System Oscillations Assessment of IBRs

Study Guidance

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Contents

Introduction

- The document describes a set of small signal studies which should be carried out by Users as part of the connection compliance process.

- These studies are necessary to demonstrate the appropriate damping performance of Inverter Based Resources (IBRs) against potential system oscillations to ensure the safe operation and stability of the transmission system.

- With the increased penetration of IBRs in the system, some undesirable SSOs were observed by different system operators across the world. The IEEE PES IBR SSO Task published 19 examples of SSO across the world from 2007 – 2021 [1].

- In the GB system, SSOs were also observed in last few years. Most recently 5-9Hz SSO occurred on five separate days during June and July 2023 [2]. Those SSO events caused disturbances on the GB power system which included the tripping of assets.

Introduction –Contd.

- The ESO have been working with academia, Transmission Owners and other key industry stakeholders on the development of this guidance. The development has also taken into consideration lessons learned from the SSO investigations and other industry best practices including CIGRE [3] and ENTSO-e [4].

- It should be noted that whilst the damping performance studies does not completely mitigate all the risk of oscillation, they have been seen to significantly reduce the risk. Further large-scale studies may still be required if necessary.

- The small signal tests proposed in this guidance document include both time domain and frequency domain techniques. It is suggested to compare both time domain and frequency domain methods to establish whether there are any issues.

Study Methodology

There are many small signal techniques that can be employed to investigate the behaviour of IBRs in a non-synchronous dominated network. Some of the techniques are advised as below:

EMT simulations:

- Step change
- Small signal injection study
- Active frequency scans

Frequency domain methods:

- Eigen value Analysis

Note that the small signal methods mentioned are for guidance only and alternative methods and techniques can be adopted by the User after consultation with the ESO.

Study Methodology- EMT simulations

1. **Step Change- EMT Simulations:**

- In this study a series of small step changes is applied to the grid voltage and phase angle to demonstrate the behaviour of the scheme being studied.
- This study provides a good indication of scheme performance and hence it is advised to be performed as a first step.
- This study should be performed with a detailed EMT model.
- Test scenarios should include all credible system conditions, scheme configuration and operational modes.
- User to provide report with study results and observations.

Acceptable Response:

- Response time should be within the timings specified in ECC.A.7.2.3 in [5].
- Overshoot should not be more than 5% peak to peak and settling time should be less than 2s.

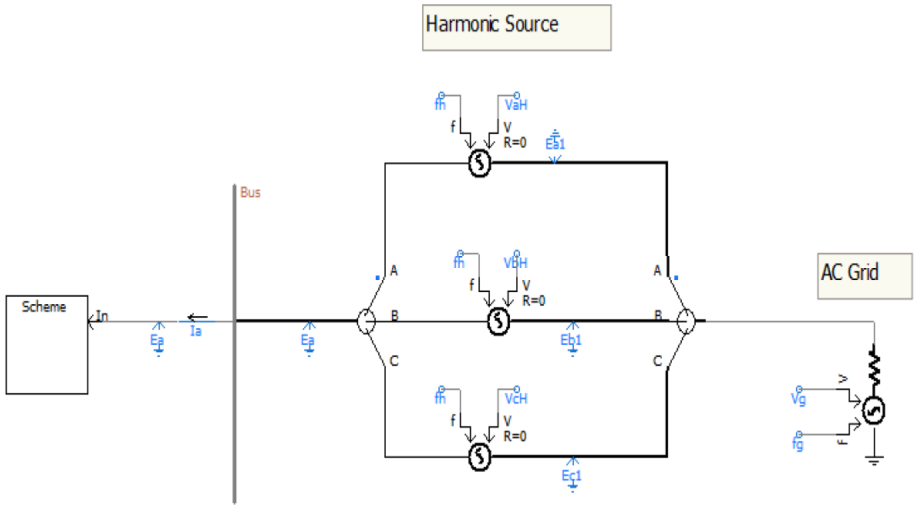
Study Methodology- EMT simulations

2. Small Signal Injection Study [3] & [6]

- Small signal EMT perturbation simulations have widely been recognised as one of the best ways to explore the behaviour of IBRs against small test signals.
- For the purposes of these studies, the AC grid is represented as a Thevenin equivalent whilst the scheme under scrutiny should be represented in detail in an EMT model.
- Frequencies ranging from 1Hz to 100Hz (or desired frequency range of interest) to be injected in series with the grid with no more than 1Hz gap in each simulation.
- Test scenarios should include all credible system conditions, scheme configuration and operational modes.
- User to provide report with study results and observations.

