DESIGN AND MODELLING OF PV-DIESEL HYBRID ENERGY SYSTEM WITH FUZZY LOGIC CONTROLLER.

BY

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A dissertation submitted in fulfilment of the requirement for the degree of Master of Science (Mechatronics Engineering)

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ABSTRACT

Renewable energy, such as wind and photovoltaic arrays, has become the core energy in micro-grids which used for supplying remote areas and areas which suffering from electricity outages. Many limitations, such as weather fluctuations and low efficiency, leads to the design and develop a hybrid energy system. The integration of photovoltaic arrays and diesel gensets has become one of the most common approaches to generating electricity for remote communities. Although the integration of photovoltaic arrays and diesel gensets has the potential to reduce the cost of electricity production by harnessing free energy from the sun to reduce the power generated by diesel engines, it tends to complicate the control of the entire system due to the intermittent nature of the renewable energy sources and changing load demand. This research propose a fuzzy logic controller of PV-Diesel hybrid energy system, which used as an effective tool in facilitating optimum power-sharing between the PV power source, charging and discharging batteries and diesel generator as a backup based on the dynamics of the available PV energy at any time. Optimizing power control in the PV-Diesel hybrid energy system is key to minimizing the cost of power generation and maximizing the overall efficiency of the PV-Diesel hybrid energy system. the MATLAB-Simulink is used to design the fuzzy logic controller of PV-Diesel hybrid energy system and to validate its performance. Five scenarios during the day have tested to show the performance of the fuzzy logic controller. The results showed the accurate controlling of the power flow in the PV-Diesel hybrid system and the power saved about 2%.

خلاصة البحث

أصبحت الطاقة المتجددة ، مثل الرياح والألوح الضوئية ، الطاقة الأساسية في الشبكات الصغيرة التي تستخدم لتزويد المناطق النائية والمناطق التي تعاني من انقطاع الكهرباء. العديد من القيود ، مثل تقلبات الطقس وانخفاض الكفاءة ، قاد إلى تصميم وتطوير نظام الطاقة الهجينة. أصبح دمج الألوح الضوئية ومولدات الديزل أحد أكثر الطرق شيوعًا لتوليد الكهرباء للمجتمعات النائية. على الرغم من أن أنظمة الطاقة الهجينة (HES) ، لديها القدرة على خفض تكلفة الكهرباء لأنها تسخر الطاقة المجانية لتعويض الطاقة المولدة بواسطة محركات الديزل ، ولكن مزيج مصادر الطاقة المتجددة ومحركات الديزل يميل إلى صعوبة وتعقيد التحكم بالنظام بأكمله بسبب الطبيعة المتقطعة لمصادر الطاقة المتجددة. سيقترح هذا البحث وحدة تحكم منطق ضبابي لنظام الطاقة الهجينة المكون من ألوح الطاقة الشمسية ومحرك الديزل ، والتي تستخدم كأداة فعالة في تسهيل المشاركة المثلى للطاقة بين مصدر الطاقة الكهروضوئية ، وشحن البطاريات وتفريغها وتشغيل مولد الديزل كنسخة احتياطية تستند إلى كمية الطاقة الكهروضوئية المتاحة في أي وقت. يعد تحسين التحكم في الطاقة في نظام الطاقة الهجينة المكون من ألوح الطاقة الشمسية ومحرك الديزل هو المفتاح لتقليل تكلفة توليد الطاقة وزيادة الكفاءة الإجمالية لنظام الطاقة الهجينة المكون من ألوح الطاقة الشمسية ومحرك الديزل. تم تصميم وحدة التحكم المنطقية المبهمة المقترحة ونظام الطاقة الهجين الكهروضوئية باستخدام برنامج MATLB-Simulink. سيتم التحقق من صحة فعالية وحدة تحكم المنطق الضبابي المقترحة من خلال المحاكاة باستخدام MATLAB-Simulink. لقد اختبرت خمسة سيناريوهات خلال اليوم لإظهار أداء وحدة تحكم المنطق الغامض. أظهرت النتائج التحكم الدقيق في تدفق الطاقة في النظام الهجين المكون من ألوح الطاقة الشمسية ومحرك الديزل وطاقة موفره 2%.

APPROVAL PAGE

I certify that I have supervised and read this study and that in my opinion, it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Master of science (Mechatronics Engineering)

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DECLARATION

I hereby declare that this dissertation is the result of my own investigations, except where otherwise stated. I also declare that it has not been previously or concurrently submitted as a whole for any other degrees at IIUM or other institutions.

Masood AL Najjar

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Firstly, In the name of Allah the most gracious and most merciful, all praise is due to Allah (S.W.T) where without whose help, this thesis would not have reached this stage. it is my utmost pleasure to dedicate this work to my dear parents and my family, who granted me the gift of their unwavering belief in my ability to accomplish this goal: thank you for your support and patience.

