

HYBRID PHOTOVOLTAIC-FUEL CELL-
SUPERCAPACITOR ENERGY SYSTEM FOR POWER
GENERATION IN STAND-ALONE OPERATION

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DEDICATION

This project report is dedicated to my father, who taught me that the best kind of knowledge to have is that which is learned for its own sake. It is also dedicated to my mother, who taught me that even the largest task can be accomplished if it is done one step at a time.

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ABSTRACT

This project presents modelling and control of photovoltaic (PV), fuel cell (FC) and supercapacitor (SC) hybrid power system for stand-alone application. This hybrid power system uses solar photovoltaic array and fuel cell as the main source and share their power effectively to meet the load demand. Due to the intermittent nature of solar energy source and the slow response of fuel cell towards transient and load changes, this problem may disturb the power balance at demand side during peak hour, thus the system needs a backup power sources. In this project, supercapacitor is used as a storage device and is added to supply energy and improve the system performance. The fast power response of a supercapacitor will complement the slow power output from the main source. Lastly, the maximum power point tracking (MPPT) control for PV and the supercapacitor state of charge (SoC) control are also addressed in this work. A detailed dynamic model of photovoltaic/fuel cell hybrid system with supercapacitor bank and control strategies are modelled and simulated using MATLAB/Simulink software. The simulation results highlight the response of the system towards transient and load changes and the efficiency of the microgrid system is analysed and compared between PC-FC system and PV-FC-SC system.

ABSTRAK

Projek ini membentangkan pemodelan dan kawalan sistem kuasa hibrid fotovoltaik (PV), sel bahan bakar (FC) dan supercapasitor (SC) untuk aplikasi sistem terasing. Sistem kuasa hibrid ini menggunakan fotovoltaik solar dan sel bahan api sebagai sumber utama dan berkongsi kuasa mereka dengan berkesan untuk memenuhi permintaan beban. Oleh kerana sifat tenaga suria yang terputus-putus dan tindak balas yang perlahan sel bahan bakar ke arah perubahan sementara dan beban, masalah ini boleh mengganggu keseimbangan kuasa pada sisi permintaan semasa waktu puncak, oleh itu sistem memerlukan sumber kuasa sandaran. Dalam projek ini, supercapasitor digunakan sebagai peranti simpanan dan ditambah untuk membekalkan tenaga dan meningkatkan prestasi sistem. Tindak balas kuasa pantas dari supercapasitor akan melengkapi keluaran kuasa yang perlahan dari sumber utama. Akhir sekali, kawalan pengesanan titik kuasa maksimum (MPPT) untuk PV dan kawalan pengecasan supercapasitor (SoC) juga dibentaang dalam kerja ini. Satu model dinamik sistem hibrid sel photovoltaic dan bahan bakar dengan strategi supercapacitor bank dan kawalan dimodelkan dan disimulasikan menggunakan perisian MATLAB / Simulink. Hasil simulasi menyerlahkan tindak balas sistem terhadap perubahan sementara dan beban dan kecekapan sistem hibrid dianalisa dan dibandingkan antara sistem PC-FC dan sistem PV-FC-SC.

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CHAPTER 1

INTRODUCTION

1.1 Research Background

The increasing of power demand in the future might cause fossil fuel depleted, if there is no new reserved is determined. So, it is an essential to conserve the resources of fossil fuel for further use and next generation. The climate conditions also are getting worsened as the gas emissions from the power plant that make use of fossil fuel are rising. The use of alternative energy or renewable energy sources in order to meet the increasing of power demand are becoming more interesting because of less pollution produced and more environmental friendly [1].

Unfortunately, this alternative or renewable energy may not be very reliable. For example, photovoltaic (PV) energy is a very common and the most effective renewable energy sources that has been used recently at the forefront of stand-alone and distributed power system. Some of the advantages of using PV as the energy sources are it is portable in nature, gives clean power thus reduce the pollution and it is suitable for many applications either in communication system or in solar cars [2].

