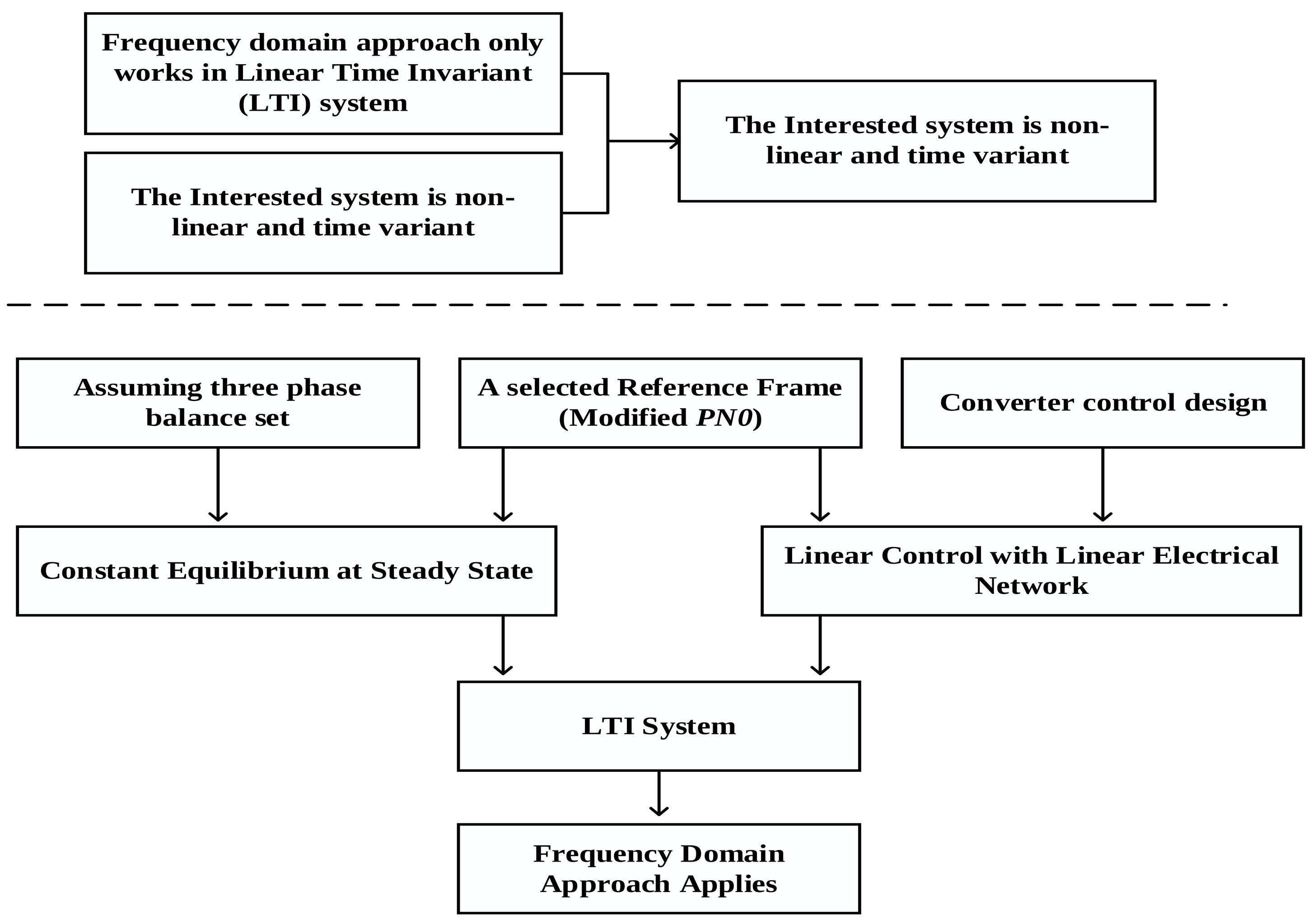
Objective

- This paper aims to identify the resonant frequencies leading to instability in Offshore Wind Farms and propose solution for same.
- Using the small signal analysis tools available and implementing same in the Offshore Wind Farm models for developing the Sequence Impedances.
- Sequence Impedances presents an idea about the sub synchronous resonant frequencies which may drive an oscillatory behaviour in the network.