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LIST OF ABBREVIATIONS

PV	Photovoltaic Array
HPS	Hybrid Power System
V_{mpp}	Maximum Power Point Voltage
I_{mpp}	Maximum Power Point Current
P_{mpp}	Maximum Power Point Power
I_{sc}	Photovoltaic Array Short Circuit Current
V_{oc}	Photovoltaic Open Circuit Voltage
MPPT	Maximum Power Point Tracker
MPP	Maximum Power Point
V_{batt}	Battery Voltage
I_{batt}	Battery Current
IC	Incremental Conductance
P&O	Perturb and Observe
PF	Power Factor
FLC	Fuzzy Logic Controller
COG	Center of Gravity

LIST OF SYMBOLS

μ	Membership Function
Ώ	Set of Fuzzy Variables
A	Ampere
V	Volte
P	Power
G	Solar Irradiance
T	Temperature

CHAPTER ONE

INTRODUCTION

1.1 OVERVIEW

Energy is very important to improve the quality of economic and social life (GARCIA, 2017). Thus, securing stable energy source in remote areas (off-grid) and areas that suffering from large energy shortages due to wars and poverty is an essential issue. These areas usually rely on a diesel generator to overcome energy problems, but the continued rise in petrol prices and its delivery to these areas is difficult and expensive as well, led them to use other energy sources like renewable energy sources. In recent years, these areas have begun to depend on renewable energy especially solar energy, due to the low cost of photovoltaic panels (PV) and improve their efficiency (Vani, 2016). They have designed and constructed many stand-alone PV systems with batteries to meet the electricity demand of their communities. Solar energy is preferred to compare than other energy sources, due to solar energy is free, abundant and clean energy compared with other energies like (diesel, coal, oil, Etc.) which cause pollution effect on the environment and peoples and cause global warming and solar energy require a very little maintenance, as it has no moving parts and continue for a long time without problems or breakdowns, sometimes 30 years or more, without routine maintenance like other energy sources, ex. diesel generators need a daily check-up and routine maintenance. In addition to these areas have a high solar radiations rate, since the daily average of solar radiation levels in the range of 3-6 kWh/m2 (Shahid,2008). But solar energy still insufficient because the weather is volatile, as the sun rays in rainy and cloudy days are very weak, thus reducing the efficiency of the PV solar system and could not meet the power demand. So, the using Hybrid Power Systems (HPS) which combine two or more different types of renewable and low carbon generators (e.g., photovoltaic, microturbines, diesel generators, wind turbines, fuel cells, etc.) are the most efficient for these areas. The main objective of combining a diesel generator with any of these renewable sources is to ensure meet power demands without interruption, minimize diesel fuel consumption and pollution emissions, thus reducing the costs of saving energy and preserving the environment. The Hybrid Power systems (HPS) usually consist of a hybrid PV-Diesel power generator. Diesel gensets combine a diesel engine with an alternator to produce electricity. Solar PV power generation is the most commonly used renewable energy source in the Hybrid Power System (HPS). PV power stations consist of an array of photovoltaic modules that directly convert light into electricity, which is then supplied as merchant power (Merchant power plants are a form of non-utility or independent power generation designed for competitive wholesale power marketplaces.) into an electrical grid. Most of the PV power plants are developed with minimum power production scale PF of 1 MWP (megawatt-peak), i.e., the DC power output of the solar array. Diesel gensets are integrated with PV power plants to guarantee a continuous supply of power when solar energy is unavailable. The combination between PV solar system and Diesel generator as a backup is a new approach which the energy engineers have designed and developed to overcome the diesel generator problems and PV solar system problems and to ensure power providing without an outage. PV-Diesel hybrid systems are the best optimal solution for these areas where these systems are reliable and cost-effective and can achieve lifetime a fuel-saving. The energy generated by the PV panels has priority to supply the load. When the PV power is low or unavailable, the diesel generator as a backup source is switched on. A decision to operate the diesel generator is taken when there is not enough generated energy by PV system to supply the load. In certain cases where the generated energy exceeds the load requirement, this excess energy is using to charge batteries. Many types of controllers have used to manage the energy in the hybrid energy system. the fuzzy logic controller is a new approach has used to control the power flow in a hybrid energy system. This research will design and develop a PV-Diesel Hybrid system, in addition, to design a fuzzy logic controller which use to control between PV solar system and Diesel generator to ensure when the power from PV solar system (include batteries) will be not enough to provide the load demand, the diesel generator will cover the power lack, that ensures stable power source without interruption, reduce the fuel consumption and pollution emissions as well .

