CHAPTER I

INTRODUCTION

1.1 General Introduction

The increasing global demand for clean and sustainable energy solutions has propelled significant interest in the multi-energy system (MES). MES integrates various energy carriers, such as electricity, heat, and gas, to optimize the production, conversion, storage, and consumption of energy across sectors. These systems represent a process shift from infrastructure single-source energy models by incorporating flexibility, efficiency, and sustainability. One of the key factors propelling MES forward is the high penetration of renewable energy (RE), such as wind and solar power, which significantly contributes to reducing greenhouse gas emissions and mitigating climate change impacts. However, the inherent variability and intermittent RE sources present challenges in ensuring grid reliability and stability. Thus, energy storage, which stores energy for later use, when necessary, is a common approach aimed at efficiently mitigating the volatility of RE sources. Moreover, Thailand's power development plans (PDP) of 2018 and the 2024 draft hearing, referred to as PDP2018 and PDP2024-hearing, respectively, outline the country's strategies for transitioning to a more sustainable energy mix by increasing the share of renewable energy and reducing dependence on fossil fuels (Ministry of Energy, 2019). A key challenge in achieving this transition is the intermittency of RE sources. To address this issue, energy storage solutions, such as hydrogen storage (HS), are essential for ensuring a reliable energy supply and able to energy arbitrage. This study aligns with the objectives of PDP2018 and PDP2024-hearing by proposing an optimal scheduling framework for MES that integrates HS with RE sources, thereby improving energy efficiency, reducing carbon emissions, and supporting Thailand’s long-term sustainability goals.

1.2 Problem Statement

According to PDP2018 to PDP2024-hearing, it has mentioned minimizing carbon dioxide emissions from electricity generation by increasing the proportion of electricity generation from RE and reducing the proportion of electricity generation from coal-fired power plants. The Alternative Energy Development Plan (AEDP) for 2018 and 2024 draft hearing, referred to as AEDP2018 and AEDP2024-hearing, respectively, emphasizes the necessity of developing alternative energy sources to minimize dependence on fossil fuels, enhance energy security, and reduce environmental impacts (Ministry of Energy, 2020). The primary goals of AEDP2018 to 2024-hearing are to increase the share of RE in the overall energy mix, enhance energy efficiency, and promote sustainable energy practices. Additionally, it aims to support technological advancements and foster innovation in RE sectors.

Energy from renewable sources is currently encountering a major obstacle due to its variability. The intermittent nature of these resources presents a significant limitation, due to the inability of many to provide a consistent energy supply. For example, wind power is subject to changes in wind speed and solar power generation fluctuates due to variations in solar irradiance, which leads to fluctuations in electricity generation (Shatnawi et al., 2018). HS is a new trend for energy storage. This solution will solve the challenges of RE, that face intermittent nature. Consequently, integrating HS into the system has generated significant interest in this research topic. In power systems, HS can be utilized to minimize daily energy loss by implementing a scheduling strategy based on peak shaving (Dechjinda & Chayakulkheeree, 2024). However, the efficiency of HS is quite lower than battery storage. To enhance efficiency, many researchers employ the energy hub (EH) model. This model is designed to optimize the supply of energy across various sectors by integrating multiple types of energy sources. The goal is to coordinate these sources effectively to reduce operational costs and advance carbon neutrality. The EH infrastructure was initially introduced by Geidl et al. (2007), with the fundamental concept of an energy hub. This concept aims to achieve the primary objectives for industrial, commercial, and residential consumers by focusing on minimizing total operating costs (TOC) and reducing electricity peak from the grid (EP). Additionally, minimizing total carbon emissions (TCE) has become a critical concern in the modern era, driven by the global push toward sustainability and reducing environmental impacts. The implementation of EH facilitates a more coordinated cost-effective and carbon neutrality approach to energy management, addressing the diverse needs of different sectors while promoting sustainability (Zidan & Gabbar, 2016). In this thesis, recognize the challenges of optimal scheduling of multi-energy systems with wind-solar power and hydrogen storage (OMES-WSPHS) to minimize TOC, TCE, and EP when considering multiple energy sources such as electricity and natural gas (NG). The proposed method is expected to be highly beneficial in helping achieve the main objectives of minimizing costs, emissions, and electricity peak from the grid, while also enhancing the overall performance of MES that integrate renewable and conventional energy sources. This work contributes to the growing body of research focused on creating more sustainable and efficient energy systems in the face of increasing environmental concerns and the global transition toward low-carbon energy solutions.