However, this photovoltaic power system is very dependent on weather condition, thus making it as an intermittent power sources [3]. PV sources also are not available during the night or during cloudy conditions. In the meanwhile, fuel cell can be available during the day and may be more reliable but have issues related economically which is the system cost will be higher [4]. In order to satisfy power demand but at the same time meets the power quality requirement, the energy sources need to be hybridized by combining the PV and fuel cell sources with storage system to form a good uninterruptable power supply [5].

Fuel cells has relatively high efficiency which is around 30% - 60% and have a limited number of moving parts with a flexible modular structure. It can be supplied either with hydrogen which is for the purchased gas container or it also can be produced from water in an electrolyser, that is supplied from the excess power from PV system [3]. However, the fuel cell has its limitation which is it has a low response and needs to be compensated with a supercapacitor or battery. The energy storage will respond faster than fuel cell for a power demand fast step increase or decrease. By using these energy storage(s), it will improve the performance and life of the fuel cell by absorbing the fast load changes and straight away will prevent the fuel cell to starve. As a result, this hybrid system is enable to follow the fast changing in load and allows the fuel cell to respond at a slower rate. In the nutshell, the system is able to manage the power flow and maintain the system instantaneous power balance [6].

1.2 Problem Statement

As the world population becomes bigger and bigger, the demand of electric power will also increase day by day. This is where the large power demand is needed and the power generation and transmission are focussing towards that population centres. Moreover, the usage of fossil fuel needs to be reduced or even cut. Fossil fuel will cause smog and acid rain, which it also will cause the greenhouse emission and earth climate will swing. However, the use of renewable sources are still limited and as mentioned above, it may suffers from power shortage which is due to the changes in weather and also the problem from energy storage. So, in order to meet the load demand even during changes in weather condition, integrating different types of renewable energy sources is needed as well as the energy storage.

1.3 Objective

The main objectives of this research can be presented as follows:

- i. Modelling and controlling the renewable energy hybrid power plant fed PV, fuel cell with a supercapacitor (SC) storage device for stand-alone operation.
- ii. To design an effective power management system for PV/FC/supercapacitor hybrid system with high quality reliable power.

1.4 Scope of Study

This study focus on the modelling of hybrid energy system that can be implemented and installed in stand-alone operation. The hybrid power system consists of PV, and fuel cells and supercapacitor. PV and fuel cell will act as the main source and will keep the storage device to be charged at a desired level while the supercapacitor will act as the storage device and ensure the system is able to supply all type of loading condition.

1.5 Limitation of Research

At the community level, there are several barriers to penetrate this hybrid energy system that are from the project planning to the implementation phase and also the maintenance. The first barrier is the economic and market barriers. This is about the pricing of the renewable energy unit which has the high impact on the power grid. Even though some technologies such as solar photovoltaic and wind are mature enough to compete economically with conventional technology generation, the final cost will depend on the resources availability and also the project design. Moreover, for new area opened or developed, there will be lack of funding schemes for this hybrid energy system installation, or in other words is less investment in this type of technology.

1.6 Report Outline

This project report is organized in 6 chapters. A general information about project report on “Hybrid Photovoltaic-Fuel Cell-Supercapacitor Energy System for Power Generation in Stand-Alone Operation” is described in Chapter 1. Besides, problem statement, objectives, scopes of the project and limitation of this research for this project report are included. Under literature review in Chapter 2, it covers the introduction about hybrid power generation system including its basic component and also previous work and research that has been done by previous researcher. Chapter 3 covers the method used including all the flow of process in simulating the proposed hybrid system. In Chapter 4, the results is presented and analyzed based on the comparison between three systems which are PV only, PV is embedded with fuel cell with and without energy storage system. Chapter 5 is the conclusion and future work recommendation and lastly, Chapter 6 is the planning schedule in completing this research.

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