

# 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

**Sabine Zange**



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**Uncertainties in Modern Power Systems** Ahmed F. Zobaa, Shady Abdel Aleem, 2020-10-26 *Uncertainties in Modern Power Systems* combines several aspects of uncertainty management in power systems at the planning and operation stages within an integrated framework This book provides the state of the art in electric network planning including time scales reliability quality optimal allocation of compensators and distributed generators mathematical formulation and search algorithms The book introduces innovative research outcomes programs algorithms and approaches that consolidate the present status and future opportunities and challenges of power systems The book also offers a comprehensive description of the overall process in terms of understanding creating data gathering and managing complex electrical engineering applications with uncertainties This reference is useful for researchers engineers and operators in power distribution systems Includes innovative research outcomes programs algorithms and approaches that consolidate current status and future of modern power systems Discusses how uncertainties will impact on the performance of power systems Offers solutions to significant challenges in power systems planning to achieve the best operational performance of the different electric power sectors

**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

**Power Electronics Design** Keith H. Sueker, 2011-04-01 This book serves as an invaluable reference to *Power Electronics Design* covering the application of high power semiconductor technology to large motor drives power supplies power conversion equipment electric utility auxiliaries and numerous other applications

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.

Electrical Engineering, 1952      *Voltage Stability Analysis of Power System* Yong Tang, 2021-04-07 This book describes comprehensively theories and methods of the power system voltage stability. It first introduces the basic theory of the power system and the basic concept and classification of the power system stability and discusses the basic concepts of voltage stability including the mechanism of voltage stability and influencing factors of transient and medium term and long term voltage stability. This book also describes the elemental characteristics and models of important power system in voltage stability analysis and discusses the theories and methods of analysis on steady transient and medium term and long term voltage stability analysis respectively. Then this book introduces the measures to improve the voltage stability. Finally two examples of voltage stability analysis in engineering applications are introduced. This book is useful as a reference for engineers and technicians who are engaged in dispatching operation planning design and scientific research of the power system and teachers and students of electrical engineering major in colleges and universities.

*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.

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electrical engineer Martin Heathcote Major revisions have been made to the sections on semiconductors power generation transformers building automation systems electric vehicles electrical equipment for use in hazardous areas and electrical installation reflecting the changes introduced to the IEE Wiring Regulations BS7671 2001 *Damping of Subsynchronous Resonance Using a Load Commutated Inverter Synchronous Motor Drive* Soebagio (Mas.),1985 Power System Engineering Frederic de la Court Chard,1962 Offshore Electrical Engineering Geoff MacAngus-Gerrard,2013-10-22 Offshore Electrical Engineering is written based on the author s 20 years electrical engineering experience of electrical North Sea oil endeavor The book has 14 chapters and five important appendices The book starts with designing for electrical power offshore application especially with aspects that are different from land based structures such as space and weight limitations safety hazards at sea and corrosive marine environment The criteria for selecting prime movers and generators for example gas turbines and reciprocating engines depending on the type of applications are examined The machinery drives are then discussed whereby the different offshore electric motor ratings are considered As in any electrical system the use of ergonomically designed controls is important Distribution switchgear transformers and cables are described The book also explains the environmental considerations power system disturbances and protection In an offshore structure lighting requirements and subsea power supplies diving life support system and equipment protection are emphasized A reliability analysis is also included to ensure continuance of service from the equipment A general checklist to be used when preparing commissioning workscopes is included and due to space and weight limitations on offshore installation the rationale of maintenance and logistics options are explained The appendices can be used as guides to descriptions offshore installations typical commissioning test sheets computerized calculations program and a comparison of world hazardous area equipment The text is a suitable reading for offshore personnel oil rig administrators and for readers from all walks of life interested in some technical aspects of offshore structures **Electrical Engineering Transactions** ,1977 **Transactions of the American Institute of Electrical Engineers** American Institute of Electrical Engineers,1958 Index of current electrical literature Dec 1887 appended to v 5 **Power and the Engineer** ,1966 **The Engineer** ,1963 **Industrial Power Systems Handbook** Donald Beeman,1955 **Power** ,1966-07 **Conference Proceedings** IEEE Power Engineering Society. Winter Meeting,2000 **Electrical & Electronics Abstracts** ,1997 *Electricity Supply* M. F. Buchan,1967

This book delves into Synchronous Generator Subtransient Reactance Prediction. Synchronous Generator Subtransient Reactance Prediction is an essential topic that needs to be grasped by everyone, ranging from students and scholars to the general public. This book will furnish comprehensive and in-depth insights into Synchronous Generator Subtransient Reactance Prediction, encompassing both the fundamentals and more intricate discussions.

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    - Chapter 3: Synchronous Generator Subtransient Reactance Prediction in Everyday Life
    - Chapter 4: Synchronous Generator Subtransient Reactance Prediction in Specific Contexts
    - Chapter 5: Conclusion
  2. In chapter 1, the author will provide an overview of Synchronous Generator Subtransient Reactance Prediction. This chapter will explore what Synchronous Generator Subtransient Reactance Prediction is, why Synchronous Generator Subtransient Reactance Prediction is vital, and how to effectively learn about Synchronous Generator Subtransient Reactance Prediction.
  3. In chapter 2, the author will delve into the foundational concepts of Synchronous Generator Subtransient Reactance Prediction. The second chapter will elucidate the essential principles that must be understood to grasp Synchronous Generator Subtransient Reactance Prediction in its entirety.
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  6. In chapter 5, this book will draw a conclusion about Synchronous Generator Subtransient Reactance Prediction. The final chapter will summarize the key points that have been discussed throughout the book.
- The book is crafted in an easy-to-understand language and is complemented by engaging illustrations. It is highly recommended for anyone seeking to gain a comprehensive understanding of Synchronous Generator Subtransient Reactance Prediction.

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