1.2 STATEMENT OF THE PROBLEM

- Remote areas which are far from the grid usually depend on diesel generators or photovoltaic arrays to provide electricity, because of the continue rising of fuel cost of the diesel generators and their cost of routine maintenance and even a depending on PV solar system alone is not enough, due to the weather variation, since in cloudy days and rainy days the sun rays are little, so the PV solar system efficiency is very low, and the output power could not meet the load demand. So, the PV-Diesel hybrid energy system will be designed and developed to secure stable energy source without outages and reduce the fuel cost for the diesel generators.
- Many PV-Diesel hybrid energy systems were designed and developed, but still, have a lack of their connections and control power drive between PV Solar system and diesel generator. In this research a fuzzy logic controller will be designed for the PV-Diesel hybrid energy system, the controller will control the power flow between three sources (PV Array, Charging/Discharging Battery, ON/OFF Diesel generator as backup) and ensure that the PV-Diesel hybrid system is working reliably by giving the right reference power measures over the whole network, to improve its efficiency and meet the power demand.

1.3 RESEARCH OBJECTIVES

The study aimed to achieve the following objectives:

1- To design hybrid energy source system, combine between PV solar system with generator.

2- To design a fuzzy logic controller which control the power supply sharing between the PV and the diesel generator.

3- To validate effectiveness of the designed controller in different operation phase with photovoltaic and diesel generators in a hybrid system.

1.4 RESEARCH METHODOLOGY

The research will follow this methodology to achieve the objectives of this project:

1. Extreme literature review on PV-Diesel hybrid energy system and fuzzy logic controller. The research will be done by collecting information from various sources such as books, online journals and conference papers.
2. Specific study for elements, like (photovoltaic panel, diesel generator, fuzzy logic, DC-DC converters and charger controller).
3. Modelling the PV-Diesel hybrid energy system (PV solar panel, MPPT controller with a DC-DC boost converter, Diesel generator with on/off controller and battery system with bidirectional charger) using MATLAB-SIMULINK
4. Design the fuzzy logic controller of the PV-Diesel hybrid energy system using Fuzzy Logic Toolbox in MATLAB SIMULINK
5. Simulate the fuzzy logic controller of PV-Diesel hybrid energy system in MATLAB-SIMULINK.

6. Validate the fuzzy logic controller accuracy to control the power flow in PV-Diesel energy system.

The next flowchart illustrates the research methodology:

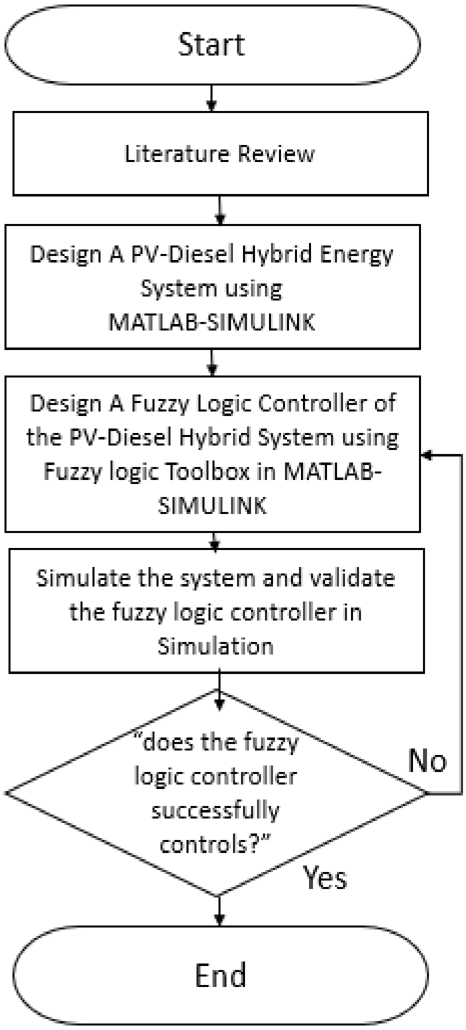

Figure 1.1: Flowchart of Research Methodology

1.5 RESEARCH SCOPE

The scope of this project encompasses both software design and implementation. the project focus to model PV-Diesel hybrid energy system and design a fuzzy logic controller between PV source and diesel generator source using MATLAB SIMULINK to get the highest efficiency, lowest life cycle cost and meet the power demand. As for designing and modelling PV array, Batteries and Diesel generator and design a fuzzy logic controller. The designing fuzzy controller should provide the optimal combination method between PV solar system and diesel generator to improve efficiency.

1.6 DISSERTATION ORGANIZATION

This study proposes a fuzzy logic controller for controlling the power flow of PV-Diesel hybrid power system with the following outlines:

Chapter 2 represents the literature review of PV-Diesel hybrid system including PV panel background, PV panel characteristics, DC-DC conversion, maximum power point tracking, DC charging controller, inverter and Diesel generator.

