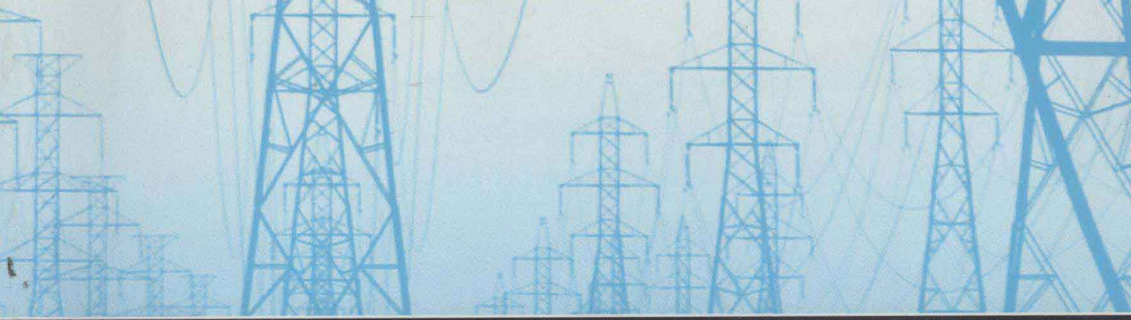

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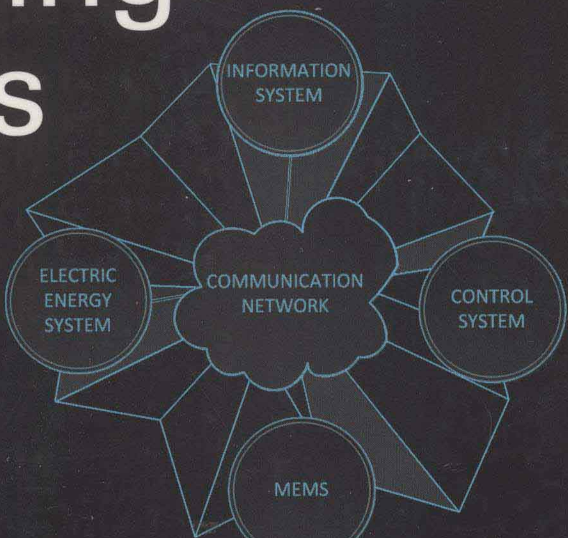

JAMES MOMOH • LAMINE MILI

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Edited by

James Momoh
Lamine Mili

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PREFACE

This is the second graduate textbook of a two-volume series that relate the interdisciplinary research activities carried out by researchers in power engineering, economics, and systems engineering funded by NSF-ONR EPNES. The NSF-ONR EPNES initiative has enabled researchers, university professors, and graduate students to engage in interdisciplinary work in all the aforementioned areas. The contributors to both volumes have expertise in economics, social sciences, and electric power systems.

Nevertheless, there remain barriers between intellectual disciplines relevant to development of efficient and secure power networks. Innovative and integrated curricula and pedagogy that incorporate advanced systems theory, economics, environmental science, policy, and technical issues must be developed. These two volumes address this need. We hope that this appeal will reach a broad audience of policy makers, executives and engineers of electric utilities, university faculty members and graduate students as well as researchers working in cross-cutting areas related to electric power systems, economics, and social sciences. To our best knowledge, there is no book that combines all these fields. The purpose of these two volumes is to provide working knowledge as well as the latest research in electric power systems theory and applications.

The companion volume of this two-volume series addresses the economic, social, and security aspects of the operation and planning of restructured electric power systems. In the present volume we focus on the operation and control of electric energy processing systems. The multidisciplinary research collected in this volume should well prepare engineers, economists, and social scientists to plan and operate secure and efficient power systems. The contributors emphasize the importance of design in achieving robust power networks that meet resiliency and sustainability requirements.

The present volume is organized in six chapters. Chapter 1, which is authored by J. Momoh, introduces the EPNES initiative. Chapter 2, which is authored by C. N. Hadjicostis, H. Rodríguez Cortés, and A. M. Stankovic, investigates several dynamical models in fault tolerant operation and control of energy processing systems. Chapter 3, which is authored by A. A. Irizarry-Rivera, M. Rodríguez-Martínez, B. Vélez, M. Vélez-Reyes, A. R. Ramirez-Orquin, E. O'Neill-Carrillo, and J. R. Cedeño, develops intelligent power routers for distributed coordination of electric energy processing networks. Chapter 4, which is authored by G. G. Karady, G. T. Heydt, E. Gel, and N. Hubele, deals with the design of power circuit breakers using an array of small micro-electro-mechanical (MEMS) switches together with diodes for faster operation and smaller equipment size aimed at reducing the vulnerability of a power system to faults. Chapter 5, which is authored by R. D. Badinelli, V. Centeno, and B. Intiyot, develops a GIS-based market simulation studies for power systems education. Finally, Chapter 6, which is authored by R. F. Hirsh, B. K. Sovacool, and R. D. Badinelli, employs a social-sciences approach to help understand the development and use of distributed generation (DG) technologies—small-scale generators that produce power near their loads—in the electric power system.