1.3 Research Objectives

The main objective of this research is to explore how integrating HS can help achieve optimal solutions in different scenarios. It employs particle swarm optimization (PSO) for daily HS scheduling and linear programming (LP) for hourly electricity and NG operations. To enhance efficiency, a hybrid PSO-LP approach is proposed for optimal MES-WSPHS scheduling. For multi-objective solutions, fuzzy multi-objective optimization (FMOO) is used to balance TOC, TCE, and EP, while Monte Carlo Simulation (MCS) handles probabilistic scheduling uncertainties.

The specific main objectives are

1) To analyze the optimal operation of MES-WSPHS.

2) To minimize TOC, TCE, and EP in MES-WSPHS.

3) To apply FMOO for trading-offs among the solution of TOC, TCE, and EP.

4) To analyze the stochastic model while considering the uncertainty of the multi-energy load and RE profile, using MCS.

1.4 Scope and Limitation

The scope and limitations of this thesis are outlined as follows:

1.4.1 Optimization parameter validation and performance analysis between PSO and PSO-LP for MES-WSPHS integration is proposed. The objective is to validate the PSO parameters and select the optimal ones for solving the daily scheduling problem. The data acquisition process and assumptions are also presented. Additionally, a comparison between the PSO and PSO-LP algorithms is conducted. For a fair comparison, the same PSO parameters are used in both algorithms.

1.4.2 Optimal scheduling of MES-WSPHS integration is conducted under TOC minimization using scenario-based case analysis. Each scenario evaluates the impact of HS or the cooperation between electricity and NG on the system's performance, leading to improved economic operation.

1.4.3 The multi-objective optimization using fuzzy is proposed in this study that aims to achieve a balanced solution among multiple conflicting objectives. This approach is employed to handle the trade-offs among the solution of TOC, TCE, and EP and ensures that the final scheduling solution reflects a fair compromise, addressing the priorities of TOC, TCE, and EP reduction effectively.

1.4.4 The uncertainties in load demand due to user behavior and renewable energy generation fluctuations caused by weather conditions are considered in this study. These uncertainties can impact the scheduling performance, leading to variations in system operations. The study incorporates scenario-based and probabilistic analysis by using MCS to address these variations, ensuring the robustness of the proposed scheduling approach.