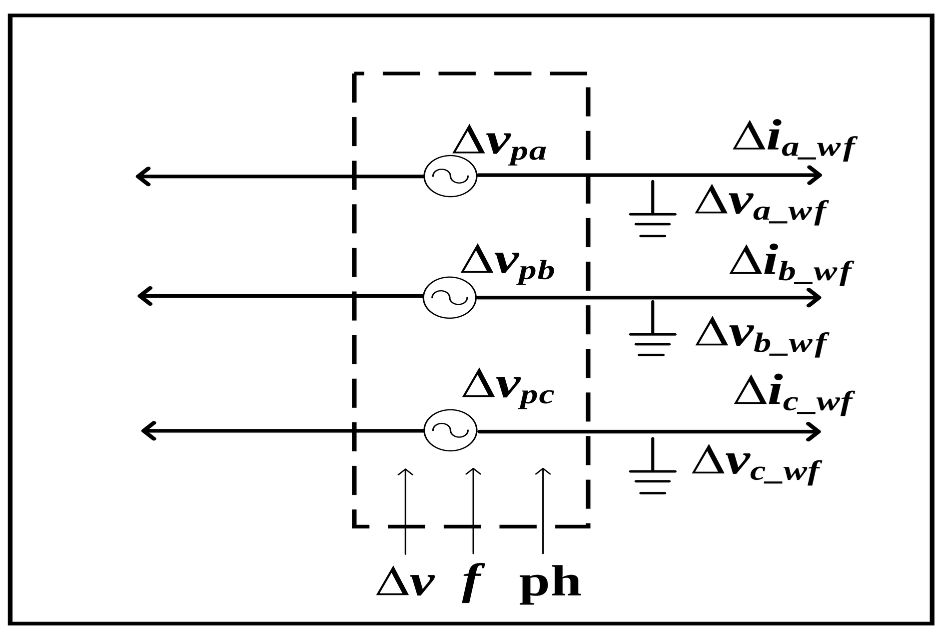
Methodology

Linearizing the time-varying system along a steady periodic trajectory yields a linear time periodic (LTP) system. Since the model which we are analysing is non-linear and time variant we need to make it a linearized one as frequency domain approach only works in Linear Time Invariant (LTI) system.

To obtain the impedance model analytically over a wider frequency band, linearization is required as represented. In order to extract the admittance in the time-domain simulation, a series of small-perturbation voltages (Δv_{pa}, Δv_{pb}, Δv_{pc}) at different frequencies are injected to the system as represented.



