

DIGITAL COMPUTATION OF ELECTROMAGNETIC TRANSIENTS IN POWER SYSTEMS: CURRENT STATUS

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Abstract- This document presents an introduction to time-domain solution of electromagnetic transients in power systems using a digital computer. Currently, the most widely used simulation tools to solve electromagnetic transients are based on the trapezoidal rule and the method of characteristics (Bergerson's method). Only works related to this solution algorithm are considered in this document which covers two main topics : solution techniques and modeling of power components.

Keywords : Electromagnetic Transients, Time-domain Simulation, Trapezoidal Rule, Numerical Oscillations, Control Systems, Modeling.

1. INTRODUCTION

Transient phenomena in power systems are caused by switching operations, faults, and other disturbances, such as lightning strokes. They involve a frequency range from DC to several MHz. A rough distinction is usually made between electromechanical transients, traditionally covered by transient stability studies, and electromagnetic transients. The latter type of transients can occur on a time scale that goes from microseconds to several cycles; they are a combination of travelling waves on lines, cables and buses, and of oscillations in lumped-element circuits of generators, transformers and other devices. Some electromechanical transients, such as subsynchronous resonance, for which detailed machine models are needed, are usually included in this class of transients.

Several tools have been used over the years to analyze electromagnetic transients. At early stages, miniature power system models, known as Transient Network Analyzers (TNA), were used. At present, the digital computer is the most popular tool, although TNAs are still used; in addition, the new generation of real-time digital systems are probably the most adequate tool in some applications for which either a very high-speed or a real-time simulation is required.

Many techniques have been developed to solve electromagnetic transients using a digital computer. They can be classified into two main groups : frequency-domain and time-domain

techniques. The subject of this document is the digital simulation of electromagnetic transients in power systems, using time-domain techniques. Presently, the most widely used solution method is based on the application of the trapezoidal rule and the Bergerson's method, also known as method of characteristics [1] - [6].

This document has been arranged as follows. Section 2 deals with the basic solution techniques either already implemented or proposed for implementation in electromagnetic transients programs (emtps). It covers not only the algorithms aimed at solving the transient solution, but procedures to reduce numerical oscillations produced by the trapezoidal rule, initialization methods, and procedures to solve the interface between power networks and control systems.

Section 3 presents a summary of modeling works related to the most important power components taking into account their frequency-dependent behaviour.

Due to difficulties for developing power component models accurate enough for a wide frequency range, much work has been done to provide modeling guidelines for digital simulation of every type of transient phenomenon. Section 4 summarizes the work done in this area and reports about works still in progress.

Some topics, such as parallel computation or real-time emtp-based simulation of electromagnetic transients, which are closely related to the main subjects of this document are not covered here.

A selected bibliography related to topics of each part has been included at the end of this document.

2. SOLUTION METHODS

2.1 TRANSIENT SOLUTION

The studies to solve travelling wave problems by means of a

Computation Of Power System Transients Monographs No 18

Thomas Griffiths



Computation Of Power System Transients Monographs No 18:

Power System Transients Gevork Gharehpetian, Atousa Yazdani, Behrooz Zaker, 2023-01-27 In this textbook a variety of transient cases that have occurred or are possible to occur in power systems are discussed and analyzed It starts by categorizing transients phenomena and specifying unfavorable situations in power systems raised by transients It then moves on to different protective measures that have been implemented in the system to prevent disasters caused by those transients It also explains different methodologies used to analyze transients in power systems This book discusses the modeling of components very extensively and provides analysis cases to assess a wide variety of transients their possible effects on the system and the types of protection commonly used for each case along with methods for designing a sound protection system **FEATURES** Detailed models of system components along with power systems computer aided design PSCAD implementation and analysis Comprehensive reference of transient cases in power systems along with design considerations and protective solutions The cases are not limited to classical transients such as lightning strikes and switching but rather the book discusses transient cases that power system operators and engineers have to deal with such as ferroresonance in detail accompanied by computer simulations A chapter on original materials related to transformer windings with induced traveling waves *Power System Transients Modelling Simulation and Applications* provides a comprehensive resource to mainly educate graduate students in the area of power system transients It also serves as a reference for industry engineers challenged by transient problems in the system

Proceedings of the ISMM International Symposium: Mini and Microcomputers and Their Applications, Lugano, Switzerland, June 19-21, 1990 International Society for Mini-Microcomputers. Technical Committee on Computers, 1990

