

# **ENERGY FUNCTION ANALYSIS FOR POWER SYSTEM STABILITY**

M. A. Pai



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# Energy Function Analysis For Power System Stability

## Power Electronics And Power Systems

**Savu C. Savulescu**



## **Energy Function Analysis For Power System Stability Power Electronics And Power Systems:**

**Energy Function Analysis for Power System Stability** Anantha Pai, 1989-08-31 This research monograph is in some sense a sequel to the author's earlier one *Power System Stability* North Holland New York 1981 which devoted considerable attention to Lyapunov stability theory construction of Lyapunov functions and vector Lyapunov functions as applied to power systems This field of research has rapidly grown since 1981 and the more general concept of energy function has found wide spread application in power systems There have been advances in five distinct areas i Developing energy functions for structure preserving models which can incorporate non linear load models ii Energy functions to include detailed model of the generating unit i.e the synchronous machine and the excitation system iii Reduced order energy functions for large scale power systems the simplest being the single machine infinite bus system iv Characterization of the stability boundary of the post fault stable equilibrium point v Applications for large power networks as a tool for dynamic security assessment It was therefore felt appropriate to capture the essential features of these advances and put them in a somewhat cohesive framework The chapters in the book roughly follow this sequence It is interesting to note how different research groups come to the same conclusion via different reasons

**Energy Function Analysis for Power System Stability** M.A. Pai, 2012-12-06 This research monograph is in some sense a sequel to the author's earlier one *Power System Stability* North Holland New York 1981 which devoted considerable attention to Lyapunov stability theory construction of Lyapunov functions and vector Lyapunov functions as applied to power systems This field of research has rapidly grown since 1981 and the more general concept of energy function has found wide spread application in power systems There have been advances in five distinct areas i Developing energy functions for structure preserving models which can incorporate non linear load models ii Energy functions to include detailed model of the generating unit i.e the synchronous machine and the excitation system iii Reduced order energy functions for large scale power systems the simplest being the single machine infinite bus system iv Characterization of the stability boundary of the post fault stable equilibrium point v Applications for large power networks as a tool for dynamic security assessment It was therefore felt appropriate to capture the essential features of these advances and put them in a somewhat cohesive framework The chapters in the book roughly follow this sequence It is interesting to note how different research groups come to the same conclusion via different reasons

**Energy Function Analysis for Power System Stability** M a Pai, 1989-08-31 *Real-Time Stability in Power Systems* Savu C. Savulescu, 2006 In the aftermath of the wave of blackouts that affected US UK and mainland Europe utilities in 2003 and 2004 renewed attention has been focused on maintaining the highest level of reliability and security in the operation of power systems The lack of adequate transmission infrastructure as well as real time tools aimed at detecting and alarming system conditions have also been highlighted In this context the need to assess stability and predict the risk of blackout in real time has become particularly relevant Early work in this field documented in technical papers published throughout the 1990s and early 2000s

underlined the importance of performing stability assessment in real time While static security assessment is conceptually straightforward innovative approaches are needed to combine it with dynamic security assessment to develop an overall scheme so that results can be used for on line decision making On October 13 2004 the IEEE Power Systems Conference and Exposition 2004 hosted the Real Time Stability Challenge panel session Organized by the Power System Dynamic Performance Committee the panel was a forum for presenting progress achieved in this field discussing new ideas and identifying the challenges to be met in the course of future research Real Time Stability in Power Systems Techniques for Early Detection of the Risk of Blackout is built around most of the panel papers updated and expanded by the authors with the new material relevant to the panel theme The chapters are contributed by well known experts in the field thus providing an authoritative reference on the theory and implementation of real time stability assessment one of the critical topics of the day Some of the issues discussed in the book include but are not limited to Stability limits and how to objectively define them Techniques for defining and measuring the distance to instability The characterization of the risk of blackout Discussion of quick approximate methods to filter out non critical contingencies and do a detailed simulation only of those that result in limit violations Theoretical description and practical experience with real time and or near real time stability applications available today in the SCADA EMS industry

