INTELLIGENT
SERVICE
Restoration in Smart
Distribution Network

UNIVERSITI
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UiTM Professorial Lecture

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PREFACE

This book emerges from a sustained effort to explore how intelligent techniques can enhance the performance and reliability of modern power distribution systems. Over time, the increasing complexity of distribution networks—driven by renewable integration, evolving load demands, and digitalisation—has raised important questions about how best to restore service quickly and efficiently when faults occur.

The idea for this book was developed out of an interest in applying optimisation and prediction methods to real distribution network scenarios. Rather than focusing solely on theory or simulation, the goal was to present practical solutions that utility operators and system planners could realistically adopt. These include intelligent reconfiguration algorithms and data-driven prediction models that support timely and informed decision-making in service restoration.

While the content is based on original research and tested case studies, this book is written with broader clarity and relevance in mind. It is intended for those involved in power system operations, smart grid research, and the application of computational intelligence in engineering practice. It also serves as a resource for postgraduate students seeking to understand the link between optimisation theory and practical grid resilience.

CHAPTER *1*

INTELLIGENT DISTRIBUTION SYSTEMS – FOUNDATIONS AND RESTORATION STRATEGIES

BACKGROUND AND MOTIVATION

The electrical power system forms the backbone of modern infrastructure, enabling social, industrial, and economic development. It comprises three major components—generation, transmission, and distribution—each operating at different voltage levels to deliver electricity from the source to end users. Among these, the distribution network plays the most crucial role in the final delivery of electrical energy. However, it is also the segment most susceptible to inefficiencies and operational challenges.

Globally, electrical power systems experience approximately 13% total power loss, with distribution networks alone accounting for over 80% of that figure [1][2]. Technical losses in distribution systems are primarily influenced by voltage instability, load variability, conductor length, and the nature of connected loads. These conditions not only degrade voltage profiles but also escalate losses throughout the system.

When faults occur due to equipment failure, environmental conditions, or operational errors, protection mechanisms such as circuit breakers are triggered to isolate the affected line section [3]. Although this prevents further damage, it interrupts supply to

Intelligent Service Restoration in Smart Distribution Network presents a practical and forward-looking approach to modern power system resilience. As distribution networks grow in complexity and renewable integration accelerates, ensuring reliable service restoration after faults becomes critical. This book introduces advanced techniques such as the Multi-Objective Cuckoo Search Spring Algorithm (MOCSSA) and a hybrid CSSA-LSSVM model for optimising network reconfiguration and predicting restoration pathways. Through tested simulations on the IEEE 69-bus system, the book demonstrates how intelligent algorithms can reduce losses, improve voltage profiles, and accelerate recovery times. Designed for engineers, researchers, and smart grid professionals, it offers an accessible yet rigorous roadmap for deploying intelligent tools in real-world grid environments. Whether you're exploring next-generation restoration strategies or enhancing grid performance, this book delivers timely insights at the intersection of automation, AI, and power distribution.

Zuhaina Zakaria holds a Bachelor's degree in Electrical Engineering from Universiti Teknologi Malaysia (UTM), a Master's degree from Napier University, Edinburgh, and a PhD in Electrical Engineering from the University of Strathclyde, Glasgow. She has served at Universiti Teknologi MARA (UiTM), Malaysia, for over 30 years and is currently a Professor at the Faculty of Electrical Engineering.

Her research focuses on energy efficiency, power quality, load profiling, and power system analysis. Throughout her career, she has held several key administrative roles at both faculty and university levels, demonstrating strong leadership and management capabilities.

Beyond academia, Professor Zuhaina actively contributes to professional engineering communities. She is a Senior Member of IEEE, a member of the Institution of Engineering and Technology (IET), and currently serves as a Council Member at The Institution of Engineers, Malaysia (IEM). Her work continues to impact both the academic and professional engineering landscapes.