ENERGY MANAGEMENT AND OPTIMAL SIZING OF A STANDALONE HYBRID RENEWABLE ENERGY SYSTEM PV/BATTERY/DIESEL GENERATOR

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DEDICATION

This dissertation is dedicated to my beloved mother, my beloved wife and my dear two daughters Haya and Linda for their endless prayer, support and encouragement. It is also dedicated to my supervisor, who always guide me throughout the whole the project.

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ABSTRACT

Providing electricity to rural towns that are disconnected from the grid and suffer from a shortage of energy, where development of the distribution network is neither possible or economically viable, needs the adoption of suitable technologies. Microgrids powered by hybrid renewable energy sources are becoming more prevalent, and they provide an exciting opportunity to electrify distant places. Stand-alone microgrids powered by hybrid renewable energy sources are an economical way to assure system dependability and energy security. In this project, a stand-alone hybrid system comprising Photovoltaic (PV), battery storage and Diesel Generator (DG) is considered. A rule-based algorithm for energy management is used to optimize the usage of renewable resources and limit the use of the battery bank and DG in order to satisfy a certain demand and minimize the Cost of Energy (COE). The proper size of this hybrid system is a critical factor affecting the performance of this system. The COE and Loss of Power Supply Probability (LPSP) are the main objectives of this project, and they are also taken as indicators for the reliability and feasibility of the proposed system. It is proposed in this dissertation to use Particle Swarm Optimization (PSO) and Gray Wolf Optimization (GWO) to fine-tune the ideal size of the system in order to fulfil the project's goals and objectives. The suggested values of LPSP that implemented in this study were 0%, 1%, and 2%. The results obtained based on these values gave more flexibility in choosing the suitable system among the three options that have been presented. The collected findings demonstrate that the suggested techniques deliver the most optimum configuration of the hybrid system. It has provided the fast and effective achievement of the ideal solution as well as a reduction of the total COE with a desired value of LPSP. These optimization algorithms were conducted using MATLAB coding. This hybrid system can be a suitable model to electrify remote areas and recommend it as solar radiation is an abundant resource.

ABSTRAK

Membekalkan tenaga elektrik kepada bandar luar bandar yang terputus dari grid dan mengalami kekurangan tenaga, di mana pembangunan rangkaian pengedaran tidak mungkin atau berdaya maju dari segi ekonomi, memerlukan penggunaan teknologi yang sesuai. Microgrid yang dikuasakan oleh sumber tenaga boleh diperbaharui hibrid semakin berleluasa, dan ia memberikan peluang menarik untuk mengelektrik tempat yang jauh. Mikrogrid bersendirian yang dikuasakan oleh sumber tenaga boleh diperbaharui hibrid ialah cara yang menjimatkan untuk memastikan kebolehpercayaan sistem dan keselamatan tenaga. Dalam projek ini, sistem hibrid berdiri sendiri yang terdiri daripada Fotovoltaik (PV), storan bateri dan Penjana Diesel (DG) dipertimbangkan. Algoritma berasaskan peraturan untuk pengurusan tenaga digunakan untuk mengoptimumkan penggunaan sumber boleh diperbaharui dan mengehadkan penggunaan bank bateri dan DG untuk memenuhi permintaan tertentu dan meminimumkan Kos Tenaga (COE). Saiz yang betul bagi sistem hibrid ini merupakan faktor kritikal yang mempengaruhi prestasi sistem ini. COE dan Kebarangkalian Bekalan Kuasa Kehilangan (LPSP) adalah objektif utama projek ini, dan ia juga diambil sebagai petunjuk untuk kebolehpercayaan dan kebolehlaksanaan sistem yang dicadangkan. Adalah dicadangkan dalam disertasi ini untuk menggunakan Pengoptimuman Particle Swarm (PSO) dan Grey Wolf Optimization (GWO) untuk memperhalusi saiz ideal sistem bagi memenuhi matlamat dan objektif projek. Nilai cadangan LPSP yang dilaksanakan dalam kajian ini ialah 0%, 1%, dan 2%. Keputusan yang diperolehi berdasarkan nilai ini memberi lebih kelonggaran dalam memilih sistem yang sesuai antara tiga pilihan yang telah dibentangkan. Penemuan yang dikumpul menunjukkan bahawa teknik yang dicadangkan memberikan konfigurasi sistem hibrid yang paling optimum. Ia telah menyediakan pencapaian penyelesaian ideal yang cepat dan berkesan serta pengurangan jumlah COE dengan nilai LPSP yang dikehendaki. Algoritma pengoptimuman ini dijalankan menggunakan pengekodan MATLAB. Sistem hibrid ini boleh menjadi model yang sesuai untuk mengelektrik kawasan terpencil dan mengesyorkannya kerana sinaran suria merupakan sumber yang banyak.

