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Frequencies Identification of NREL 5MW ITI Barge Wind Turbine: First Approach

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***Abstract* – In this work we present a process to identify the main frequencies that affects a floating offshores wind turbine (FOWT), specifically, the NREL 5MW ITI Barge Wind Turbine. This floating platform is highly affected by surge and sway translational movements due to the strong winds and mainly the waver it is subjected to. However, one of the most important modes is the 1st tower fore-aft bending mode, whose frequency has the same value than the forced 3P component, provoking these frequencies to be highly excited. In this work this effect is observed in the power spectrum of the tower top acceleration signal along the nacelle "x" axis.**

***Keywords* –** *floating wind turbine, barge, frequency identification, surge, sway, 3P, 1st tower fore-aft bending mode, FFT.*

I. WIND TURBINE VIBRATION MODES IDENTIFICATION

Besides reducing carbon print, meeting the increasing demand of renewable energies, mainly wind based, requires their installation in more challenging and harsh environments [1]. However, as these new and larger wind turbines are installed offshore in deep water, the strong winds, waves and currents they are subjected to may cause significant damage to the entire structural system [2, 3].

Considering the fact of time-varying process of offshore structures, it is often necessary to understand the variation of frequencies with time by employing time-frequency analysis methods, which can describe the frequency energy intensity of a signal at different times [4]. The well-known Fast Fourier Transform (FFT) can be used to analyse the power spectrum of the time window.

In the case of a Spar-Buoy Floating Wind Turbine, there are two main modes, the Platform Pitch and 1st Tower Fore-Aft FA bending [5]. In this paper, the authors check how modes are modified by enabling and disabling different degrees of freedom (DOF). In [6], load evaluation was performed according to time series and FFT results. The main findings of this study related to the problem here addressed are: first, in the correlation analysis, the tower-top deflection had the highest correlation, and this further affects nacelle acceleration. Second, the tower-base pitch moment increased with the significant wave height. In [7], the effect of load (wave, wind and dynamic bending moment) on the first natural frequency is investigated using different analysis techniques in the frequency domain and time domain for a monopile offshore wind turbine. A clear correlation between load level and first natural frequency is demonstrated.

However, in this paper frequency modification is not the target of the analysis, but the gain variation based on the deactivation, one by one, of a specific DOF in simulation. This way, a DOF is deactivated each time and then the FFT of the tower top acceleration signal along "x" and "y" nacelle axes are checked to see which peak has been damped. This process is repeated for each of the following DOF:

FlapDOF1, FlapDOF2, EdgeDOF, DrTrDOF, GenDOF, YawDOF, TwFADOF1, TwFADOF2, TwSSDOF1, TwSSDOF2, PtfmSgDOF, PtfmSwDOF, PtfmHvDOF, PtfmRDOF, PtfmPDOF and PtfmYDOF.

To do so, different test with a 5MW NREL Floating ITI Barge Wind Turbine [8] were carried out using OpenFAST, an aero-hydro-servo-elastic fully coupled analysis tool, with Matlab/Simulink software. All DOFs were considered in the simulations, except the one deactivated in each simulation, including the blades, tower, and platform, together.

The environment conditions to identify the main frequencies are:

- Wind speed: 13m/s. This ensure that the turbine is operating at rated power and generator speed.
- Wind turbulence: Steady, no turbulence. This allows the frequencies to be shown with no wind perturbations.
- Wave mode: none, still water. This allows the frequencies to be shown with no wave perturbations.

The OpenFAST variables analysed are:

- YawBrTAxp [m/s2]: Tower-top / yaw bearing fore-aft (translational) acceleration (absolute). Directed along the xp-axis.
- YawBrTAyp [m/s2]: Tower-top / yaw bearing side-to-side (translational) acceleration (absolute). Directed along the yp-axis.

Fig 1 represents the simulations results obtained and shows different frequencies that affect the nacelle acceleration. The FFT has been obtained from a simulation of 4500 s to ensure a good resolution. First 1500 s has been discarded to allow the platform to be stabilized from the initialization. Resolution used is 27307 points.

