INNOVATION DESIGN AND APPLICATION OF POWER ENGINEERING SERIES 2

Editors:
Siti Amely Jumaat
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Mahyuzie Jenal

Abstract: Innovation Design and Application of Power Engineering (Series 2) present a collection of cutting-edge research addressing modern energy challenges. This volume explores diverse frontiers, from ecofriendly gas mixtures for high-voltage insulation to the optimization of multi-junction photovoltaic cells. Readers will discover innovations in mobile and remote technologies, including solar-powered systems for electric vehicles and IoT-integrated battery monitoring. Additionally, the book highlights how bioinspired algorithms and smart sensors revolutionize agriculture via solar-powered incubators. By bridging theoretical modeling and real-world prototyping, this series provides essential insights for engineers and researchers dedicated to developing a greener, more resilient, and sustainable energy future.

Keywords: Power engineering, sustainable energy systems, energy resilience

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CONTENTS

PREFACE

As global electricity demand rises, the transition toward sustainable energy systems remains a critical engineering challenge. "Innovation Design and Application of Power Engineering (Series 2)" addresses these needs through advanced modeling, experimental validation, and emerging technologies. This volume presents six chapters exploring the frontiers of power engineering, from high-voltage insulation to smart applications:

- **Advanced Insulation Research:** Investigation into eco-friendly alternatives to SF_6 gas by examining the breakdown characteristics of N^2 + O^2 mixtures under lightning impulses.
- **Electric Vehicle (EV) Innovations:** Design and simulation of solar-powered auxiliary battery systems to enhance EV efficiency and reduce the load on primary propulsion batteries.
- **Modeling and Optimization:** Advanced computational techniques, including the use of Matlab/Simulink for multi-junction PV cell modeling and the application of Artificial Neural Networks (ANN) integrated with Bee Colony Optimization (BCO) to predict solar panel output.
- **IoT and Smart Applications:** Development of real-time battery monitoring systems and smart, solar-powered incubators that use IoT for remote monitoring and automated environmental control.

By combining theoretical frameworks with practical prototypes, this book provides engineering insights for the development of more resilient and sustainable energy infrastructures.

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Mahyuzie Jenal

CHAPTER 1

N_2 + O_2 BREAKDOWN CHARACTERISTIC UNDER LIGHTNING IMPULSE WITH NEEDLE-PLANE GAP

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1.1 INTRODUCTION

Circuit breakers are essential for protecting electrical power systems by interrupting electric currents during fault conditions [1]. SF_6 gas circuit breakers use Sulphur hexafluoride as an insulating and arc-quenching medium due to its excellent dielectric properties [2]. However, SF_6 is also a potent greenhouse gas with a Global Warming Potential (GWP) 22,800 times greater than CO_2 and can remain in the atmosphere for thousands of years [3]. In Malaysia's Biennial Update Report 3, most SF_6 emissions were linked to electrical equipment, particularly transmission switchgear, reflecting the growing demand for electricity [4]. These environmental concerns have prompted increasing efforts to find suitable alternatives to SF_6 in power systems [3].

CHAPTER 2

DESIGN OF A SOLAR-POWERED AUXILIARY BATTERY FOR ELECTRIC VEHICLES

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2.1 INTRODUCTION

After years of the evolution of electric vehicles (EV), it is the most significant changes of world transportation which being off the increasingly growing demand for reducing the greenhouse gas emissions and counter the climate changes. Electric mobility has gained a real movement over the last few decades, as several sense governments, environmental organizations, and consumers have increasingly recognized the environmental and economic benefits of shifting away from traditional internal combustion engine vehicles [1]. Incentives range from tax breaks to ambitious targets as many countries around world enact policies and regulations designed to spur the adoption of EVs and the eventual elimination of gasoline-powered cars [2]. EV manufacturers such as Tesla, BYD and Nissan has invested billions of dollars in research and production to build sophisticated electric cars with better battery technologies and longer available driving distance [3]. Solar EVs can help lessen their dependence on the grid, lowering carbon emissions, and providing additional

CHAPTER 3

MODELLING OF MULTI-JUNCTION PV CELL FOR ENERGY CONVERSION IMPROVEMENT USING MATLAB/SIMULINK

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3.1 INTRODUCTION

The rapid growth of industrialization, urbanization, and global population has increased the demand for energy, leading to greater dependence on finite fossil fuel resources and environmental issues [1]. Solar energy, known for its abundance and sustainability, has become a vital renewable energy option, with photovoltaic (PV) technology playing a key role [2]. However, the efficiency of conventional single-junction PV cells remains limited due to their restricted ability to convert sunlight effectively [3]. Multi-junction PV cells offer a technological advancement by using multiple semiconductor layers with different bandgap energies to capture a wider solar spectrum, reducing energy losses and achieving efficiencies above 30% under ideal conditions [4]. Despite these benefits, challenges such as spectral mismatch losses, thermal degradation, and complex manufacturing processes limit their scalability and real-world use

CHAPTER 4

DEVELOPMENT OF A REAL-TIME BATTERY MONITORING SYSTEM USING IOT AND SOLAR ENERGY FOR LOW-POWER DEVICES

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4.1 INTRODUCTION

Access to reliable electricity in rural and remote areas remains limited due to the high cost and logistical challenges of extending traditional power grids. This lack of stable power disrupts daily activities, reduces productivity, and affects access to essential services. Conventional uninterruptible power supply often relies mainly on grid charging, which results in high operational costs and limited resilience. Solar-based hybrid systems provide a sustainable alternative, yet many existing configurations lack real-time monitoring capabilities that are crucial for efficient operation and fault detection. Solar energy continues to gain widespread adoption because it is abundant and cost effective. Previous

CHAPTER 5

PREDICTION OF OUTPUT POWER FROM PV PANELS USING AN ARTIFICIAL NEURAL NETWORK (ANN) INTEGRATED WITH BEE COLONY OPTIMIZATION (BCO)

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5.1 INTRODUCTION

Malaysia is increasingly turning to solar photovoltaic (PV) systems to meet growing energy demands in a sustainable way. However, the power output of PV panels is affected by fluctuating environmental conditions such as solar irradiance and temperature. Accurate prediction models are needed to optimize energy generation. Artificial Neural Networks (ANN) can handle nonlinear relationships in data but often require precise tuning. By integrating Bee Colony Optimization (BCO), a nature-inspired algorithm, with ANN, this study aims to improve prediction accuracy while reducing computational complexity. Predicting PV output is difficult due to variable environmental conditions. While ANN can model these complex relationships, it requires extensive data and careful parameter tuning. This tuning process is often time-consuming and computationally expensive.

CHAPTER 6

SOLAR-POWERED IOT-BASED SMART TEMPERATURE AND HUMIDITY MONITORING SYSTEM FOR INCUBATORS

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6.1 INTRODUCTION

In modern agriculture, precise control of environmental conditions like temperature and humidity is essential, especially for hatching eggs without brooding hens. Incubators is a device that creates a controlled environment which regulates temperature, humidity, and air circulation to replicate the conditions needed for eggs to hatch successfully [1]. It is widely used in poultry farming to increase productivity and it allows farmers to hatch large numbers of eggs simultaneously, control hatching schedules, and reduce dependency on natural conditions, which can be inconsistent [2]. This project aims to improve hatching rates and reduce energy costs through a sustainable, efficient incubator system targeted at smallholder farmers in remote areas.

This project leverages solar energy as a clean power source combined with wireless communication and offers a sustainable and energy efficient approach to hatching eggs, especially in

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