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LIST OF ABBREVIATIONS

E_t	-	Generated energy in year t
F_t	-	Fuel costs for the year t
I_t	-	Years of investment spending
M_t	-	Expenditures on operations and maintenance in year t
N_{DG}	-	Number of DG
N_b	-	Number of Battery
N_{con}	-	Number of Converter
N_{pv}	-	Number of PV
$P_{i(t)}$	-	Power generated from the i_{th} sources
$P_{l(t)}$	-	Demand power
$cost_{fuel}$	-	Fuel Cost
$cost_{invest}$	-	Investment Cost
$cost_{opemain}$	-	Operation and Maintenance Cost
$cost_{replace}$	-	Replacement Cost
BSS	-	Battery Storage Systems
COE	-	Cost Of Energy
CPV	-	Cumulative Present Value
CSA	-	Crow Search Algorithm
DG	-	Diesel Generator
DOD	-	Depth Of Discharge
EENS	-	Expected Energy Not Supplied
EPBT	-	Energy Payback Time
ESS	-	Energy Storage Systems
FC	-	Fuel Consumption
FPA	-	Flower Pollination Algorithm
GA	-	Genetic Algorithm
GOA	-	Grasshopper Optimization Algorithm
GWO	-	Gray Wolf Optimization
HRE	-	Hybrid Renewable Energy

LCC	-	Life Cycle Cost
LCOE	-	Levelized Cost of Energy
LP	-	Linear Programming
LPSP	-	Loss of Power Supply Probability
MILP	-	Mixed-Integer Linear Programming
MPPT	-	Maximum Power Point Tracker
MPSO	-	Multi-objective PSO
NPC	-	Net Present Cost
NPC_t	-	Total Net Present Cost
O&M	-	Operation and Maintenance
PSO	-	Particle Swarm Optimization
PV	-	Photovoltaic
RES	-	Renewable Energy Sources
R_i	-	Real Interested Rate
SOC	-	State Of Charge
WT	-	Wind Turbine
n	-	The technology's lifespan
r	-	Rate of discount

LIST OF SYMBOLS

η	-	Efficiency
$	-	The basic monetary unit of the US
σ	-	Hourly self-discharge rate of the battery
α	-	The first best value of GWO method
β	-	The second-best value of GWO method
δ	-	The third best value of GWO method

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background of Study

There is no denying that the world's population is increasing, economies are developing, and the world's overall energy consumption is increasing quickly in contrast to any other period in history [1]. Oil, coal, and fossil fuels are today's principal sources of energy. There is a growing need for power that conventional energy sources cannot provide.

In addition, the emission of greenhouse gases that result from the use of fossil fuels in the generation of energy creates environmental problems [2, 3]. Concerns about global warming, increasing power costs, and increased electricity usage have spread around the globe.

A stable, economical, environmentally friendly, and long-term power supply may be ensured by integrating renewable energy sources in various nations across the globe. Renewable energy output increased by around 200 GW in 2019, bringing the global total to 2,588 GW at the end of 2019. Globally, 27.3 percent of the world's electricity production is anticipated to be generated by green technology deployed [4]. As a result, the worldwide demand for power is on the rise. Figure 1.1 shows that demand for electricity increased by roughly 72 percent between 2000 and 2018, with an annual rise of around 4% [5].

