

# 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

**Keith H. Sueker**



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**Dynamics and Control of Electric Transmission and Microgrids** K. R. Padiyar, Anil M. Kulkarni, 2019-02-04 A guide to the latest developments in grid dynamics and control and highlights the role of transmission and distribution grids Dynamics and Control of Electric Transmission and Microgrids offers a concise and comprehensive review of the most recent developments and research in grid dynamics and control In addition the authors present a new style of presentation that highlights the role of transmission and distribution grids that ensure the reliability and quality of electric power supply The authors noted experts in the field offer an introduction to the topic and explore the basic characteristics and operations of the grid The text also reviews a wealth of vital topics such as FACTS and HVDC Converter controllers the stability and security issues of the bulk power system loads which can be viewed as negative generation the power limits and energy availability when distributed storage is used and much more This important resource Puts the focus on the role of transmission and distribution grids that ensure the reliability and quality of electric power supply Includes modeling and control of wind and solar energy generation for secure energy transfer Presents timely coverage of on line detection of loss of synchronism wide area measurements and applications wide area feedback control systems for power swing damping and microgrids operation and control Written for students of power system dynamics and control electrical power industry professionals Dynamics and Control of Electric Transmission and Microgrids is a comprehensive guide to the recent developments in grid dynamics and control and highlights the role of transmission and distribution grids that ensure the reliability and quality of electric power supply

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Design engineers design drafters and technicians in the power electronics industry as well as students studying power electronics in various contexts will benefit from Keith Sueker's decades of experience in the industry. With this experience the author has put the overall power electronics design process in the context of primary electronic components and the many associated components required for a system. The seeming complexity of power electronics design is made transparent with Keith Sueker's simple direct language and a minimum reliance on mathematics. Readers will come away with a wealth of practical design information that has hundreds of explanatory diagrams to support it, having also seen many examples of potential pitfalls in the design process. A down-to-earth approach free of complex jargon and esoteric information. Over 200 illustrations to clarify discussion points. Examples of costly design goofs will provide invaluable cautionary advice.

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*Alternative Energy Systems* Mike West, Peter White, Brian Loughridge, 2013-10-22 *Alternative Energy Systems: Electrical Integration and Utilisation* covers the proceedings of the conference held at the Coventry Lanchester Polytechnic, Coventry, England, from 10th to 12th of September 1984. The book presents 24 papers that tackle alternative energy systems and their electrical integration and utilization. The text covers different alternative energy sources such as hydro, solar, wind, wave and waste materials. The book discusses the practical, technical and economic aspects of alternative energy systems and their electrical integration and utilization. The book will be of great use to individuals who are interested in the application of alternative energy systems.

**Conference Proceedings** IEEE Power Engineering Society. Summer Meeting, 2002      Newnes Electrical Pocket Book E A Reeves, Martin Heathcote, 2013-06-17 *Newnes Electrical Pocket Book* is the ideal daily reference source for electrical engineers, electricians and students. First published in 1932, this classic has been fully updated in line with the latest technical developments, regulations and industry best practice. Providing both in-depth knowledge and a broad overview of the field, this pocket book is an invaluable tool of the trade. A handy source of essential information and data on the practice and principles of electrical engineering and installation. The 23rd edition has been updated by engineering author and consultant.

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