FEASIBILITY STUDY IN IMPLEMENTING OF MICROGRID BY USING FUEL CELLS

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Bachelor of Electrical Engineering

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"I hereby declare that I have read through this report entitle "Feasibility Study in Implementing of Microgrid by using Fuel Cells" and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering (Industrial Power)".

Signature : ....

Supervisor's Name : ....

Date : ....

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A report submitted in partial fulfillment of the requirement for the degree of Bachelor of Electrical Engineering majoring in Industrial Power

Faculty of Electrical Engineering
UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2013

I declare that this report entitle "Feasibility Study in Implementing of Microgrid by using Fuel Cells" is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ....

Name : ....

Date : ....

Dedicated to my beloved mother and father

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ABSTRACT

Distributed generation or microgrid technology has the potential in reducing the stress faced by most power plants due to constant increase in electrical demand each year. This can help in reducing the need to construct new power plant which mostly required large area and costly to be build. In this research, the feasibility of implementing fuel cells in microgrid is carry out. The fuel cell and the microgrid simulation model is modeled by using Matlab simulink. The fuel cell is modeled by using the fuel cell stack block found in the simulink library while the microgrid is modeled by designing a boost converter and three phase inverter to transform the output voltage characteristic. Both simulations are done in order to check the suitability of fuel cell stack output voltage which will be connected to the grid whereas this simulation is in ideal form. A 6-bus system network is modeled by using Matlab Power Simulation Analysis Tools (PSAT) in order to evaluate the potential of implementing microgrid in a bus system network. To evaluate the potential, three study cases has been done to this bus system network where a power generator with different power but same voltage is injected to the bus system for each study case respectively. The output of each study case in term of power loss and voltage drop is compared between the study case result and before the microgrid is injected to the bus system network. In the result obtain, the fuel cell stack output voltage after connected to the boost converter and three phase inverter shows convincing output voltage. The implementation of microgrid to bus system network also shows improvement in term of power loss and voltage drop. This means that fuel cells has the potential to be implemented in microgrid whereas microgrid is suitable to be implemented in a bus system network.

ABSTRAK

Teknologi penjanaan agihan atau gridmikro mempunyai potensi dalam mengurangkan tekanan yang dihadapi oleh kebanyakan loji janakuasa disebabkan oleh peningkatan yang berterusan dalam permintaan elektrik setiap tahun. Ini boleh membantu dalam mengurangkan keperluan untuk membina loji janakuasa baru yang kebanyakannya memerlukan kawasan yang besar dan mahal untuk di bina. Dalam kajian ini, kebolelaksanaan sel bahan api di dalam gridmikro adalah dijalankan. Simulasi pemodelan sel bahan api dan microgrid dimodelkan dengan menggunakan Matlab simulink. Sel bahan api di modelkan dengan menggunakan blok yang boleh didapati di perpustakaan simulink manakala microgrid di modelkan dengan membuat reka bentuk penukar voltan dan penyongsang tiga fasa untuk mengubah ciri-ciri keluaran voltan. Kedua-dua simulasi dilakukan untuk memeriksa kesesuaian keluaran voltan tumpukan sel bahan api yang akan disambungkan ke grid di mana sebagai simulasi ini dijalankan dalam bentuk yang ideal. Satu rangkaian sistem 6-bas dimodelkan dengan menggunakan Matlab Power Simulation Tools (PSAT) untuk menilai potensi melaksanakan microgrid ke dalam rangkaian sistem bas. Untuk menilai potensi tersebut, tiga kajian telah dilakukan untuk rangkaian sistem bas ini di mana penjana kuasa dengan kuasa yang berbeza tetapi voltan yang sama disambungkan ke sistem bas tersebut untuk setiap kajian. Pengeluaran yang diperolehi dari setiap kajian dari segi kehilangan kuasa dan kejatuhan voltan dibandingkan antara hasil kajian dan semasa sebelum microgrid tersebut disambung kepada rangkaian sistem bas. Hasil keputusan mendapati, keluaran voltan dari tumpukan sel bahan api selepas disambungkan dengan penukar voltan dan penyongsang tiga fasa menunjukkan voltan keluaran yang meyakinkan. Pelaksanaan microgrid kepada rangkaian sistem bas juga menunjukkan peningkatan ke arah kebaikan dari segi kehilangan kuasa dan kejatuhan voltan. Ini bermakna sel-sel bahan api mempunyai potensi untuk dilaksanakan ke dalam gridmikro sebagaimana gridmikro ini juga sesuai untuk dilaksanakan ke dalam rangkaian sistem bas.

