

Article

Parametric Sensitivity Analysis of Rotor Angle Stability Indicators [†]Ashish Shrestha ^{*} and Francisco Gonzalez-Longatt ^{*}

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Abstract: With the increasing penetration rate of Power Electronic Converter (PEC) based technologies, the electrical power systems are facing the problem of transient stability since the PEC based technologies do not contribute to the system inertia, and the proportion of synchronous generators (i.e., the source of inertia) is in decreasing rate. In addition, PEC based technologies' components have poor inherent damping. It is very important to analyze the system characteristics of a power system to minimize the potential instabilities during the contingencies. This paper presents the parametric sensitivity analysis of the rotor angle stability indicators for the 39-bus New England power system. The indicators of rotor angle stability analysis such as critical fault clearing time (CCT), Eigenvalue points, damping ratio, frequency deviation, voltage deviation, and generator's speed deviation are identified and analyzed for three case scenarios; each scenario has six sub-cases with different inertia constants. The results show that the CCTs for each component will be reduced if the inertia reduces at any section of a multi-machine power system. Although the applied three scenarios with six sub-cases are identified to be stable in this analysis, the decreasing inertia constant has significant impact on the power system dynamics.

Keywords: power system dynamics; power system stability; low inertial power system



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1. Introduction

Power systems have become more complex than in the past, caused by the integration of numerous Distributed Generation Resources (DGRs) and the rapidly growing power electronic converter (PEC) based technologies. The modern power system faces complex transformation in all levels, such as generation, transmission, distribution, and utilization [1]. With this rapid transformation, the modern power system faces significant changes in the power system dynamics; one of the main reasons behind this is reduction of system inertia because of these PEC-based technologies [2]. In the conventional power system, most of the power generators were of the synchronous type; they are characterized as the source of rotational inertia in a power system, whereas in a modern power system, the proportion of synchronous generators is at a decreasing rate [3]. Moreover, the PEC-based technologies adopted in the generation (e.g., kinetic energy less solar PV and doubly-fed induction generator based wind turbines), transmission line (e.g., HVDC), distribution system (e.g., controllers), and utilization level (e.g., controller based equipment) do not contribute to the system inertia, which results in a drop of system inertia in the modern power system, resulting in drastic changes in the system dynamics [4]. Not only these but the transient stability of the DGR integrated power system is also highly sensitive to the proportion of the penetration level, fault location and its severity [5]. Titiens et al. presented a detailed study on the relevance of inertia in the operation and control of a power system, which shows that the decreasing system inertia results in the high Rate of Change of Frequency (RoCoF) values and frequency deviation, which may increase the system instability [6]. The DGRs are integrated into the distribution lines at a low voltage

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Anthony V. Fiacco



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Sensitivity, Stability, and Parametric Analysis Anthony V. Fiacco, 1984 **Encyclopedia of Operations Research and Management Science** Saul I. Gass, Carl M. Harris, 2012-12-06 Operations Research 1934 1941 35 1 143 152 British The goal of the Encyclopedia of Operations Research and Operational Research in World War II 35 3 453 470 Management Science is to provide to decision makers and U S Operations Research in World War II 35 6 910 925 problem solvers in business industry government and and the 1984 article by Harold Lardner that appeared in academia a comprehensive overview of the wide range of Operations Research The Origin of Operational Research ideas methodologies and synergistic forces that combine to 32 2 465 475 form the preeminent decision aiding fields of operations research and management science OR MS To this end we The Encyclopedia contains no entries that define the fields enlisted a distinguished international group of academics of operations research and management science OR and MS and practitioners to contribute articles on subjects for are often equated to one another If one defines them by the which they are renowned methodologies they employ the equation would probably The editors working with the Encyclopedia s Editorial stand inspection If one defines them by their historical Advisory Board surveyed and divided OR MS into specific developments and the classes of problems they encompass topics that collectively encompass the foundations applica the equation becomes fuzzy The formalism OR grew out of tions and emerging elements of this ever changing field We the operational problems of the British and U s military also wanted to establish the close associations that OR MS efforts in World War II **Multi-parametric Optimization and Control** Efstratios N. Pistikopoulos, Nikolaos A. Diangelakis, Richard Oberdieck, 2020-11-24 Recent developments in multi parametric optimization and control Multi Parametric Optimization and Control provides comprehensive coverage of recent methodological developments for optimal model based control through parametric optimization It also shares real world research applications to support deeper understanding of the material Researchers and practitioners can use the book as reference It is also suitable as a primary or a supplementary textbook Each chapter looks at the theories related to a topic along with a relevant case study Topic complexity increases gradually as readers progress through the chapters The first part of the book presents an overview of the state of the art multi parametric optimization theory and algorithms in multi parametric programming The second examines the connection between multi parametric programming and model predictive control from the linear quadratic regulator over hybrid systems to periodic systems and robust control The third part of the book addresses multi parametric optimization in process systems engineering A step by step procedure is introduced for embedding the programming within the system engineering which leads the reader into the topic of the PAROC framework and software platform PAROC is an integrated framework and platform for the optimization and advanced model based control of process systems Uses case studies to illustrate real world applications for a better understanding of the concepts presented Covers the fundamentals of optimization and model predictive control Provides

