

Reliability Assessment of Redundant Electrical Power Supply Systems using Fault Tree Analysis, Reliability Block Diagram, and Monte Carlo Simulation Methods

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Abstract—This paper deals with the reliability assessment of electrical power supply systems under redundancy. For doing so, three probabilistic safety analysis (PSA) methods are proposed and developed namely fault tree analysis (FTA), reliability block diagram (RBD), and Monte Carlo Simulation (MC) method. The FTA method is performed using RiskSpectrumPSA® software and the RBD and MC methods are coded using Matlab software. The electrical power supply system reliability is analyzed and enhanced considering various cases of redundancy. The FTA method is based on qualitative and quantitative reliability assessment. The quantitative assessment calculates the failure probability of the top event, and the qualitative approach determines the minimal cut sets (MCS). However, the RBD and MC methods are proposed to compute the system failure probability. The considered methods are applied on three case studies and the obtained results are compared to each other. The obtained results show that the three methods provide almost the same results. Furthermore, the reliability of the electrical power supply is clearly enhanced with the number of redundant components.

Keywords—electrical power system reliability; probabilistic safety assessment; fault tree analysis; reliability block diagram; Monte Carlo simulation; Redundancy; RiskSpectrumPSA software; minimal cut sets; qualitative and quantitative safety assessment.

I. INTRODUCTION

The electric energy is considered as the heart of the industry development, the human's life comfort and the operation safety of industrial installations. This electric energy must be reliable and must have the best quality in order to fulfill the predefined industrial installations requirements. Generally, the reliability of a system is defined as the probability that this system can perform its intended function for a specified interval under stated conditions. Therefore, the electrical power supply system of an industrial installation must be designed in a manner that provides a best quality and reliability of electrical power. For this, some critical industries need a high level of electrical power supply reliability and don't allow its loss. However, an unreliable electrical power

supply system can cause severe accidents [1]. Therefore, the electric power supply reliability must be continuously evaluated and assessed. This evaluation can be performed during different lifetime stages of the installation (e.g. design, construction, operation, aging, and/or decommissioning).

Various approaches for systems reliability assessment have been proposed in the literature [2], where, the electrical power supply reliability is usually performed using either the deterministic or the probabilistic methods. The deterministic assessment of electric power reliability is generally based on N-1 and N-2 methods. The N-1 method considers the outage of one electric component (e.g. transmission line, generator, or transformer) and check if the electric parameters of power system remain in the nominal interval of variation. The N-2 method considers the failure of an electric component and the maintenance of another one.

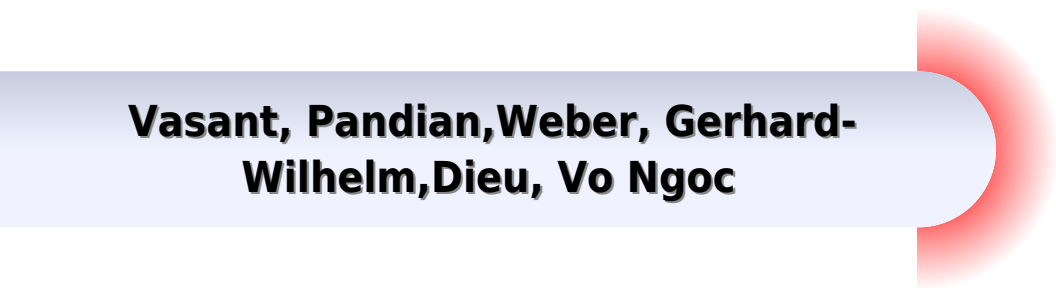
The probabilistic assessment of power system is based on the analysis of all possible events that may occur according to their probabilities in order to compute the failure probability of the overall system. The most popular methods used for power system reliability assessment are: Fault Tree Analysis (FTA), Reliability Block Diagram (RBD), Markov chain, and Monte Carlo Simulation (MC).