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LIST OF ABBREVIATIONS

PSAT	-	Power Simulation Analysis Tools
DC	-	Direct Current
AC	-	Alternating Current
CO_2	-	Carbon Dioxide
PEMFC	-	Polymer Electrolyte Membrane Fuel Cell
AFC	-	Alkaline Fuel Cell
PAFC	-	Phosphoric Acid Fuel Cell
MCFC	-	Molten Carbonate Fuel Cell
SOFC	-	Solid Oxide Fuel Cell
CHP	-	Combine Heat and Power
CHHP	-	Combine Heat, Hydrogen and Power
PLL	-	Phase Lock Loop

LIST OF SYMBOLS

V_s	-	Voltage supply
V_o	-	Voltage output
D	-	Duty ratio
T	-	Switching period
I_L	-	Inductor current
L	-	Inductor
L_{min}	-	Minimum inductor
R	-	Resistor
C	-	Capacitor
f	-	Frequency
$P_{p.u.}$	-	Power in per unit
P_{actual}	-	Actual power
P_{base}	-	Base power
Ω	-	Ohm’s
A	-	Ampere
V	-	Voltage
Hz	-	Hertz
p.u.	-	Per Unit
kV	-	Kilo-Volt
MW	-	Mega-Watt

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CHAPTER 1

INTRODUCTION

1.1 Background

Electricity plays an important role in our daily life. Each day the demand for electricity has increased steadily and this was expected to continue a few decades in the future [1]. As electricity demand increased, the supplied electricity also needs to be increase and this required the expansion of our existing power plant or building of a new power plant itself. Not only that, the electrical utility and the high voltage transmission line functioning in providing long distance electricity will be under a lot of stress due to increase in electricity demand. A new ways of providing electricity without having to stress out much on the power plant, on the electrical utility and on the transmission line are need to be developed.

One of it is by directly connecting a Distributed Generation to the load. Distributed Generation is a power generating technologies that can be used in improving both quality and reliability of electricity supply with the combination of both load management and energy storage system [2]. Example of distributed energy is small generator, photovoltaic (PV), fuel cell, wind power and many more. Some distributed energy can be grouped together to provide energy to the local load which also can be called as microgrid. In other word, this distributed energy is connected to the grid using a low voltage network which is used to supply electricity to the domestic load in order to decrease the stress on electricity demand where at the same time can be used to provide additional energy for the main grid if excess energy exists.

Among the distributed energy, fuel cells stand the most as fuel cells technology is attracting an increasing attention nowadays. This is because fuel cells offer the potential in lowering the greenhouse gas emissions besides having a superior efficiency if compared to combustion engines [3]. Fuel cell is a conversion device which provides energy by converting a chemical energy stored in fuel into electricity [4]. With the advantage of high efficiency, low greenhouse gas emissions, and flexibility made these fuel cells as one of the important technologies that need to be develop even more in order to generate distribution energy that not only can provide electricity but also save the environment by reducing the greenhouse effect cause by most power plant exist today [4].

1.2 Problem Statement

Almost all power plant existing now a day mostly on coal-fired power plants, despite can produce a large amount of electricity, is affecting the environment greatly with their contribution toward the increasing of greenhouse gas emissions [5]. It was predicted that coal-fired power plant would contribute up to 37 percent of the total world CO_2 emission by 2025 [5]. One way to encounter this effect is by implementing the use of renewable energy power plant replacing the coal-fired power plant. But then again, implementing of this renewable energy power plant such as photovoltaic system and hydropower system required large spaces to be fully utilized and can be implemented at a specific area only. Not only that, construction of this power plant is very costly thus not everyone can afford it.