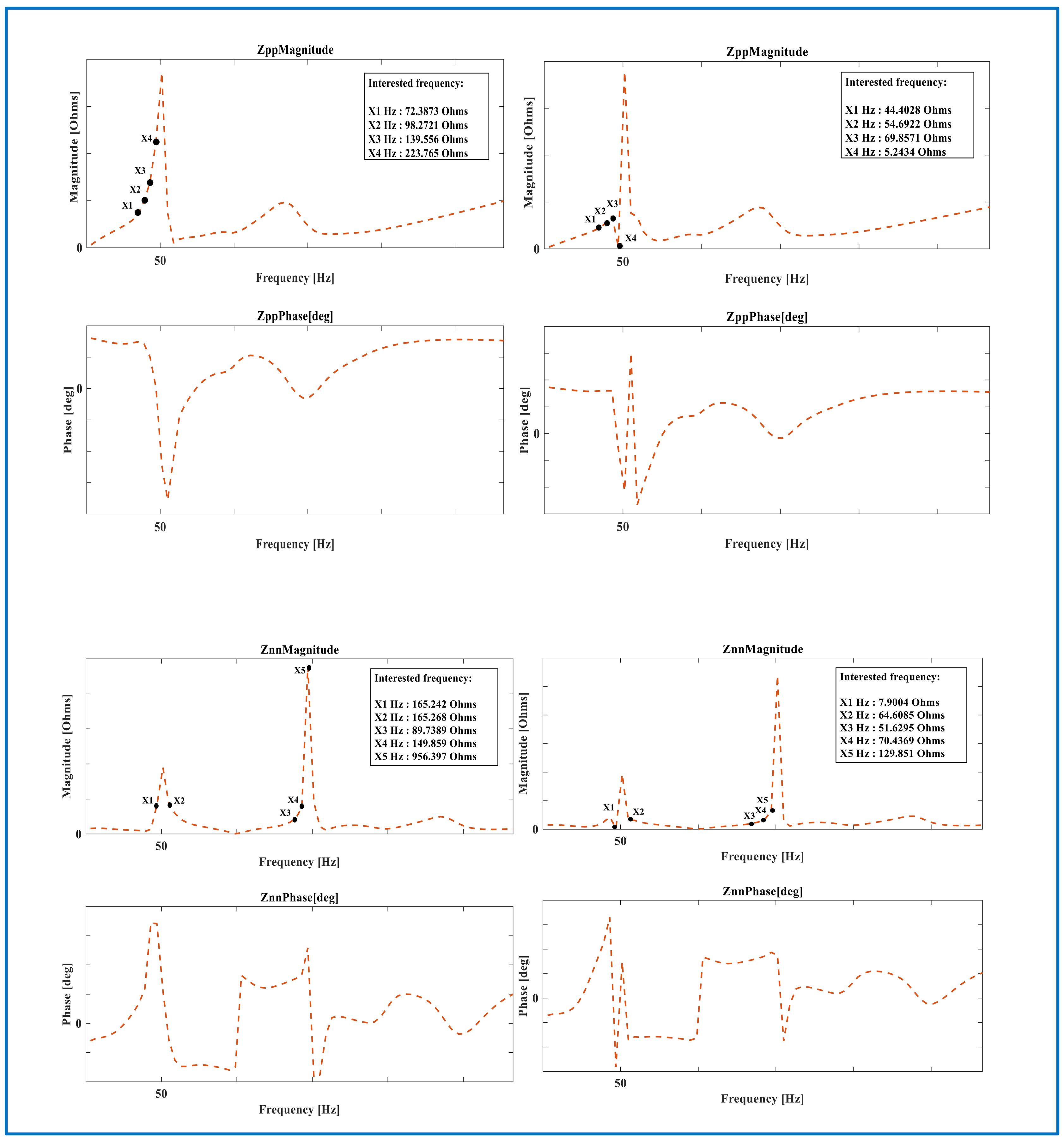
Small Signal Scan Method



Modelling and Results

Small signal analysis of the offshore wind farm model for a given operating state is developed via a method which injects a source disturbance across a frequency range of 0-238 Hz into the model, at magnitudes varied between 4 kV and 15 kV. These injections are desirably undertaken with different operating points of the wind turbine model, and across Different outage states of the connecting AC network and Statcom to have a varying impedance characteristic for the small signal studies. Impedance plots for the Offshore Wind Farm were plotted in MATLAB/Simulink using the output file generated from the PSCAD/EMTDC Model.

By analysing the impedance plots magnitude and phase angle we can see the possible set of frequencies which can have interaction and result in oscillations which can further lead to the trip of the wind farm. Positive and Negative Phase sequence Impedance results were compared in both cases i.e., Statcom alone and the combination of Statcom and Synchronous compensator as represented.



Conclusions

From analysing the frequency domain scan of the offshore wind farm model across a range of operating points it is clear that inter-harmonic interactions are present and therefore, have the potential to complement or drive oscillatory behaviour within the wider system. The observed resonant frequencies varies by the Power reference point of the Wind Farm model and STATCOM operating mode.

The paper showed that the sequence impedance response of the Offshore Wind farm is analysed and that the use of a Synchronous Compensator in combination with Statcom was able to damp out some of the frequencies driving these oscillations.

References

1 Y. Chen, L. Xu, A. Egea-Àlvarez, B. Marshall, M. H. Rahman, and A. D. Oluwole, "MMC impedance modelling and interaction of converters in close proximity," IEEE Journal of Emerging and Selected Topics in Power Electronics, vol. 9, no. 6, pp. 7223- 7236, 2020

2 R. Pintelon and J. Schoukens, "Frequency-domain identification of linear time-invariant systems under nonstandard conditions," IEEE transactions on instrumentation and measurement, vol. 46, no. 1, pp. 65-71, 1997