論　文　の　要　旨

題　目　Comprehensive Design for Enhancing Resilience in Prosumer-Based Microgrid Operations through Modeling and Optimization
(プロシューマ主体型マイクログリッド運用における，モデル化と最適化，レジリエンス向上のための包括的設計)

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As the integration of renewable energy sources into power systems continues to grow, the efficient operation of microgrids has become increasingly crucial. However, the inherently variable nature of solar energy introduces challenges for maintaining grid reliability and efficiency. This thesis tackles these challenges by developing and optimizing models for accurate photovoltaic (PV) power prediction within prosumer-based microgrids. Employing a comprehensive blend of machine learning algorithms and advanced optimization techniques, this research makes significant contributions to enhance microgrid operation and reliability. Specifically, this work utilizes the capabilities of MATLAB/Simulink for simulation and MATLAB's Optimization Toolbox for advanced computational analysis.

The research's novelty lies in its multi-faceted approach to flexible microgrid modelling that leverages fast and accurate solar power prediction and harmonizing predicted and real-time optimization. Firstly, the thesis introduces a resilient prosumer model for microgrids, which employs resilience hardening control schemes that include PV curtailment (PVC), non-critical load shedding (NCLS), and flexible load switching (FLS) to complement the inbuilt voltage and frequency control schemes in an energy management system (EMS), battery energy storage systems (BESS), PV systems, and. This model, validated through simulations and case studies executed via MATLAB/Simulink, marks a pioneering effort in existing literature.

Secondly, the research presents a novel solar power prediction model which employs an Iterative Network Pruning (IP) Technique in feedforward neural networks (FNNs), leading to significant gains in forecast accuracy and computational efficiency. The weather-based FNNs (WFNNs) employ weather clustering algorithms to further refine prediction accuracy under different weather conditions. The model considers the setting of confidence intervals, thereby providing a reliability measure for the forecasts.

Thirdly, this thesis utilizes predictive linear programming and model predictive optimization strategies for real-time energy management in microgrids. This novel approach incorporates adjustments for discrepancies between forecasted and actual energy production and consumption, offering a more dynamic and responsive EMS for mitigating uncertainties and prioritizing critical loads.

Considering the simulation results presented in this research, it is evident that the proposed models and methodologies significantly enhance the resilience and adaptability of microgrid operations. The advanced prosumer model, with its integrated BESS and PV systems, demonstrates robust performance under varying weather conditions and in post-disaster scenarios, as validated by simulation. Furthermore, the solar power prediction model, utilizing the IP technique, effectively reduced computational load, maintaining high prediction accuracy, a crucial factor for real-time applications in microgrids. These results underscore the efficacy of the developed models and optimization strategies in managing the complexities and dynamic nature of microgrid operations, paving the way for more sustainable and reliable energy systems.

The research methods, findings, and comparative analyses are meticulously detailed below across seven chapters that include;

Chapter 1: This chapter lays the groundwork for the research by introducing the significance of microgrids and renewable energy, particularly solar power. It outlines the challenges tied to the unpredictability of solar power and presents the research objectives, methodologies, and contributions of this thesis.

Chapter 2: This chapter elucidates key concepts and definitions, such as what constitutes a microgrid, photovoltaic power, neural networks, and other terms pertinent to the research. This chapter then delves into existing literature concerning microgrids, photovoltaic systems, solar power prediction techniques, and optimization strategies in microgrids. The aim is to identify gaps in current research that this thesis aims to fill.

Chapter 3: This chapter focuses on the resilience of prosumer models within microgrids. It discusses various resilience hardening control schemes, including BESS, PV systems, the proposed load model and energy management concepts and systems. The chapter also includes case studies and simulations to demonstrate the effectiveness of resilient prosumer models.

Chapter 4: An approach to solar power prediction is proposed based on WFNNs for improved accuracy followed by an IP technique to reduce the computational burden. The chapter also explores how to provide confidence intervals to increase the reliability of predictions.

Chapter 5: This chapter presents advanced optimization techniques to improve microgrid operation. It includes predictive optimization for energy management systems and discusses optimal coordination and power balancing among prosumers. Case studies focusing on a grid-connected prosumer along with simulations and results, demonstrate the efficacy of the proposed optimization techniques.

Chapter 6: This final chapter synthesizes the contributions of the thesis, summarizing key findings and making recommendations for future research endeavors.