**Modelling and Simulation of Power Electronic Converter Dominated Power Systems in PowerFactory** Francisco M. Gonzalez-Longatt, José Luis Rueda Torres, 2020-11-02 This book provides an overview of power electronic converters for numerical simulations based on DlgSILENT PowerFactory It covers the working principles key assumptions and implementation of models of different types of these power systems The book is divided into three main parts the first discusses high voltage direct currents while the second part examines distribution systems and micro grids Lastly the third addresses the equipment and technologies used in modelling and simulation Each chapter includes practical examples and exercises and the accompanying software illustrates essential models principles and performance using DlgSILENT PowerFactory Exploring various current topics in the field of modelling power systems this book will appeal to a variety of readers ranging from students to practitioners

**High Performance Computing in Power and Energy Systems** Siddhartha Kumar Khaitan, Anshul Gupta, 2012-09-07 The twin challenge of meeting global energy demands in the face of growing economies and populations and restricting greenhouse gas emissions is one of the most daunting ones that humanity has ever faced Smart electrical generation and distribution infrastructure will play a crucial role in meeting these challenges We would need to develop capabilities to handle large volumes of data generated by the power system components like PMUs DFRs and other data acquisition devices as well as by the capacity to process these data at high resolution via multi scale and multi period simulations cascading and security analysis interaction between hybrid systems electric transport gas oil coal etc and so on to get meaningful information in real time to ensure a secure reliable and stable power system grid Advanced research on development and implementation of market ready leading edge high speed

enabling technologies and algorithms for solving real time dynamic resource critical problems will be required for dynamic security analysis targeted towards successful implementation of Smart Grid initiatives This books aims to bring together some of the latest research developments as well as thoughts on the future research directions of the high performance computing applications in electric power systems planning operations security markets and grid integration of alternate sources of energy etc      **Applied Mathematics for Restructured Electric Power Systems** Joe H. Chow,Felix F.

Wu,James A. Momoh,2006-06-03 Applied Mathematics for Restructured Electric Power Systems Optimization Control and Computational Intelligence consists of chapters based on work presented at a National Science Foundation workshop organized in November 2003 The theme of the workshop was the use of applied mathematics to solve challenging power system problems The areas included control optimization and computational intelligence In addition to the introductory chapter this book includes 12 chapters written by renowned experts in their respected fields Each chapter follows a three part format 1 a description of an important power system problem or problems 2 the current practice and or particular research approaches and 3 future research directions Collectively the technical areas discussed are voltage and oscillatory stability power system security margins hierarchical and decentralized control stability monitoring embedded optimization neural network control with adaptive critic architecture control tuning using genetic algorithms and load forecasting and component prediction This volume is intended for power systems researchers and professionals charged with solving electric and power system problems      **Transient Stability of Power Systems** Mania Pavella,Damien Ernst,Daniel

Ruiz-Vega,2012-12-06 The market liberalization is expected to affect drastically the operation of power systems which under economical pressure and increasing amount of transactions are being operated much closer to their limits than previously These changes put the system operators faced with rather different and much more problematic scenarios than in the past They have now to calculate available transfer capabilities and manage congestion problems in a near on line environment while operating the transmission system under extremely stressed conditions This requires highly reliable and efficient software aids which today are non existent or not yet in use One of the most problematic issues very much needed but not yet en countered today is on line dynamic security assessment and control enabling the power system to withstand unexpected contingencies without experienc ing voltage or transient instabilities This monograph is devoted to a unified approach to transient stability assessment and control called Single Machine Equivalent S1ME      *Voltage Stability of Electric Power Systems* Thierry van Cutsem,Costas Vournas,2007-11-27 Voltage Stability of Electric Power Systems presents a clear description of voltage instability and collapse phenomena It proposes a uniform and coherent theoretical framework for analysis and covers state of the art methods The book describes practical methods that can be used for voltage security assessment and offers a variety of examples This is a first attempt to condense the technical papers and reports on this subject into a single coherent and theoretically sound presentation Transmission generation and load aspects of the voltage

