

# Synchronous Generator Subtransient Reactance Prediction Using Transient Circuit Coupled Electromagnetic Analyses & Odd Periodic Symmetry

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## Abstract

For synchronous 3 phase electrical generator machine design, the ability to predict the subtransient reactance of a particular machine design is of prime importance. The subtransient reactance has a significant impact on the magnitude of the fault currents generated within the machine during an event such as a 3 phase short-circuit. Power system designers routinely use the generator subtransient reactance as a key parameter to aid in the design of the complete power generation system. For new generator designs the subtransient reactance is routinely tested for as part of a thorough evaluation of the generator performance characteristics. In this paper, a method is presented to calculate the subtransient reactance of a particular generator design using transient circuit coupled finite element electromagnetic analyses. The finite element modeling technique presented utilizes odd periodic symmetry along with a "moving" interface at the rotor-stator air-gap. The use of odd periodic symmetry allows for the simulations to be accomplished with half of the model size as compared to even periodic symmetry. The calculated generator subtransient reactance from the finite element modeling technique presented is compared to generator test data as well as previous calculation methods. Other key pieces of information which may be generated throughout the process are also documented, such as calculated voltage harmonics and the open-circuit saturation curve.

## Introduction

Kato Engineering primarily manufactures synchronous 3 phase electrical generators. The ability to predict the subtransient reactance of a particular generator design is of prime importance. Power system designers routinely use the generator subtransient reactance as a key parameter to aid in the design of the complete electrical power generation system.

The subtransient reactance,  $X''_d$ , is the generator internal impedance element that is effective in the first cycles of a transient load event and determines the magnitude of the instantaneous fault current from the generator. The transient reactance,  $X'_d$ , becomes effective after approximately 6 cycles into a transient load event and determines the amount of voltage change seen at the generator terminals due to the step change in load. As stated, the reactances of a generator have a direct effect on the transient fault currents experienced in an electrical power generation system, as well as the motor starting capability of the generator. The magnitudes of the fault currents need to be calculated so that breakers, etc. can be sized accordingly. The peak magnitudes of the 3 phase fault currents are inversely proportional to the subtransient reactance of the generator. For new generator designs, the transient and subtransient reactances are routinely tested for as part of a thorough evaluation of the generator's performance characteristics.

Traditional reactance prediction methods have served engineers well when new designs closely mirror previous designs which have been tested and their reactance predictions validated. From the perspective of the machine designer, an uncomfortable level of uncertainty always accompanied a new design that deviated significantly from standard forms. In this paper, a method is presented to calculate the transient and subtransient reactance of a generator using transient dynamic circuit-coupled finite element electromagnetic analyses. Finite Element electromagnetic analysis offers a powerful tool to reduce the risk in new generator design.

# Synchronous Generator Subtransient Reactance Prediction

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## **Table of Contents Synchronous Generator Subtransient Reactance Prediction**

1. Understanding the eBook Synchronous Generator Subtransient Reactance Prediction
  - The Rise of Digital Reading Synchronous Generator Subtransient Reactance Prediction
  - Advantages of eBooks Over Traditional Books
2. Identifying Synchronous Generator Subtransient Reactance Prediction
  - Exploring Different Genres
  - Considering Fiction vs. Non-Fiction
  - Determining Your Reading Goals
3. Choosing the Right eBook Platform
  - Popular eBook Platforms
  - Features to Look for in an Synchronous Generator Subtransient Reactance Prediction
  - User-Friendly Interface
4. Exploring eBook Recommendations from Synchronous Generator Subtransient Reactance Prediction
  - Personalized Recommendations
  - Synchronous Generator Subtransient Reactance Prediction User Reviews and Ratings
  - Synchronous Generator Subtransient Reactance Prediction and Bestseller Lists
5. Accessing Synchronous Generator Subtransient Reactance Prediction Free and Paid eBooks
  - Synchronous Generator Subtransient Reactance Prediction Public Domain eBooks
  - Synchronous Generator Subtransient Reactance Prediction eBook Subscription Services

- Synchronous Generator Subtransient Reactance Prediction Budget-Friendly Options
- 6. Navigating Synchronous Generator Subtransient Reactance Prediction eBook Formats
  - ePub, PDF, MOBI, and More
  - Synchronous Generator Subtransient Reactance Prediction Compatibility with Devices
  - Synchronous Generator Subtransient Reactance Prediction Enhanced eBook Features
- 7. Enhancing Your Reading Experience
  - Adjustable Fonts and Text Sizes of Synchronous Generator Subtransient Reactance Prediction
  - Highlighting and Note-Taking Synchronous Generator Subtransient Reactance Prediction
  - Interactive Elements Synchronous Generator Subtransient Reactance Prediction
- 8. Staying Engaged with Synchronous Generator Subtransient Reactance Prediction
  - Joining Online Reading Communities
  - Participating in Virtual Book Clubs
  - Following Authors and Publishers Synchronous Generator Subtransient Reactance Prediction
- 9. Balancing eBooks and Physical Books Synchronous Generator Subtransient Reactance Prediction
  - Benefits of a Digital Library
  - Creating a Diverse Reading Collection Synchronous Generator Subtransient Reactance Prediction
- 10. Overcoming Reading Challenges
  - Dealing with Digital Eye Strain
  - Minimizing Distractions
  - Managing Screen Time
- 11. Cultivating a Reading Routine Synchronous Generator Subtransient Reactance Prediction
  - Setting Reading Goals Synchronous Generator Subtransient Reactance Prediction
  - Carving Out Dedicated Reading Time
- 12. Sourcing Reliable Information of Synchronous Generator Subtransient Reactance Prediction
  - Fact-Checking eBook Content of Synchronous Generator Subtransient Reactance Prediction
  - Distinguishing Credible Sources
- 13. Promoting Lifelong Learning
  - Utilizing eBooks for Skill Development
  - Exploring Educational eBooks
- 14. Embracing eBook Trends

- Integration of Multimedia Elements
- Interactive and Gamified eBooks

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