As the demand for electricity has increases steadily and was expected to continue for several more decades [1], depending on power plant alone is not encouraged as the transmission line used to provide long distance electricity will be put under a lot of stress due to this rises in electricity demand. One way or another, microgrid is the best solution for this problem. Microgrid give motivation to this project as it can provide additional power to the load when at the same time also can moderate the stress due to the electricity demand. In addition, microgrid is almost affordable to anyone and doesn't need large spaces. Among the distributed generation used in microgrid, fuel cells attract the most attention because as one of the renewable energy, fuel cell has the advantage in lowering the greenhouse gas emission cause by coal-fired generator. With advantage of higher efficiency compare to combustion engines and its flexibility, fuel cell makes a nice suggestion for microgrid.

1.3 Objective

1. To model a fuel cell simulation model by using simulation software.
2. To design a microgrid simulation model by using simulation software.
3. To evaluate the potential of implementing microgrid in a bus system network.

1.4 Scopes

1. The method of analyzing the microgrid will be by using power simulation software.
2. The power simulation software used is MATLAB software.
3. A 6-bus system network selected from a journal in IEEE [6] will be used to apply the microgrid power system network.
4. The fuel cell simulation model is only designed in order to see the behavior of the fuel cell output voltage either suitable or not to be implemented to the grid.
5. Fuel cell simulation model are designed in ideal form.

1.5 Report Outline

In this report, it consists of 5 chapters which have been well organized to smooth the report writing for better understanding of the project. Simple description of each chapter will be shown below.

In Chapter 1, it basically tells about the introduction of this project as in general. The project background, problem statement, objective and scope are included in this section.

In Chapter 2, it's mostly described about the literature review of other people project which might have same similarity in some part of the project. Some theory on which can be used in this project is included in this chapter.

In Chapter 3, the methodology describe about how this research was carry out. The Project Flow Chart and Project Block Diagram and each step or process of the research are included and will be described in detailed in this chapter.

Chapter 4 describe about the outcome result recorded after following the research process described in Chapter 3. All result was shown and each result is analyzed and discussed in this chapter.

This project was concluded in this chapter and the recommendation for future study work from this report was included in this chapter.

CHAPTER 2

THEORY AND LITERATURE REVIEW

2.1 Introduction

For this project, literature review is needed in order to have a better understanding toward the ongoing project. The literature review can be taken from various sources of information with related topic such as from technical paper report, books and journal. Most of the literature reviews used come from journal which can be found in IEEE as it is the easiest sources available. As for theory, it acts as a guide which can be used in completing this project. The theory on how to conduct the research mostly found in MATLAB guide where it descripts the parameter that to be used in the simulation such as fuel cells stack, switching, and so on. The theory or basic principle of component used in this project are discussed including their general characteristic, basic function, advantages, disadvantages and many more.

2.2 Fuel Cells

Most fuel cells system consist of four major components which is fuel cell stack, fuel processor, current inverter and conditioner and heat recovery system [7]. Fuel cell stack is the most important component in generating electricity. A single fuel cell can generate small amount of electricity around 05V to 1V but when combine in series forming a fuel cell stack, a large amount of electricity can be generated. A fuel processor function is to convert a hydrogen-rich fuel such as methanol, gasoline and gasified coal into a form useable by the fuel cell. It is unnecessary for fuel cell which is fed by pure hydrogen fuel. As fuel cell generate DC output, the current inverter and conditioner is used to convert the DC power to AC power in order to meet the requirement load demand as most housing electrical utility use AC power supply. As some fuel cell operates at high temperature, heat recovery system is used to convert the excess heat energy produced to increase the overall energy efficiency of the fuel cell.

By referring to Appendix A, it show some example of fuel cell exist in current technology now a day [7]. Those fuel cells are Proton Exchange Membrane (PEM), Alkaline (AFC), Phosphoric Acid (PAFC), Molten Carbonate (MCFC), and Solid Oxide (SOFC). From Appendix B, Table B1, by comparison, Solid Oxide Fuel Cell (SOFC) is the best because SOFC has high efficiency, has fuel flexibility and has typical stack size ranging from as low as 1kW and up to as high as 2MW which is suitable to be applied as a distributed generation in electrical grid. With high operating temperature and the advantage of suitable for combine heat and power (CHP) and combine heat, hydrogen and power (CHHP), Heat recovery system can be applied and thus increasing the energy efficiency of this fuel cells.

SOFC is one of regenerative fuel cells type which produced electricity from the chemical reaction of hydrogen and oxygen and the byproduct of this chemical reaction is heat and water which is very environment friendly.