information on key topics such as the basic sensitivity theorem linear programming quadratic programming mixed integer linear programming optimal control of continuous systems and multi parametric optimal control An appendix summarizes the history of multi parametric optimization algorithms It also covers the use of the parametric optimization toolbox POP which is comprehensive software for efficiently solving multi parametric programming problems Modern Methods of Optimization Werner Krabs, Jochem Zowe, 2013-03-14 This volume contains the proceedings of the summer school Modern Methods of Optimization held at the Schloß Thurnau of the University of Bayreuth October 1-6 1990 Like other branches of applied mathematics the area of optimization is undergoing a rapid development since the beginning of the computer age Optimization methods are of increasing importance for both science and industry The aim of the summer school was to present state of the art knowledge by inviting 12 specialists from Optimization and related fields to present their areas of activity in the form of survey talks This volume contains 10 of these presentations in slightly extended form Most lectures started from an undergraduate level and outlined the developments up to the latest scientific achievements This enabled the audience consisting of about 45 students and young researchers to get an excellent overview of the latest trends in Optimization as well as a grasp of the breadth of its potential applications Equally important to the success of the summer school was the nonmeasurable part of the activities inherent in such a summer school Here the inspiring atmosphere of a place like Thurnau helped to establish numerous contacts between teachers and students The summer school was organized by the Universität Bayreuth together with the Technische Hochschule Darmstadt and was generously sponsored by the Volkswagen Stiftung and the Universitätssverein Bayreuth Their interest in the meeting and their support is hereby gratefully acknowledged

Mathematics of Optimization: Smooth and Nonsmooth Case Giorgio Giorgi, A. Guerraggio, J. Thierfelder, 2004-03-10 The book is intended for people graduates researchers but also undergraduates with a good mathematical background involved in the study of static optimization problems in finite dimensional spaces It contains a lot of material from basic tools of convex analysis to optimality conditions for smooth optimization problems for non smooth optimization problems and for vector optimization problems The development of the subjects are self contained and the bibliographical references are usually treated in different books only a few books on optimization theory deal also with vector problems so the book can be a starting point for further readings in a more specialized literature Assuming only a good even if not advanced knowledge of mathematical analysis and linear algebra this book presents various aspects of the mathematical theory in optimization problems The treatment is performed in finite dimensional spaces and with no regard to algorithmic questions After two chapters concerning respectively introductory subjects and basic tools and concepts of convex analysis the book treats extensively mathematical programming problems in the smooth case in the nonsmooth case and finally vector optimization problems Self contained Clear style and results are either proved or stated precisely with adequate references The authors have several years experience in this field Several subjects some of them non usual in books

of this kind in one single book including nonsmooth optimization and vector optimization problems Useful long references list at the end of each chapter **Parametric Optimization and Related Topics** Jürgen Guddat, Hubertus Th. Jongen, Bernd Kummer, František Nožička, 1987-12-31 No detailed description available for Parametric Optimization and Related Topics

