Summary of Small Signal Method Used in INCENTIVE for Interactions Study

Project INCENTIVE selected test scenarios from the latest guidelines from NESO, Great Britain Grid Forming Best Practices Guide [1]. Besides grid code compliance testing, small signal scan methods were used, including; Network Frequency Perturbations (NFP) for inertia and damping estimation, and small signal impedance scan for control interaction studies. The National HVDC Centre has developed internal frequency scanning tools for these two small signal scan methods.

The active power response to a frequency perturbation on the network will be measured using a technique known as Network Frequency Perturbations (NFP). The approach applies sinusoidal perturbations of small amplitude (<5 %) to the system frequency of 50Hz. The oscillatory power response of the plant is monitored and analysed using FFTs (Fast Fourier Transform) to derive the amplitude and phase angle in relation to the input perturbation. The test is performed for perturbation frequencies typically between 0.02Hz and 20Hz. The Bode plot (including the amplitude and phase angle response) is charted using all test points. This gives an accurate picture of the dynamic characteristic of the plant over the range of frequencies where electromechanical interactions typically occur in a power system. This test can determine both the inertia constant and damping factor and identify any other undesirable dynamic characteristics of the plant.

The frequency scanning tool from The National HVDC Centre can be used to generate impedance and admittance plots in various reference frames. The preferred frame is the modified sequence domain in which the positive and negative sequence components are represented along with the off-diagonal terms which indicate the coupling between the positive and negative sequences. If a simple representation is required, the negative sequence components can be disregarded, and analysis can be conducted using the positive sequence only. The overall control behaviour could be misrepresented by only using the positive sequence. In Project INCENTIVE, frequency scanning is considered in both positive and negative sequences.

The impedance plots represent the small-signal behaviour of the system and describe the relationship between voltage and current on the system for small disturbances. When considering passive systems, these relationships follow well known electrical laws. However, when converter control is considered, the relationship between voltage and current on the network is no longer completely determined by the passive components on the network during quasi-steady state conditions. The equivalent converter impedance or admittance can then be considered. These impedances contain a wealth of information about the voltage-current characteristic of the converter and associated control and can be used to identify resonances and other possible sources of control interaction. It is important to note that for the information to be useful, linear behaviour must be maintained therefore large changes in operating point will require a unique plot of impedance.

The main benefit of these techniques is the accurate representation of the control algorithms at unique frequencies. The exact frequency of an interaction can be identified, and the effect of any possible remedial action can be easily evaluated. Other methods of screening such as interactions factors do not include the same level of control detail and often focus too greatly on steady state and frequencies surrounding the fundamental.

The small-signal tests conducted showed no identifiable resonances in the INCENTIVE STATCOM impedances at any SCR or operating points. However, the frequency sweeps of the windfarm models indicated a significant volume of negative damping and resonant points which provided some degree of validation to the previous tests where significant high frequency oscillations were visible.
The small-signal tests conducted showed no identifiable resonances in the INCENTIVE BESS impedances at any SCR or operating points. However, the frequency sweeps of the windfarm models indicated a small volume of negative damping which INCENTIVE BESS did significant work to reduce and improve the stability of the system.
In project INCENTIVE, INCENTIVE STATCOM and INCENTIVE BESS model have been provided by OEMs, which is a generic OEMs black box model, and the offshore wind farm model uses the generic model. Once the project moves to the industrial project, a re-examine is recommended during the detailed development and design phase.
The National HVDC Centre hosted a webinar to introduce this small signal technique, which is also used outside Project INCENTIVE and can be used for a better understanding of this technique [2].

References

[1] N. G. ESO, “Great Britain Grid Forming Best Practice Guide,” National Grid ESO, 2023.

[2] The National HVDC Centre, “Small Signal Analysis Studies Webinar (18th June 2024),” The Natioanl HVDC Centre, 18th June 2024. [Online]. Available: https://www.hvdccentre.com/films-list/small-signal-analysis-studies-webinar/. [Accessed 14 October 2024].