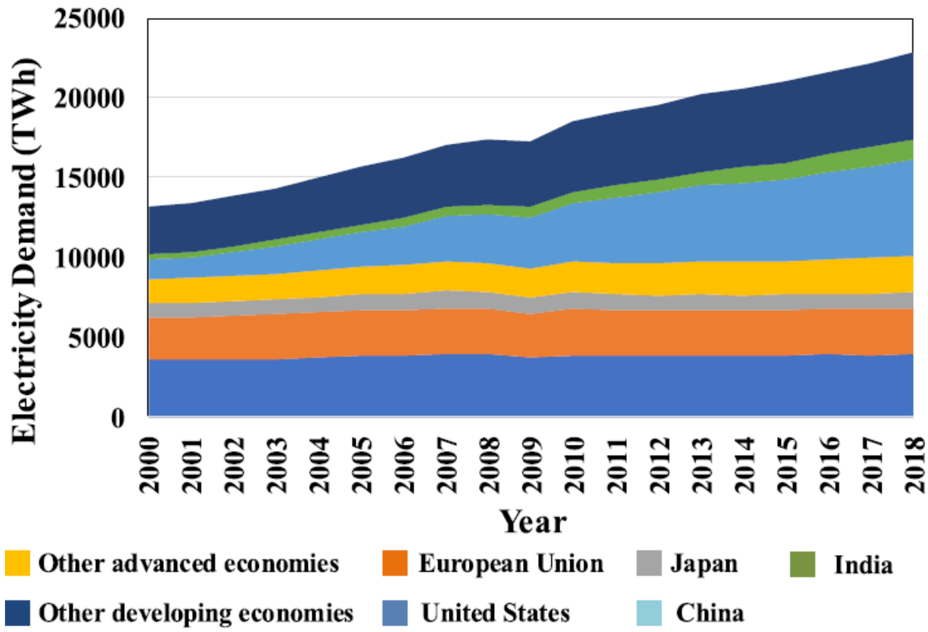

Figure 1.1 Electricity Demand

People in rural regions without electricity may also profit from such resources by creating new business possibilities. Renewable energy sources including solar, wind, hydro, and geothermal are expected to provide the majority of the world's future power demands. With their cheap start-up costs and quick technological innovation, photovoltaic (PV) technologies have been one of the fastest growing segments of the solar energy industry. However, solar PV systems may be linked to the transmission and distribution networks. There may be a reduction in transmission and distribution costs by locating solar arrays PV panels near the load for power generating [6]. Many parts of the globe do not have an electrical network or it is hard to expand an electrical network to them for a variety of reasons, including geographical or economic. This feature serves these places. Furthermore, depending entirely on a single type of renewable energy to drive this fast development of cities and people may result in a shortfall in the amount of energy needed to meet the demand for energy. Because of developments in renewable energy technology, as well as rises in the price of petroleum products, hybrid renewable energy systems are becoming more viable as independent power systems for supplying electricity to distant areas. It is common for a hybrid energy system to consist of more than one renewable energy source, as well as a backup energy source, which are used in conjunction to improve system efficiency and increase energy supply flexibility [7]. Because of this, adopting hybrid energy systems such as solar PV-wind-diesel generator, solar PV-battery storage-diesel generator, and tidal power-hydro-biomass is more efficient and cost-effective [8].

1.2 Electricity in Iraq

Because of the several crises that have plagued the country over the last three decades, Iraq is now experiencing a serious deficit in the generation of electric energy. Furthermore, the growth of cities and advances at the economic level, such as the construction of shopping malls and housing complexes, among other things, have had a detrimental impact on the electrical sector. Iraq's reliance on diesel and natural gas generators to produce energy has resulted in a rise in environmental pollutants as well as high temperatures around the country. Furthermore, solar power plants have the potential to provide a fraction of the electricity required by the energy system. The construction of long-distance high-voltage transmission lines is not required for the delivery of energy to local small networks, which reduces the cost of developing electricity distribution networks. The location of solar power facilities has an influence on the amount of energy they produce.

