Chapter 9
Computer Modeling of Rotating Machines

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ABSTRACT

Modeling and simulating rotating machines in power systems under various disturbances are important not only because some disturbances can cause severe damage to the machines, but also because responses of the machines can affect system stability, safety, and other fundamental requirements for systems to remain in normal operation. Basically, there are two types of disturbances to rotating machines from disturbance frequency point of view. One type of disturbances is in relatively low frequency, such as system short-circuit faults, and generation and load impacts; and the other type of disturbances is in high frequency, typically including voltage and current surges generated from fast speed interruption device trips, and lightning strikes induced travelling waves. Due to frequency ranges, special models are required for different types of disturbances in order to accurately study machines behavior during the transients. This chapter describes two popular computer models for rotating machine transient studies in lower frequency range and high frequency range respectively. Detailed model equations as well as solution techniques are discussed for each of the model.

INTRODUCTION

Rotating machines are essential components in power systems. Their dynamic and frequency responses to system disturbances are important to determine system stability and safety. To correctly simulate rotating machine responses in power system transient studies, two things need to be considered: (1) understanding origin and especially frequency ranges for various power system disturbances, and (2) determining rotating machine computer models and applying them properly to different types of simulation studies.

Power system disturbances can have different origins and cover a wide range for frequency. Table 1 lists some typical transient phenomena in power systems and the associated frequency range classifications (Martinez, Mahseredjian & Walling, 2005).

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Table 1. Power system disturbances and their frequency ranges

Disturbance Origin	Frequency Range (Hz)
Ferroresonance	$10^{-1} – 10^{3}$
Load rejection	$10^{-1} – 3 \times 10^{3}$
Fault clearing	$50/60 – 3 \times 10^{3}$
Line switching	$50/60 – 2 \times 10^{4}$
Transient recovery voltage	$50/60 – 10^{5}$
Lightning overvoltages	$10^{4} – 3 \times 10^{6}$
Disconnector switching in GIS	$10^{5} – 5 \times 10^{7}$

These classifications are proposed by International Electrotechnical Commission (IEC, 1985) and CIGRE (CIGRE, 1990). IEC and CIGRE further classify these disturbances into four categories, according to their frequency ranges:

- Low-frequency oscillations – disturbance signal frequency from 10^{-1} to 10^{3} Hz
- Slow-front surges – disturbance signal frequency from 50/60 to 2×10^{4} Hz
- Fast-front surges – disturbance signal frequency from 10^{4} to 3×10^{6} Hz
- Very-fast-front surges – disturbance signal frequency from 10^{5} to 5×10^{7} Hz

Computer models of rotating machines for power system transient studies should consider frequency characteristics under disturbances at different waveforms. Several international standards have addressed issues related to rotating machine modeling for transient studies under different frequency ranges.

(a) Document "Guideline for Representation of Network Elements when Calculating Transients" written by the CIGRE WG 33-02 (CIGRE, 1990) proposes presentations of the most important power system components including rotating machines.

(b) IEC Standard 60034-4 "Rotating Electrical Machines – Part 4: Methods for Determining Synchronous Machine Quantities from Tests" (IEC, 1985) covers synchronous machine model parameters used for machine transient simulations.

(c) IEEE Standard 1110-2002 "IEEE Guide for Synchronous Generator Modeling Practices and Applications in Power System Stability Analyses" (IEEE, 2002) approves various synchronous machine frequency dependent models based on machine build and level of details in computer simulation.

(d) IEEE Standards 115-1995 "IEEE Guide: Test Procedures for Synchronous Machines" (IEEE, 1995) and 112-1996 "IEEE Guide: Test Procedure for Polyphase Induction Motors and Generators" (IEEE, 1996) define machine model parameters for synchronous and induction machines respectively.

Based on disturbance frequency ranges, there are two sets of computer models that have been developed for rotating machine transient studies. One set of computer models is that implemented in all EMTP (ElectromMagnetic Transient Program) type computer modeling and simulation programs. These models are developed based on rotating machines under low frequency responses.