We are grateful to Katherine Drew from ONR for financial and moral support, Ed Zivi from ONR for the benchmarks, and colleagues from ONR and NSF for fostering a congenial environment that allowed this work to grow and flourish. We thank former NSF division directors, Dr. Rajinder Khosla and Dr. Vasu Varadan, who provided seed funding for this initiative. We also thank Dr. Paul Werbos and Dr. Kishen Baheti from NSF for facilitating interdisciplinary discussions on power systems reliability and education. We are thankful to NSF-DUE program directors, Prof. Roger E. Salters from the NSF Division of Undergraduate Education and Dr. Bruce Hamilton of NSF BES Division.

We acknowledge the contributions of our graduate students at Howard University and at Virginia Tech who helped prepare these volumes for publication.

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CONTENTS

1

A FRAMEWORK FOR INTERDISCIPLINARY RESEARCH AND EDUCATION

James Momoh

Howard University

1.1 INTRODUCTION

Electric power networks efficiency and security (EPNES) deals with fundamental issues of understanding the security, efficiency, and behavior of large electric power systems, including utility and US Navy power system topologies, under varying disruptive or catastrophic events. Because the US Navy ship power system is an integrated power system (IPS) consisting of AC/DC components and several operational frequencies, they require different modeling and simulation tools than those being using in standard industrial or bulk AC power systems. Accurate contingency evaluation of the Naval Integrated Power System should be based on a comprehensive system model of the naval ship system. For both systems, robustness characteristics are to be measured in terms of various attributes such as survivability, security, efficiency, sustainability, and affordability.

There is an urgent need for the development of innovative methods and conceptual frameworks for analysis, planning, and operation of complex, efficient, and secure electric power networks. If this need is to be met and sustained in the long run, there must be appropriate educational resources developed and available to teach those who will design, develop, and operate those networks. Hence educational pedagogy and

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curricula improvement must be a natural part of this endeavor. The next generation of high-performance dynamic and adaptive nonlinear networks, of which power systems are an application, will be designed and upgraded with the interdisciplinary knowledge required to achieve improved survivability, security, reliability, reconfigurability, and efficiency.

Additionally, in order to increase interest in power engineering education and to address workforce issues in the deregulated power industry, an interdisciplinary research-based curriculum that prepares engineers, economists, and scientists to plan and operate power networks is necessary. To accomplish this goal, it must be recognized that these networks are sociotechnical systems, meaning that successful functioning depends as much on social factors as technical characteristics. Robust power networks are a critical component of larger efforts to achieve sustainable economic growth on a global scale.

The continued security of electric power networks can be compromised not only by technical breakdowns but also by deliberate sabotage, misguided economic incentives, regulatory difficulties, the shortage of energy production and transmission facilities, and the lack of appropriately trained engineers, scientists, and operations personnel.

Addressing these issues requires an interdisciplinary approach that brings researchers from engineering, environmental, and social-economic sciences together. NSF anticipates that the research activities funded by this program will increase the likelihood that electric power will be available throughout the United States at all times, at reasonable prices, and with minimal deleterious environmental impacts. It is hoped that a convergence of socioeconomic principles with new system theories and computational methods for systems analysis will lead to development of a more efficient, robust, and secure distributed network system. Figure 1.1 depicts the unification of knowledge through research and education.

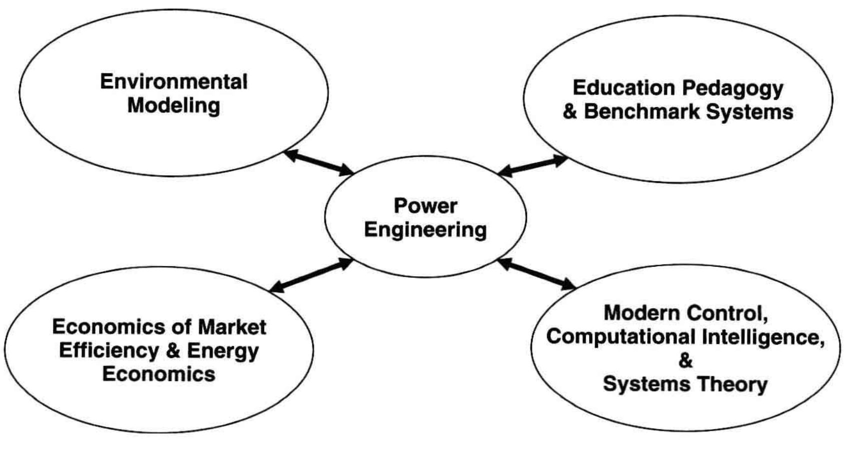

Figure 1.1 Unification of knowledge through research and education.