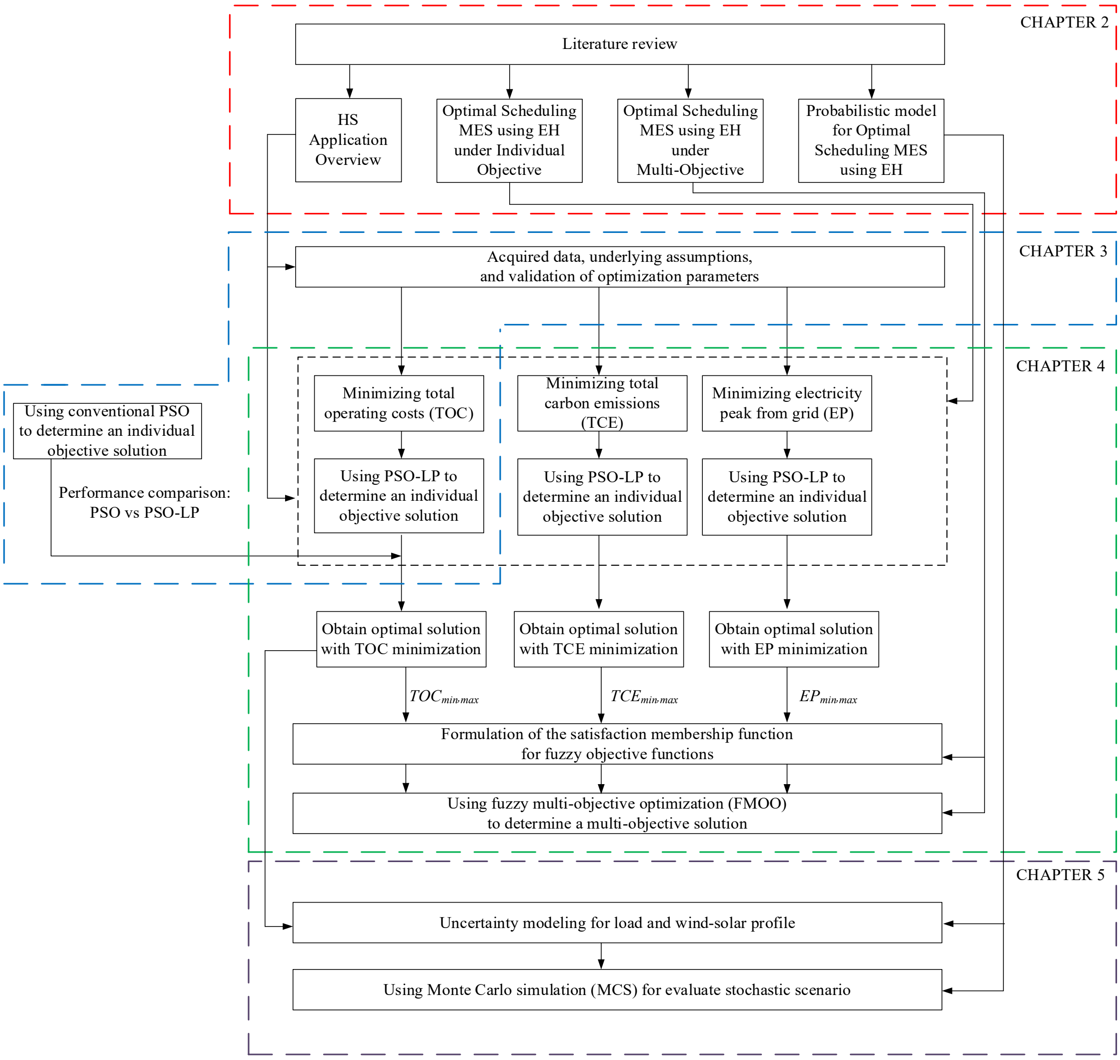

Figure 1.1 Framework of thesis

The limitations of this work are neglect of both the natural gas flow computation and the power flow analysis in the bulk system. The energy management framework presented primarily focuses on the end-use level, targeting energy consumers such as residential and industrial loads, rather than large-scale, system-wide operations.

1.5 Conception

The overall idea of this thesis is to solve the problem of energy management strategy to minimize TOC, TCE, and EP. This concept considers the load profile as a typical summer day in the northeastern region of Thailand. The wind and solar profile are derived from data collected on a summer day in Pakchong, Thailand, with the wind turbines (WTs) and photovoltaic panels (PVPs), respectively. However, the probabilistic model is proposed for evaluating the fluctuation conditions by using MCS and represents the results through a probability density function (PDF). The objective needs to handle constraints such as device limitations and power balance. This study is conducted using MATLAB, where the TOC, TCE and EP are simulated using a hybrid of PSO-LP. The optimization integrates hourly scheduling for multi-energy dispatch and daily scheduling for HS to determine the optimal scheduling solution. This study focuses on integrating green hydrogen into the system to mitigate RE curtailment when WTs and PVPs generate excessive power while ensuring optimal operation across energy sectors. Finally, a multi-objective approach is considered, employing FMOO to find the optimal balance among TOC, TCE, and EP.

1.6 Research Benefits

Technological advancements now enable better coordination of multiple energy sources. This research, aligned with the PDP2018 to PDP2024 plan, focuses on integrating HS with wind-solar power and coordinating electricity and NG systems. By optimizing scheduling and enhancing algorithms to address scheduling challenges, this proposed procedure advances the energy scheduling problem in the field of MES-based EH research. Ultimately, this work contributes to sustainable energy solutions for the future.

1.7 Thesis Outline

The rest of the thesis is organized as follows: Chapter 2 presents a literature review covering key aspects of HS applications, optimal scheduling of MES using EH under both individual and multi-objective frameworks, and the probabilistic modeling approach for optimal MES scheduling. Chapter 3 details the validation of the PSO algorithm and compares PSO-LP with PSO for optimizing scheduling. The focus is on minimizing TOC under the pricing mechanism while analyzing the impact of HS integration and the cooperation between electricity and NG on system performance. Chapter 4 presents the FMOO techniques for determining the optimal scheduling by balancing all objective functions simultaneously. The results aim to achieve a compromise among the three discussed objectives. Chapter 5 presents uncertainty modeling and stochastic analysis for optimal scheduling of MES-WSPHS integration. It addresses the impact of load and renewable energy fluctuations using probabilistic modeling and MCS to enhance the robustness of the scheduling strategy. Finally, Chapter 6 provides a comprehensive summary of the key findings, highlighting the most significant insights drawn from the analysis.

1.8 Chapter Summary

Chapter 1 introduces research on optimizing MES-WSPHS integration to address the challenges arising from the variability of RE. The study is contextualized within the national energy development plans, particularly from PDP2018 to PDP2024, highlighting its relevance to sustainable and resilient energy solutions. The chapter outlines the problem statement, defines the scope and limitations, and clarifies the main objectives and expected benefits of the research. Additionally, it provides an overview of the thesis structure, explaining the organization of content and analysis across the subsequent chapters.