Transient Analysis of Power Systems Juan A. Martinez-Velasco, 2015-01-27 The simulation of electromagnetic transients is a mature field that plays an important role in the design of modern power systems Since the first steps in this field to date a significant effort has been dedicated to the development of new techniques and more powerful software tools Sophisticated models complex solution techniques and powerful simulation tools have been developed to perform studies that are of supreme importance in the design of modern power systems The first developments of transients tools were mostly aimed at calculating over voltages Presently these tools are applied to a myriad of studies e g FACTS and Custom Power applications protective relay performance simulation of smart grids for which detailed models and fast solution methods can be of paramount importance This book provides a basic understanding of the main aspects to be considered when performing electromagnetic transients studies detailing the main applications of present electromagnetic transients EMT tools and discusses new developments for enhanced simulation capability **Key features** Provides up to date information on solution techniques and software capabilities for simulation of electromagnetic transients Covers key aspects that can expand the capabilities of a transient software tool e g interfacing techniques or speed up transients simulation e g dynamic model averaging Applies EMT type tools to a wide

spectrum of studies that range from fast electromagnetic transients to slow electromechanical transients including power electronic applications distributed energy resources and protection systems Illustrates the application of EMT tools to the analysis and simulation of smart grids **IEEE Proceedings** ,1981 **Proceedings of MELECON ...** ,1989 1981 *IEEE Proceedings, April 13-15, 1981, Lincoln Plaza Forum, Oklahoma City, Oklahoma* ,1981 Proceedings India. Central Board of Irrigation and Power. Research and Development Session,1985 Scientific and Technical Books and Serials in Print ,1989 **Proceedings** Southeastern Symposium on System Theory,University of Tennessee, Knoxville,1986 *Books in Print* ,1991 Associations' Publications in Print ,1981 1981 in 2 v v 1 Subject index v 2 Title index Publisher title index Association name index Acronym index Key to publishers and distributors abbreviations **Transient Phenomena in Electrical Power Systems** V. A. Venikov,2014-06-20 Transient Phenomena in Electrical Power Systems analyzes transient phenomena in electro mechanical systems and of the steady conditions which precede or follow such transient condition The book deals with the short period transient processes connected with changes in the electro mechanical condition of the system the normal steady state and also the steady fault condition The text also investigates electro mechanical and electromagnetic phenomena including the inter actions of the components in the system with emphasis on the determination of conditions leading to stability The book deals with transient phenomena either by assuming linearity for all circuit parameters or by allowing for some non linearity The text progresses from simplified physical concepts to more rigorous developments of appropriate mathematical models using principles related to the laws of mechanics and to the laws of electromagnetism The book recommends practical stability calculations some methods of improving power handling capacities as well as the stability of transmission lines and power systems The book is beneficial to electrical engineers technical designers and structural engineers whose works are related with power generation or hydro electric stations

Modeling and Simulation ,1985 Modeling of Frequency Dependence in Untransposed Transmission Lines Abdallah Husain Al-Bahrani,1983 **Power Systems** Leonard L. Grigsby,2017-12-19 Power Systems Third Edition part of the five volume set The Electric Power Engineering Handbook covers all aspects of power system protection dynamics stability operation and control Under the editorial guidance of L L Grigsby a respected and accomplished authority in power engineering and section editors Andrew Hanson Pritindra Chowdhuri Gerry Shebl and Mark Nelms this carefully crafted reference includes substantial new and revised contributions from worldwide leaders in the field This content provides convenient access to overviews and detailed information on a diverse array of topics Concepts covered include Power system analysis and simulation Power system transients Power system planning reliability Power electronics Updates to nearly every chapter keep this book at the forefront of developments in modern power systems reflecting international standards practices and technologies New sections present developments in small signal stability and power system oscillations as well as power system stability controls and dynamic modeling of power systems With five new and 10 fully revised chapters the

book supplies a high level of detail and more importantly a tutorial style of writing and use of photographs and graphics to help the reader understand the material New chapters cover Symmetrical Components for Power System Analysis Transient Recovery Voltage Engineering Principles of Electricity Pricing Business Essentials Power Electronics for Renewable Energy A volume in the Electric Power Engineering Handbook Third Edition Other volumes in the set K12642 Ele **Books in Series**,1985 Vols for 1980 issued in three parts Series Authors and Titles Conference Record, Industry Applications Society, IEEE-IAS Annual Meeting (1981) IEEE Industry Applications Society. Annual Meeting,IEEE Industry Applications Society,1986 **The Electric Power Engineering Handbook - Five Volume Set** Leonard L. Grigsby,2018-12-14 The Electric Power Engineering Handbook Third Edition updates coverage of recent developments and rapid technological growth in crucial aspects of power systems including protection dynamics and stability operation and control With contributions from worldwide field leaders edited by L L Grigsby one of the world s most respected accomplished authorities in power engineering this reference includes chapters on Nonconventional Power Generation Conventional Power Generation Transmission Systems Distribution Systems Electric Power Utilization Power Quality Power System Analysis and Simulation Power System Transients Power System Planning Reliability Power Electronics Power System Protection Power System Dynamics and Stability Power System Operation and Control Content includes a simplified overview of advances in international standards practices and technologies such as small signal stability and power system oscillations power system stability controls and dynamic modeling of power systems Each book in this popular series supplies a high level of detail and more importantly a tutorial style of writing and use of photographs and graphics to help the reader understand the material This resource will help readers achieve safe economical high quality power delivery in a dynamic and demanding environment Volumes in the set K12642 Electric Power Generation Transmission and Distribution Third Edition ISBN 9781439856284 K12648 Power Systems Third Edition ISBN 9781439856338 K13917 Power System Stability and Control Third Edition 9781439883204 K12650 Electric Power Substations Engineering Third Edition 9781439856383 K12643 Electric Power Transformer Engineering Third Edition 9781439856291 Monographic Series Library of Congress,1978
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