In order to achieve success, it is important to prioritize places according to their environmental, economic, climatic, and social circumstances. When selecting solar power plants, one of the most important characteristics to consider is the potential value of radiation. This parameter accounts for the bulk of the weights considered when creating solar power plants [9].

The use of solar renewable energy in Iraq is particularly well suited, and the country is capable of making great progress toward a dependence on fossil fuels, although this would certainly need support from relevant national governments [10]. The Iraqi government has lately ordered the adoption of renewable energy as a second source of electric power in the country as a result of this decision. Iraq is one of the nations that is exposed to the sun for the majority of the time throughout the day. With this PV energy from the sun, it is possible to gain from a shortfall in electric power output and make up for lost time as well as to electrify the remote areas that cannot be connected to the national grid because it is difficult and costly to construct a distribution network for these areas.

1.3 Problem Statement

Nowadays, the population of Iraq is rising, cities are expanding, and there is a lack of electricity generation in the country. Because of this, Iraq requires a lot more power to make up for the shortfall and meet the growing demand in its towns and cities. It is costly to construct new power plants which to operate need many sources such as water and fossil fuel. Moreover, the high cost of fuel transportation and the increased price of diesel pricing. Indeed, these remote rural areas are usually fed by stand-alone diesel generators alternately with the national grid which suffers from a lack of production. Consequently, the need for a hybrid PV system works alternatively with the diesel generators to reduce dependence on diesel generators as well as reduce the total cost of producing electrical energy in the long run and supply the demand load flexibly. It is therefore important to build up a suitable hybrid system to meet this shortage in electricity with cost-effectiveness.

1.4 Research Objectives

(a) To design a standalone hybrid PV/Battery/Diesel Generator system using rule-based energy management system.

(b) To analyse the reliability and economic factors of the system using Loss of Power Supply Probability (LPSP) and Cost Of Energy (COE) as indices.

(c) To size the system using Particle Swarm Optimization (PSO) and Gray Wolf Optimization (GWO) algorithms.

1.5 Scopes of Study

The study is to evaluate the economic and technical effectiveness of a standalone PV/Battery/DG hybrid energy system. This research evaluates important data and determines the best system setup. MATLAB coding was used to run the simulation and analyse the results. This study just considers the viability of PV/DG/Battery hybrid energy systems among other hybrid renewable energy systems such as wind/PV/diesel and hydro/PV/diesel generator energy and geothermal energy systems.

1.6 Research Contribution

Hybridizing renewable energy sources like photovoltaic, wind, and hydropower is a great concept for power production. It is possible to combine renewable and traditional energy sources in a synergistic network, which will have the ability to increase dispatchability and stability while also improving efficiency and reducing capital expenditures and the ability to operate more pliable by switching between available sources. In addition, we can save our world by adopting renewable energy, which reduces carbon emissions.

1.7 Research Methodology

Stand-alone hybrid power systems with photovoltaic (PV), battery, and diesel generator components are the focus of this research. Renewable energy sources will be the primary source of power for this project, with the ultimate goal of completely eliminating fossil fuels. When renewable energy sources fail to meet the system's needs, a diesel generator is activated as a backup. MATLAB coding was used to manage and size this system optimally. Table 1.1 shows the Gantt chart of the research work.

Table 1.1 The Gantt Chart of the Research Work

Tasks	Project/Months									
	1	2	3	4	5	6	7	8	9	10
Objectives & Problem Statement										
Research field selection										
Literature review										
Methodology										
Data collection										
Design modules										
Testing and simulating										
Review research objective										
result and recommendations										
submission										

1.8 Report Structure

The project containing five chapters. Next chapter reviews on the literature review about the hybrid power system and micro grids. Chapter 3 represents the research methodology. Chapter 4 discussed the results of the work. The last chapter is the conclusion.

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