As a summary, the main natural identified modes are the following:

- Platform horizontal surge translation (PtfmSgDOF): 0.0097 Hz.
- Platform horizontal sway translation (PtfmSwDOF): 0.085 Hz.
- First fore-aft tower bending-mode (TwFADOF1): between 0.55 and 0.6 Hz.
- First side-to-side tower bending-mode (TwSSDOF1): 0.6 Hz.
- First edgewise blade mode (EdgeDOF): 1.28 Hz.
- Second fore-aft tower bending-mode (TwFADOF2): 3 Hz.
- Second side-to-side tower bending-mode (TwSSDOF2): 3 Hz.

Nonetheless, it is important to highlight the effect of the forced 3P frequency, which coincides with the 1st tower fore-aft mode at 0.6 Hz, very different from non-floating turbines [9, 10]. This is a forced frequency due to the wind shear effect, which causes that the higher the height, the higher the wind speed. Therefore, the blade in the top is receiving more wind than the others and the thrust is higher for this blade, pushing back the nacelle. This phenomenon happens every time that one blade is at the top. Tower shadow also affects this mode.

The 3P frequency value is calculated in equation (1), where rated rotor speed is 12.1 rpm and there are three blades. Therefore, at rated operation point 3P frequency is 0.605 Hz. It is possible to see how this value matches the results shown in Fig. 1.

$$3P\,[Hz] = \text{nº of blades} \cdot \frac{\text{RotorSpeed\_Rated}\,[rpm]}{60\,[s/min]} \tag{1}$$

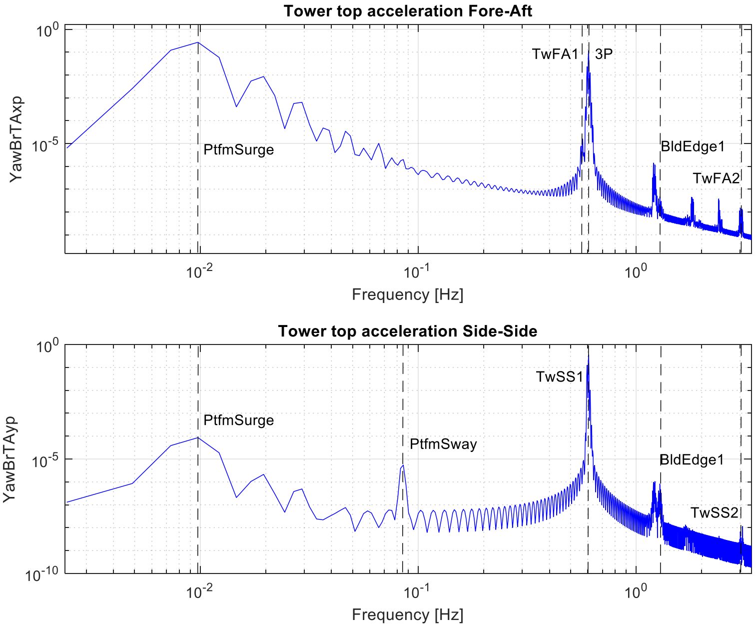

Fig 1. Wind Turbine Vibration Modes in tower top fore-aft and side-side direction.

II. CONCLUSIONS AND FUTURE WORKS

Floating ITI Barge wind turbine is mainly affected by platform translation movements, such as surge along “x” axis and sway along “y” axis, as well as the 1st tower fore-aft and side-side bending modes. Moreover, 3P forced component at rated generator speed has the same value than 1st tower modes. This coincidence should be avoided by all means because it generates a high frequency peak visible in Fig 1, which will be then transferred to tower base loads, reducing the useful life of the turbine.

As further works, tower stiffness could be modified to move tower modes. Another possibility is to change gear box ratio, keeping the same rated generator speed, so that rotor speed can be different and hence 3P value does not match with 1st tower modes.

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