instability problem are treated in detail and a comprehensive power system model for use in voltage stability analysis is developed and explained. Notions and concepts from nonlinear system theory are presented in a tutorial manner for the use of those new to the field. Loadability sensitivity and bifurcation analysis of voltage stability are introduced and treated in depth. Voltage instability mechanisms are classified and minutely examined together with the countermeasures that can be used to avoid them. In addition, voltage security criteria and methods are reviewed, analyzed and illustrated through realistic computer results. Voltage Stability is a relatively recent and challenging problem in Power Systems Engineering. It is gaining in importance as the trend of operating power systems closer to their limits continues to increase. **Robust Control in**

**Power Systems** Bikash Pal, Balarko Chaudhuri, 2006-07-02 Robust Control in Power Systems deals with the applications of new techniques in linear system theory to control low frequency oscillations in power systems. The book specifically focuses on the analysis and damping of inter area oscillations in the systems which are in the range of 0.2-1 Hz. The damping control action is injected through high power electronic devices known as flexible AC transmission system (FACTS) controllers. Three commonly used FACTS controllers: controllable series capacitors (CSCs), controllable phase shifters (CPSs) and static var compensators (SVCs) have been used in this book to control the inter area oscillations. The overview of linear system theory from the perspective of power system control is explained through examples. The damping control design is formulated as a norm optimization problem. The  $H_2$  norm of properly defined transfer functions are minimized in linear matrix inequalities (LMI) framework to obtain desired performance and stability robustness. Both centralized and decentralized control structures are used. Usually the transmission of feedback signal from a remote location encounters delays making it difficult to control the system. Smith predictor based approach has been successfully explored in this book as a solution to such a problem. Robust Control in Power Systems will be valuable to academicians in the areas of power control and system theory as well as professionals in the power industry. Fundamentals Of Electric Power Engineering Isaak D

Mayergoyz, Patrick Mcavoy, 2014-11-13 Electric power engineering has always been an integral part of electrical engineering education. Providing a unique alternative to existing books on the market, this text presents a concise and rigorous exposition of the main fundamentals of electric power engineering. Contained in a single volume, the materials can be used to teach three separate courses: electrical machines, power systems and power electronics, which are in the mainstream of the electrical engineering curriculum of most universities worldwide. The book also highlights an in-depth review of electric and magnetic circuit theory with emphasis on the topics which are most relevant to electric power engineering. *State Estimation in Electric Power Systems* A. Monticelli, 2012-12-06 State Estimation in Electric Power Systems: A Generalized Approach provides for the first time a comprehensive introduction to the topic of state estimation at an advanced textbook level. The theory as well as practice of weighted least squares (WLS) is covered with significant rigor. Included are an in-depth analysis of power flow basics, proper justification of Stott's decoupled method, observability theory and matrix solution.

methods In terms of practical application topics such as bad data analysis combinatorial bad data analysis and multiple snapshot estimation are covered The book caters both to the specialist as well as the newcomer to the field State estimation will play a crucial role in the emerging scenario of a deregulated power industry Many market decisions will be based on knowing the present state of the system accurately State Estimation in Electric Power Systems A Generalized Approach crystallizes thirty years of WLS state estimation theory and practice in power systems and focuses on techniques adopted by state estimation developers worldwide The book also reflects the experience of developing industrial grade state estimation software that is used in the USA South America and many other places in world