The reliability evaluation of electrical systems using FTA has been widely proposed [3-9]. In [6], the qualitative and quantitative reliability assessment of an electrical power supply system is presented using FTA and Minimal Cut Sets (MCS). In [7, 8], the FTA is used to evaluate the power system reliability at the load points. The quantitative and qualitative FTA assessments were used to identify the most important elements in the power system. In [9], the FTA method is applied for customer reliability assessment of a distribution power system.

Many practical uses can be highlighted for utilization of RBD in reliability assessment. In [10], RBD and FTA methods are developed for reliability analysis of a fire pump. Likewise,

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Reliability Assessment of Electric Power Systems Using Monte Carlo Methods Billinton, W. Li, 2013-06-29 The application of quantitative reliability evaluation in electric power systems has now evolved to the point at which most utilities use these techniques in one or more areas of their planning design and operation Most of the techniques in use are based on analytical models and resulting analytical evaluation procedures Improvements in and availability of high speed digital computers have created the opportunity to analyze many of these problems using stochastic simulation methods and over the last decade there has been increased interest in and use made of Monte Carlo simulation in quantitative power system reliability assessment Monte Carlo simulation is not a new concept and recorded applications have existed for at least 50 yr However localized high speed computers with large capacity storage have made Monte Carlo simulation an available and sometimes preferable option for many power system reliability applications Monte Carlo simulation is also an integral part of a modern undergraduate or graduate course on reliability evaluation of general engineering systems or specialized areas such as electric power systems It is hoped that this textbook will help formalize the many existing applications of Monte Carlo simulation and assist in their integration in teaching programs This book presents the basic concepts associated with Monte Carlo simulation

Systemic Design Methodologies for Electrical Energy Systems Xavier Roboam, 2012-12-17 This book proposes systemic design methodologies applied to electrical energy systems in particular analysis and system management modeling and sizing tools It includes 8 chapters after an introduction to the systemic approach history basics fundamental issues index terms for designing energy systems this book presents two different graphical formalisms especially dedicated to multidisciplinary devices modeling synthesis and analysis Bond Graph and COG EMR Other systemic analysis approaches for quality and stability of systems as well as for safety and robustness analysis tools are also proposed One chapter is dedicated to energy management and another is focused on Monte Carlo algorithms for electrical systems and networks sizing The aim of this book is to summarize design methodologies based in particular on a systemic viewpoint by considering the system as a whole These methods and tools are proposed by the most important French research laboratories which have many scientific partnerships with other European and international research institutions Scientists and engineers in the field of electrical engineering especially teachers researchers because of the focus on methodological issues will find this book extremely useful as will PhD and Masters students in this field

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New Computational Methods in Power System Reliability David Elmakias, 2008-07-07. Power system reliability is the focus of intensive study due to its critical role in providing energy supply to modern society. This comprehensive book describes application of some new specific techniques: universal generating function method and its combination with Monte Carlo simulation and with random processes methods, Semi Markov and Markov reward models and genetic algorithm. The book can be considered as complementary to power system reliability textbooks.

Risk Assessment Of Power Systems Wenyuan Li, 2005-05-13. Power system risk assessment is becoming an important and mandatory task in planning, operation, maintenance and asset management of utilities particularly under the deregulation environment. This book will provide readers with the tools to solve practical problems using appropriate risk assessment techniques. Both analytical and Monte Carlo evaluation methods are discussed with an emphasis on applied techniques and actual considerations in generation, transmission, substation and distribution systems.

Flexible and Active Distribution Networks Peng Li, Haoran Ji, Yang Mi, Hao Yu, Yue Zhou, Nian Liu, 2021-08-02. **Innovation in Electrical**

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Unifying Electrical Engineering and Electronics Engineering Song Xing, Suting Chen, Zhanming Wei, Jingming Xia, 2013-08-24 Unifying Electrical Engineering and Electronics Engineering is based on the Proceedings of the 2012 International Conference on Electrical and Electronics Engineering (ICEE 2012). This book collects the peer-reviewed papers presented at the conference. The aim of the conference is to unify the two areas of Electrical and Electronics Engineering. The book examines trends and techniques in the field as well as theories and applications. The editors have chosen to include the following topics: biotechnology, power engineering, superconductivity, circuits, antennas, technology, system architectures and telecommunication. *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

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