Acceptable Response:

No increase in magnitude of injected oscillations, ideally the system should damp any oscillations. The response shall be demonstrated by plotting the transmission interface point (TIP) or PCC voltage with and without the scheme being studied. Refer to appendix for expected response from this study.

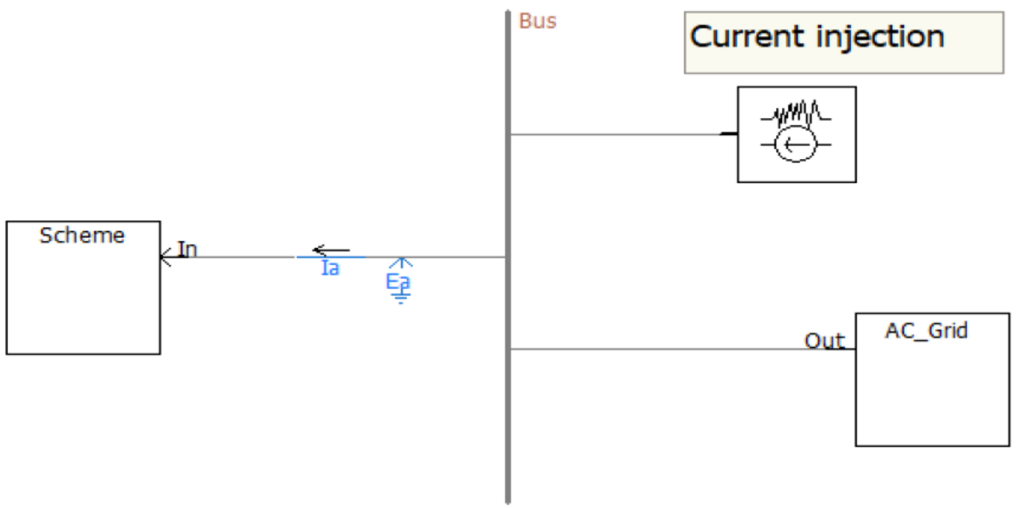


Typical Voltage Injection Test Setup

Study Methodology- EMT simulations

3. Active Frequency Scans [3] & [4]

- A Dynamic Frequency Scan is a method to evaluate scheme impedance and phase angle that provides insight into scheme behaviour.
- In order to conduct this study, the scheme under scrutiny is represented as a detailed EMT model while the AC grid is represented as a Thevenin equivalent.
- A small signal of a multitude of frequencies of interest is injected into the scheme being studied. The small signal can be a voltage signal in series with a grid or a current injection in parallel with a grid.
- Test scenarios should include all credible system conditions, scheme configuration and operational modes.
- User to provide report with study results and observations.



Active frequency scan current Injection Test Setup

Acceptable Response:

The resistance (R) of the scheme under scrutiny should be positive throughout the frequency range. In case the negative resistance is observed further investigation shall be required.

Study Methodology- Frequency Domain

4. Eigenvalue Method

- The Eigenvalue analysis is another method of calculating the oscillation modes, frequency of oscillation and damping co-efficient.
- This is a frequency domain study, but detailed EMT model assumptions are required for the scheme under scrutiny.
- In this methodology the linear state space representation of the system and connected AC grid are represented as a Thevenin equivalent and are used to determine the Eigenvalues of the full system.
- Test scenarios should include all credible system conditions, scheme configuration and operational modes.
- User to provide report with study results and observations.

Acceptable Response:

- Minimum 10% damping ratio is expected for all oscillation modes.

Conclusion

- This guidance describes a set of small signal studies which should be carried out by Users as part of the connection compliance process.
- It is essential for the Users to ensure that their plant design is robust and complies with the requirements of these guidelines.
- These studies are required to demonstrate the damping performance of Inverter based resources (IBRs) against potential system oscillations to ensure safe operation and system stability.

Thanks