Basic Mathematical Programming Theory Giorgio Giorgi, Bienvenido Jiménez, Vicente Novo, 2023-07-18 The subject of static optimization also called mathematical programming is one of the most important and widespread branches of modern mathematics serving as a cornerstone of such scientific subjects as economic analysis operations research management sciences engineering chemistry physics statistics computer science biology and social sciences This book presents a unified progressive treatment of the basic mathematical tools of mathematical programming theory The authors expose said tools along with results concerning the most common mathematical programming problems formulated in a finite dimensional setting forming the basis for further study of the basic questions on the various algorithmic methods and the most important particular applications of mathematical programming problems This book assumes no previous experience in optimization theory and the treatment of the various topics is largely self contained Prerequisites are the basic tools of differential calculus for functions of several variables the basic notions of topology and of linear algebra and the basic mathematical notions and theoretical background used in analyzing optimization problems The book is aimed at both undergraduate and postgraduate students interested in mathematical programming problems but also those professionals who use optimization methods and wish to learn the more theoretical aspects of these questions Introduction to Numerical Continuation

Methods Eugene L. Allgower, Kurt Georg, 2003-01-01 Numerical continuation methods have provided important contributions toward the numerical solution of nonlinear systems of equations for many years The methods may be used not only to compute solutions which might otherwise be hard to obtain but also to gain insight into qualitative properties of the solutions Introduction to Numerical Continuation Methods originally published in 1979 was the first book to provide easy access to the numerical aspects of predictor corrector continuation and piecewise linear continuation methods Not only do these seemingly distinct methods share many common features and general principles they can be numerically implemented in similar ways Introduction to Numerical Continuation Methods also features the piecewise linear approximation of implicitly defined surfaces the algorithms of which are frequently used in computer graphics mesh generation and the evaluation of surface integrals

Nonlinear Optimization and Applications Gianni Pillo, F. Giannessi, 2013-11-11 This volume contains the edited texts of the lectures presented at the workshop on Nonlinear Optimization Theory and Applications held in Erice at the G Stampacchia School of Mathematics of the E Majorana International Centre for Scientific Culture June 13 21 1995 The meeting was conceived to review and discuss recent advances and promising research trends concerning theory algorithms and innovative applications in the field This is a field of mathematics which is providing viable of Nonlinear Optimization tools in engineering in economics and in other applied sciences and which is giving a great contribution also in the solution

of the more practiced linear optimization problems The meeting was attended by approximately 70 people from 18 countries Besides the lectures several formal and informal discussions took place The result was a broad exposure providing a wide and deep understanding of the present research achievements in the field We wish to express our appreciation for the active contributions of all the participants in the meeting Our gratitude is due to the Ettore Majorana Center in Erice which offered its facilities and stimulating environment its staff was certainly instrumental for the success of the meeting Our gratitude is also due to Francisco Facchinei and Massimo Roma for the time spent in the organization of the workshop and to Giuliana Cai for the careful typesetting of this volume

Finite-Dimensional Variational Inequalities and Complementarity

Problems Francisco Facchinei, Jong-Shi Pang, 2007-06-14 The finite dimensional nonlinear complementarity problem NCP is a system of finitely many nonlinear inequalities in finitely many nonnegative variables along with a special equation that expresses the complementary relationship between the variables and corresponding inequalities This complementarity condition is the key feature distinguishing the NCP from a general inequality system lies at the heart of all constrained optimization problems in finite dimensions provides a powerful framework for the modeling of equilibria of many kinds and exhibits a natural link between smooth and nonsmooth mathematics The finite dimensional variational inequality VI which is a generalization of the NCP provides a broad unifying setting for the study of optimization and equilibrium problems and serves as the main computational framework for the practical solution of a host of continuum problems in the mathematical sciences The systematic study of the finite dimensional NCP and VI began in the mid 1960s in a span of four decades the subject has developed into a very fruitful discipline in the field of mathematical programming The developments include a rich mathematical theory a host of effective solution algorithms a multitude of interesting connections to numerous disciplines and a wide range of important applications in engineering and economics As a result of their broad associations the literature of the VI CP has benefited from contributions made by mathematicians pure applied and computational computer scientists engineers of many kinds civil chemical electrical mechanical and systems and economists of diverse expertise agricultural computational energy financial and spatial

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