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IEEE Recommended Practice for Excitation System Models for Power System Stability Studies

IEEE Power and Energy Society

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Energy Development and Power Generation Committee

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USA

IEEE Std 421.5™-2016
(Revision of
IEEE Std 421.5-2005)

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Abstract: Excitation system and power system stabilizer models suitable for use in large-scale system stability studies are presented. Important excitation limiters and supplementary controls are also included. The model structures presented are intended to facilitate the use of field test data as a means of obtaining model parameters. The models are, however, reduced order models and do not necessarily represent all of the control loops of any particular system. The models are valid for frequency deviations of ±5% from rated frequency and oscillation frequencies up to 3 Hz. These models would not normally be adequate for use in studies of subsynchronous resonance or other shaft torsional interaction behavior. Delayed protective and control features that may come into play in long-term dynamic performance studies are not represented. A sample set of data for each of the models, for at least one particular application, is provided.

Keywords: excitation limiter models, excitation systems models, IEEE 421.5™, power system stability, power system stabilizer models

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Introduction

This introduction is not part of IEEE Std 421.5™-2016, IEEE Recommended Practice for Excitation System Models for Power System Stability Studies.

Excitation system models suitable for use in large-scale system stability studies are presented in this recommended practice. With these models, most of the excitation systems presently in widespread use on large, system-connected, synchronous machines in North America can be represented.

This recommended practice applies to excitation systems applied on synchronous machines, which include synchronous generators, synchronous motors, and synchronous condensers. Since most applications of this recommended practice involve excitation systems applied to synchronous generators, the term *generator* is often used instead of *synchronous machine*. Unless otherwise specified, use of the term *generator* in this document should be interpreted as applying to the synchronous machine in general, including motors and synchronous condensers.

In 1968, models for the systems in use at that time were presented by the Excitation Systems Subcommittee and were widely used by the industry. Improved models that reflected advances in equipment and better modeling practices were developed and published in the IEEE Transactions on Power Apparatus and Systems in 1981. These models included representation of more recently developed systems and some of the supplementary excitation control features commonly used with them. In 1992 the 1981 models were updated and presented in the form of the recommended practice IEEE Std 421.5. In 2005 this document was further revised to add information on reactive differential compensation, excitation limiters, power factor and var controllers, and new models incorporating proportional-integral-derivative (PID) control.

The model structures presented are intended to facilitate the use of field test data as a means of obtaining model parameters. The models are, however, reduced order models and do not necessarily represent all of the control loops of any particular system. The models are valid for frequency deviations of ±5% from rated frequency and oscillation frequencies up to 3 Hz. These models would not normally be adequate for use in studies of subsynchronous resonance or other shaft torsional interaction behavior. Delayed protective and control features that may come into play in long-term dynamic performance studies are not represented. A sample set of data for each of the models, for at least one particular application, is provided.

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1. Overview

1.1 Scope

This document provides mathematical models for computer simulation studies of excitation systems and their associated controls for three-phase synchronous generators. The equipment modeled includes the automatic voltage regulator (AVR) as well as supplementary controls including reactive current compensation, power system stabilizers, overexcitation and underexcitation limiters, and stator current limiters. This revision is an update of the recommended practice and includes models of new devices which have become available since the previous revision, as well as updates to some existing models.

1.2 Background

When the behavior of synchronous machines is to be simulated accurately in power system stability studies, it is essential that the excitation systems of the synchronous machines be modeled in sufficient detail (see Byerly and Kimbark [B1], Kundur [B33][1]). The desired models should be suitable for representing the actual excitation equipment performance for large, severe disturbances as well as for small perturbations.

[1] The numbers in brackets correspond to those of the bibliography in Annex J.