**Computational Methods for Large Sparse Power Systems Analysis** S.A. Soman, S.A. Khaparde, Shubha Pandit, 2012-12-06 Computational methods in Power Systems require significant inputs from diverse disciplines such as data base structures numerical analysis etc Strategic decisions in sparsity exploitation and algorithm design influence large scale simulation and high speed computations Selection of programming paradigm shapes the design its modularity and reusability This has a far reaching effect on software maintenance Computational Methods for Large Sparse Power Systems Analysis An Object Oriented Approach provides a unified object oriented OO treatment for power system analysis Sparsity exploitation techniques in OO paradigm are emphasized to facilitate large scale and fast computing Specific applications like large scale load flow short circuit analysis state estimation and optimal power flow are discussed within this framework A chapter on modeling and computational issues in power system dynamics is also included Motivational examples and illustrations are included throughout the book A library of C classes provided along with this book has classes for transmission lines transformers substation etc A CD ROM with C programs is also included It contains load flow short circuit analysis and network topology processor applications Power system data is provided and systems up to 150 buses can be studied Other Special Features This book is the first of its kind covering power system applications designed with an OO perspective Chapters on object orientation for modeling of power system computations data structure large sparse linear system solver sparse QR decomposition in an OO framework are special features of this book

**Power System Dynamics and Stability** Jan Machowski, Janusz W. Bialek, Janusz Bialek, James Richard Bumby, 1997-10-20 As the demand for electrical power increases power systems are being operated closer to their stability limits than ever before This text focuses on explaining and analysing the dynamic performance of such systems which is important for both system operation and planning Placing emphasis on understanding the underlying physical principles the book opens with an exploration of basic concepts using simple mathematical models Building on these firm foundations the authors proceed to more complex models and algorithms Features include Progressive approach from simplicity to complexity Detailed description of slow and fast dynamics Examination of the influence of automatic control on power system dynamics Stability enhancement including the use of PSS and Facts Advanced models and algorithms for power system stability analysis Senior undergraduate postgraduate and

research students studying power systems will appreciate the authors accessible approach Also for electric utility engineers this valuable resource examines power system dynamics and stability from both a mathematical and engineering viewpoint

**Structure Preserving Energy Functions in Power Systems** K.R. Padiyar, 2013-03-15 A guide for software development of the dynamic security assessment and control of power systems Structure Preserving Energy Functions in Power Systems Theory and Applications takes an approach that is more general than previous works on Transient Energy Functions defined using Reduced Network Models A comprehensive presentation of theory and applications this book Describes the analytics of monitoring and predicting dynamic security and emergency control through the illustration of theory and applications of energy functions defined on structure preserving models Covers different facets of dynamic analysis of large bulk power systems such as system stability evaluation dynamic security assessment and control among others Supports illustration of SPEFs using examples and case studies including descriptions of applications in real time monitoring adaptive protection and emergency control Presents a novel network analogy based on accurate generator models that enables an accurate yet simplified approach to computing total energy as the aggregate of energy in individual components The book presents analytical tools for online detection of loss of synchronism and suggests adaptive system protection It covers the design of effective linear damping controllers using FACTS for damping small oscillations during normal operation to prevent transition to emergency states and emergency control based on FACTS to improve first swing stability and also provide rapid damping of nonlinear oscillations that threaten system security during major disturbances The author includes detection and control algorithms derived from theoretical considerations and illustrated through several examples and case studies on test systems

**Automatic Learning Techniques in Power Systems** Louis A. Wehenkel, 2012-12-06 Automatic learning is a complex multidisciplinary field of research and development involving theoretical and applied methods from statistics computer science artificial intelligence biology and psychology Its applications to engineering problems such as those encountered in electrical power systems are therefore challenging while extremely promising More and more data have become available collected from the field by systematic archiving or generated through computer based simulation To handle this explosion of data automatic learning can be used to provide systematic approaches without which the increasing data amounts and computer power would be of little use Automatic Learning Techniques in Power Systems is dedicated to the practical application of automatic learning to power systems Power systems to which automatic learning can be applied are screened and the complementary aspects of automatic learning with respect to analytical methods and numerical simulation are investigated This book presents a representative subset of automatic learning methods basic and more sophisticated ones available from statistics both classical and modern and from artificial intelligence both hard and soft computing The text also discusses appropriate methodologies for combining these methods to make the best use of available data in the context of real life problems Automatic Learning