Chapter 3 focuses on design and model PV array, DC-DC boost converter with MPPT, DC Battery charger, Invertor, Diesel generator and Fuzzy logic controller.

Chapter 4 gives a detailed analysis and discussion of simulation results.

Chapter 5 concludes of this project by highlighting the outcome of this research. This chapter also discusses the limitation of this work by giving recommendation for future work.

CHAPTER TWO

LITERATURE REVIEW

2.1 SOLAR ENERGY

2.1.1 Background

Renewable energy resources will be the most important part of energy generation in the next years. In addition to helping to reduce greenhouse gas emissions, they add the necessary flexibility to the combination of energy resources by decreasing dependence on fossil fuels. The energy reaching the earth's surface is about 3.2 EJ. If we are able to collect even a small part of the energy available on the earth's surface, we could solve our energy problems. A photovoltaic (PV) system directly converts sunlight into electricity. The basic device of a photovoltaic system is the photovoltaic cell. Cells can be grouped together to form panels or arrays. The figure below shows the equivalent circuit of solar array which consist of several photovoltaic cells.

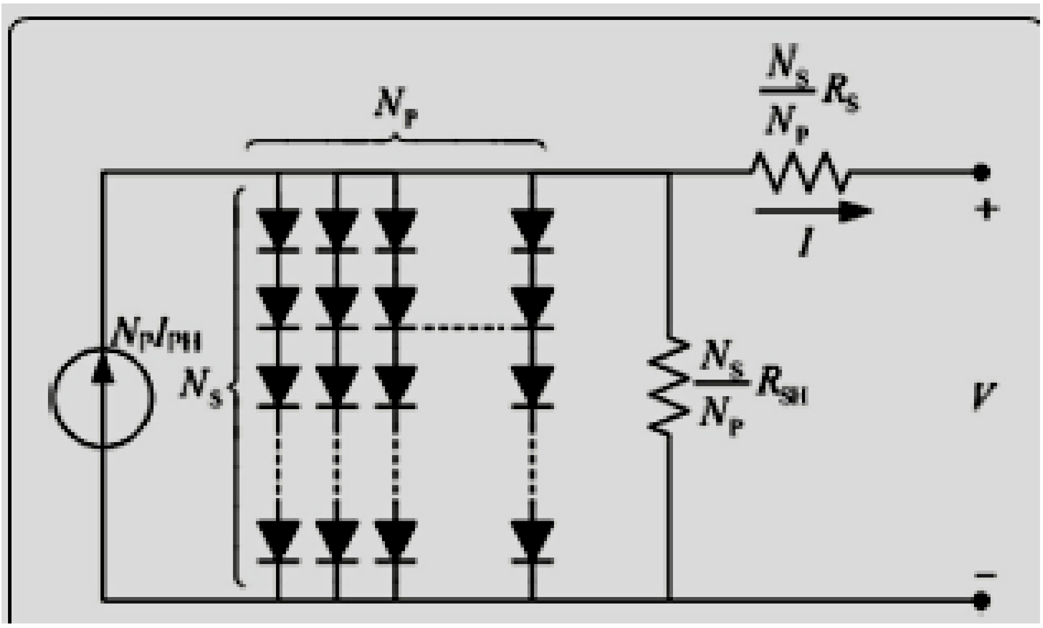

Figure 2.1: Equivalent Circuit of Solar Array (Nguyen, 2015)

The power produced by a single module is rarely enough for commercial use so, the modules are connected to form the array to supply the load. The connection of the modules in the array is the same as that of the cells in a module. The modules can also be connected in series to achieve a voltage increase or in parallel to achieve a current increase. The voltage and current available at the terminals of a photovoltaic device can directly feed small loads, such as lighting systems and DC motors. The most sophisticated applications require electronic converters to process the electricity of the photovoltaic device. These converters can be used to regulate the voltage and current in the load, to control the flow of energy in the grids connected to the system.

2.1.2 Working Principle of PV Cell

Solar cells are the basic components of photovoltaic panels. Most solar cells are manufactured using silicon also other materials are employed. Solar cells have property of photoelectric effect where some semiconductors have capability of changing electromagnetic radiation precisely to electrical current. The charged particles produced using incident radiation is distinguished smoothly to develop an electrical current by using suitable layout of the solar cell. A solar cell is essentially a P-N junction formed using two distinct layers of silicon are doped using small amount of impurity atoms. So, when the two layers are combines, close to the junction, the free electrons of the N-layer are dispersed in the P-layer, leaving behind an area positively charged created by the donors. Likewise, the free holes in the P-layer are dispersed in the N-layer, leaving behind a region negatively charged created by the acceptors. This generates an electric field between the two layers, it’s called potential barrier used to act as barrier to permit or prevent the current flow to go through it. When the electrons and holes cannot overcome the potential barrier the equilibrium in the junction is reached and