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Requirements for Electro-Magnetic Transient Model and Associated Studies for Synchronous Generators

July 2024

Foreword

These notes have been prepared by the National Grid Electricity System Operator (NGESO) to provide information on the type of studies for which the Company (ESO) require Electromagnetic Transient (EMT) models for synchronous generators.

The Operability Innovation Manager (see contact details below) will be happy to provide clarification and assistance required in relation to these notes.

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Executive Summary

With the increasing penetration of Inverter Based Resources (IBR) in the power system, Root Mean Squared (RMS) models are simply not adequate to analyse complex power system behaviours such as electromagnetic transient phenomena. This document is created to provide information on the type of studies for which the Company (ESO) require Electromagnetic Transient (EMT) models for synchronous generators.

Document Change Record and Signatures

Report No.	Prepared By: (Date)	Checked By: (Date)	Approved By: (Date)
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Introduction

With the increasing penetration of Inverter Based Resources (IBR) in the power system, Root Mean Squared (RMS) models are simply not adequate to analyse complex power system behaviours such as electromagnetic transient phenomena. This document is created to provide information on the type of studies for which the Company (ESO) require Electromagnetic Transient (EMT) models for synchronous generators. This document highlights the different types of studies and highlights that EMT models for synchronous generators are of utmost importance to ESO, from a perspective of network operations and planning, to carry out Sub Synchronous Interactions (SSI) and transient stability studies.

This document also highlights the importance of synchronous generator EMT model with detailed representation of AVR, excitation system including over and under excitation limiters and Power System Stabiliser (PSS).

Need for Electromagnetic Transient (EMT) Models for Synchronous Generators

With the increasing penetration of inverter-based resources (IBR) in the power system, Root Mean Squared (RMS) models are simply not adequate to analyze complex power system behaviours such as electromagnetic transient phenomena. These phenomena include fast control-loop behaviour, rapid transients associated with switching and lightning events, as well as slower transients related to subsynchronous interactions, control, and harmonic interaction. RMS studies do assist in screening the potential oscillation and stability issues. However, detailed investigations require Electromagnetic Transient (EMT) models and studies. For a given study area or network, the level of modelling detail for power system components will depend upon the study type and the frequency range of interest. Table 1 shows the appropriateness of some of the typical power system studies and corresponding model types.

Table 1: Model vs. Study type

Model Type / Study type	RMS	EMT
Sub-synchronous Interaction (control and torsional)		✓
Transient Stability	✓	✓
Power Quality		✓
Switching and Lightning		✓
Load flow	✓	

From a perspective of network operations and planning, **subsynchronous interactions** (SSI) and **transient stability studies** are of utmost importance to ESO.

Sub-synchronous interaction (SSI) refers to adverse interaction between two or more electrical or electromechanical power system components often with a dominant frequency of less than the nominal power system frequency. The different classifications of SSI are shown in Fig. 1. While sub-synchronous control interaction (SSCI) is a faster developing phenomenon which is purely electrical interaction between controllers of power electronic devices or between controllers of power electronic devices and a series compensated AC line, the sub-synchronous torsional interaction (SSTI) and sub-synchronous resonance (SSR) is a relatively slower developing electromechanical interaction between power electronic device, a series compensated AC line and **the rotating masses of the turbine-generator in synchronous machines**. Detailed EMT model of synchronous generator is extremely crucial for SSI studies with study network containing detailed representation of IBRs along with their control system. Further, the representation of synchronous generators' rotors would require each shaft section individual mass separately modelled, that would include all the relevant turbine stages, the generator rotor and the exciter in the case of a rotating excitation system. The rotor model would need all the relevant parameters, these would be inertia constants, torsional stiffness between adjacent masses, and damping coefficient associated with each mass.

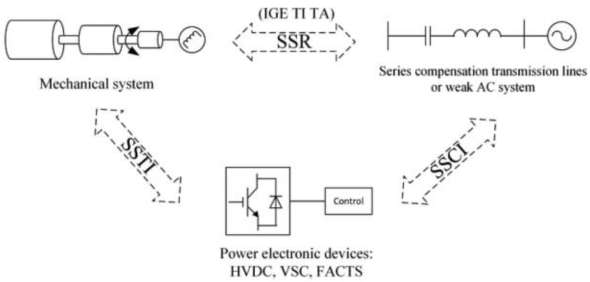

Fig. 1 *Classification of the SSIs*

Source: Gu, K., Wu, F. and Zhang, X. (2018). Sub-synchronous interactions in power systems with wind turbines: a review. IET Renewable Power Generation, 13(1), pp.4–15.

As the penetration of IBRs increases in the power system, it becomes increasingly crucial to incorporate EMT models in order to address the limitations of RMS models during standard transient stability assessments. This is especially important when examining the impact of fast-acting controls of IBRs (such as PLL) in conditions of low system strength. Studies have also revealed the significant influence (interaction) of synchronous generator components, such as AVR, exciter (including over and under excitation limiters) and Power System Stabilizer (PSS) with the control system of IBRs and their overall impact on the power system transient stability.

Consequently, it can be concluded that the utilization of EMT models for synchronous generators is imperative to ensure the security of the system, as it significantly enhances the accuracy of studies involving transient stability and detailed investigations of sub-synchronous interactions.