Techniques in Power Systems is a useful reference source for professionals and researchers developing automatic learning systems in the electrical power field

Analysis of Subsynchronous Resonance in Power Systems K.R. Padiyar, 2012-12-06

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**Power System Oscillations** Graham Rogers, 2012-12-06

Power System Oscillations deals with the analysis and control of low frequency oscillations in the 0.2-3 Hz range which are a characteristic of interconnected power systems. Small variations in system load excite the oscillations which must be damped effectively to maintain secure and stable system operation. No warning is given for the occurrence of growing oscillations caused by oscillatory instability since a change in the system's operating condition may cause the transition from stable to unstable. If not limited by nonlinearities, unstable oscillations may lead to rapid system collapse. Thus it is difficult for operators to intervene manually to restore the system's stability. It follows that it is important to analyze a system's oscillatory behavior in order to understand the system's limits. If the limits imposed by oscillatory instability are too low, they may be increased by the installation of special stabilizing controls. Since the late 60s when this phenomena was first observed in North American systems, intensive research has resulted in design and installation of stabilizing controls known as power system stabilizers (PSS). The design, location and tuning of PSS require special analytical tools. This book addresses these questions in a modal analysis framework with transient simulation as a measure of controlled system performance. After discussing the nature of the oscillations, the design of the PSS is discussed extensively using modal analysis and frequency response. In the scenario of the restructured power system, the performance of power system damping controls must be insensitive to parameter uncertainties. Power system stabilizers, when well tuned, are shown to be robust using the techniques of modern control theory. The design of damping controls which operate through electronic power system devices (FACTS) is also discussed. There are many worked examples throughout the text. The Power

System Toolbox for use with MATLAB is used to perform all of the analyses used in this book. The text is based on the author's experience of over 40 years as an engineer in the power industry and as an educator.

Wide Area Power Systems Stability, Protection, and Security Hassan Haes Alhelou, Almoataz Y. Abdelaziz, Pierluigi Siano, 2020-09-21. This book proposes new control and protection schemes to improve the overall stability and security of future wide area power systems. It focuses on the high penetration levels of renewable energy sources and distributed generation particularly with the trend towards smart grids. The control methods discussed can improve the overall stability in normal and abnormal operation conditions while the protection methods presented can be used to ensure the secure operation of systems under most severe contingencies. Presenting stability security and protection methods for power systems in one concise volume, this book takes the reader on a journey from concepts and fundamentals to the latest and future trends in each topic covered, making it an informative and intriguing read for researchers, graduate students, and practitioners alike.

*Electromagnetic Modelling of Power Electronic Converters* J.A. Ferreira, 2013-03-09. The era of the personal computer has without doubt permanently altered our life style in a myriad of ways. The brain of the personal computer is the microprocessor together with RAM and ROM which makes the decisions needed for the computer to perform in the desired manner. The microprocessor continues to evolve as increasingly complex tasks are required. While not sharing the limelight of the microprocessor, the heart of the personal computer, namely the power supply, is equally important since without the necessary source of power the microprocessor would be a useless piece of silicon. The power supply of twenty years ago was much different than its modern day equivalent. At the dawn of the personal computer era in the late 1970s, power was obtained from a simple diode bridge. However, the need for smooth regulated DC at low voltage required at the same time both a bulky input transformer and a large DC side filter. Those computer fans present at the birth of this industry can remember the large boxes housing our Altair, Cromemco, and Northstar computers, which was made necessary largely because of the huge power supply. It is not well appreciated but certainly true that the huge success of the Apple II computer in those days was due at least in part to the relatively slim profile of the machine. This sleek appearance was largely due to the adoption of the then new and unproven switched mode power supply.

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