Offshore Wind Power Plants with 66 kV Collection Grids
Study of Resonance Frequencies

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Introduction

Nowadays, large offshore wind power plants (OWPPs) are characterized by a complex electrical infrastructure comprising of a number of wind turbines with step-up transformers, offshore transformers and large offshore array collection cable grid which is typically connected to the grid via HVAC transmission cable. Such a system creates challenges in analysis and design covering harmonic propagation and transient studies. Standard voltage level of collection grids of large OWPPs is approximately 33 kV. Doubling it might provide technical or economic benefits; therefore, it is foreseen that a part of the large offshore wind power plants in the future will be at 66 kV level. This change might influence harmonic and transient behaviour of an OWPPs as compared to those known today. It is therefore important to analyse how the increase of the collection grid voltage level changes characteristic of the electrical environment of a wind power plant in a wide range of frequencies.

Procedure

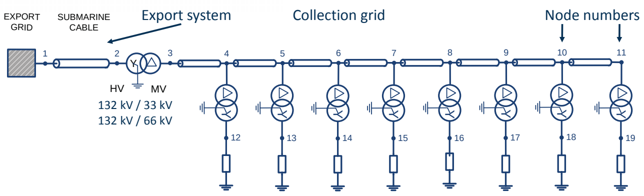
In this study, a comparison is made between elements of frequency- -dependent, wide-band admittance matrix of an OWPPs with 66 kV collection grid and one with corresponding power and at 33 kV collection grid:

- Wide-band models (20 Hz – 1 MHz) are developed in Matlab and represented as admittance matrix using state-of-the-art component models
- Cables (33 kV and 66 kV) represented based on design information using traveling-wave model with frequency dependency of all parameters
- Transformers (33 kV): black box model based on sweep frequency response measurements of real turbine and park transformers; accuracy at lower frequencies improved by incorporation of 50 Hz manufacturer's information
- Transformers (66 kV): models based on data manipulation of 33 kV models
    - Adjusted voltage ratio (positive sequence)
    - Adjusted winding resonance frequencies

Wind farm structure and main assumptions (33 kV and 66 kV models)

Transformers: wind park: 90 MVA, wind turbines: 6.8 MVA
Number of turbines per string: 8
Cables: three-core submarine cables with armour

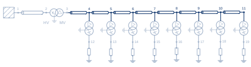
- Same cable cross-section in whole string:
    - 66 kV: 95 mm2
    - 33 kV: 500 mm2
- Length per section: 1000 m



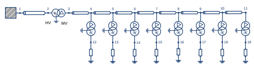
Results

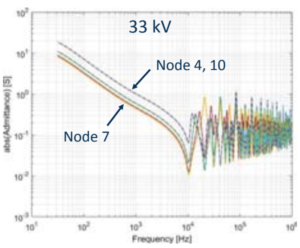
Driving point admittance at selected nodes of the collection grid

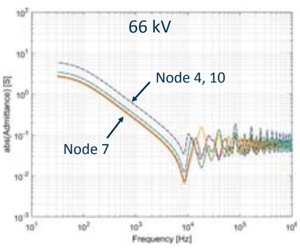
Only collection grid cables

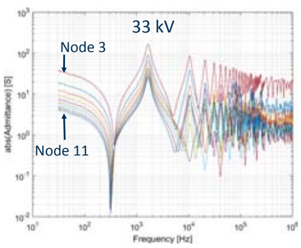


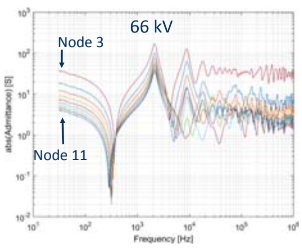
Entire offshore wind power plant





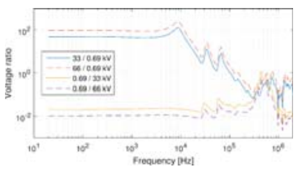




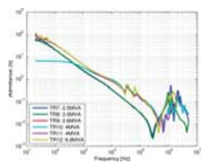


Change of voltage level in transformers

Approximation of winding resonance frequency: $f(\mathrm{kHz}) = C_1 \cdot \frac{MVA^{C_2}}{kV^{C_3}}$



Positive sequence voltage ratios of 6.8 MVA transformer. 66/0.69 kV and 33/0.69 kV



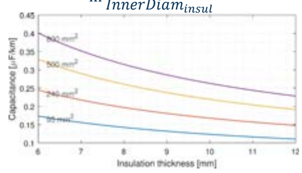
Wide-band characteristic of LV winding on wind-turbine and distribution transformers (measured)

Change of voltage level in cables

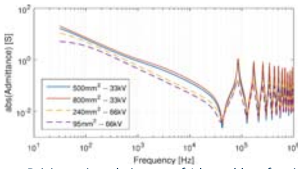
$$C = \frac{2\pi\epsilon}{\ln \frac{OuterDiam_{insul}}{InnerDiam_{insul}}}$$

Quarter wave resonance frequency:

$$f = \frac{1}{4l\sqrt{LC}}$$



Cable capacitance for different conductor cross-sections and insulation thickness (33kV: 8mm, 66kV: 9mm)



Driving point admittance of 1 km cables of various conductor cross-sections and voltage levels

Conclusions

- Keeping the same power in a radial but increasing the voltage level causes the use of cables with different conductor cross-sections, what changes capacitance, inductance and damping of cables. This influences both harmonic and transient behaviour of a wind farm.
- Depending on construction, increasing voltage level might shift resonance frequency of transformer winding to lower values.
- Changing voltage level influences cable capacitance and therefore, its resonance frequency.

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