One major drawback of a fuel cell is its slow output response and it is very critical in time when the load change rapidly. One solution for this drawback is by attaching energy storage system to the fuel cell. In Appendix C, there are two example of energy storage system being compared. From the table, even though super capacitor has fast charging speed and high circle life which can charge and discharge many times, the output voltage of this capacitor not constant as it decreases through time when discharging. Thus, battery bank will be selected as the fuel cell energy storage system as it can produce the same output voltage which is very crucial in providing a constant power supply to the load.

2.3 Microgrid

The implementation of distributed generation in power system shows great potential but the implementation of individual distributed generator can cause more problems than the problem that it can solve [8]. The implementation of microgrid is used in order to solve this problem where it can bring the potential of each distributed generation by reducing the problems that may occur by the implementation of individual generator. Microgrid views the distributed generation and the load involved or connected as a subsystem to the main power system or main grid [8]. This microgrid can be separated from the main power system to isolate the microgrid's load from the disturbance without affecting the main power system.

In implementing a microgrid, all distributed generation will be connected together and will provide combine power to the main grid or utility grid. To connect all the distributed generators together, there are a few problems that need to be solved first. Not all distributed generator is the same. This is because a distributed generator can be wind power, photovoltaic, ac or dc motor generator, hydropower and fuel cell stack. To connect different distributed generation together and produce combine power to the main grid, the voltage produce by each distributed generator should be the same to produce the same voltage output. The power of each distributed generator can be vary as long as the output voltage is the same. The microgrid combine output voltage should be the same with the main grid. Converter and inverter can be used in order to achieve this. Despite voltage, the output frequency of all distributed generators should be the same also and should follow the main grid frequency value. As most power system usually use AC voltage, phase shift exist in voltage waveform. The output voltage phase from the microgrid should be the same with the main grid and thus a phase lock loop (PLL) need to be implemented together with microgrid. A battery bank needs to be connected within the microgrid in order to store energy to compensate any slow output response from any distributed generator such as fuel cell to prevent any lack power supply load demand power suddenly changed.

2.4 Equivalent Fuel Cell Stack Model

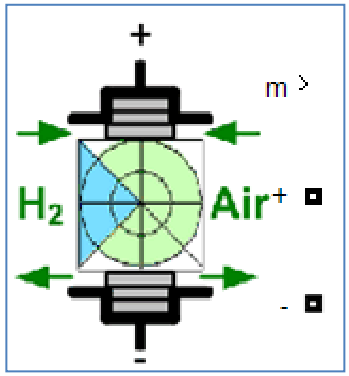

Figure 2.1: Equivalent Hydrogen Fuel Cell Stack Model [9]

The equivalent Fuel Cell Stack Model as seen in Figure 2.1 can be found in MATLAB under simulink library. This block implements a generic model of generic hydrogen fuel cell stack model. The block can be represented in two versions of stack model which is a simplified model and a detailed model [9].

2.4.1 Simplified Model

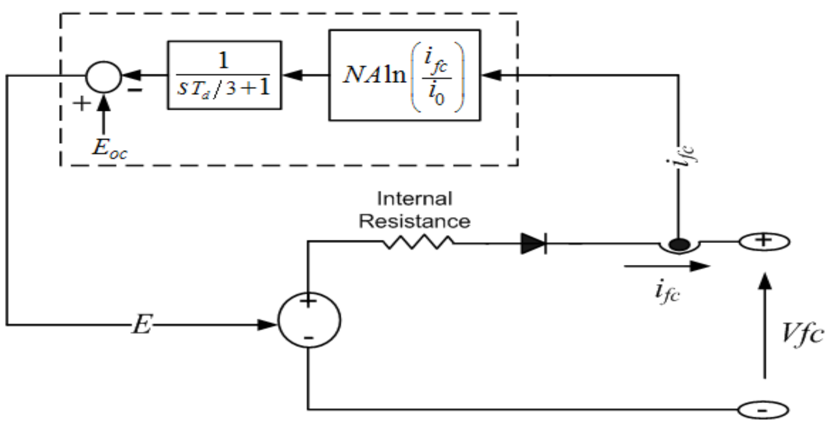

Figure 2.2: Equivalent circuit of Simplified Fuel Cell Stack Model [9]