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MODELLING AND ANALYSIS FUEL CELL WITH BATTERY STORAGE MICROGRID SYSTEM BASED ON GREEN ENERGY

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2015

"I hereby declare that I have read through this report entitle "Modelling and Analysis of Fuel Cell with Battery Storage Microgrid System Based on Green Energy" and found that it has comply the partial fulfillment for awarding the Degree of Bachelor of Electrical Engineering (Industrial Power)"

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MODELLING AND ANALYSIS OF FUEL CELL WITH BATTERY STORAGE MICROGRIS SYSTEM BASED ON GREEN ENERGY

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

Faculty of Electrical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2016

I declare that this report entitle "*Modelling and Analysis of Fuel Cell with Battery Storage Microgrid System Based on Green Energy*" is the result of my own research except as cited in references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : .....

Name : Nor Athira Binti Ali Osman

Date : 10th of June 2016

I dedicate this report to my parents. Without their pray, understanding, support and most of all love, the completion of work would not have been possible.

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ABSTRACT

Nowadays, the implementation of distribution generation(DG) are increasing per day to find out the most convenient and available alternatives from the several choice of DG. Fuel Cell technology is considered to be one of the most reasonable DG that is free from any climatic changes. Normally traditional grid is used to supply the electricity to the consumer but through this project two types of DG are connected to main grid. This type of connection is called Microgrid(MG) system. The two types of DG that connected to main grid are fuel cell and battery storage. There will be two designed which are first is fuel cell is connected to main grid and the second design is battery storage connected to main grid. These circuit are designed by using MATLAB Simulink Software and the simulation results are indicated the output data for power, three phase voltage and three phase current.

ABSTRAK

Pada masa kini, perlaksanaanpemasangan Generator Pengagihan(DG) semakinmeningkatsetiaphariuntukmengenalpastialternatif yang paling sesuaidanmudahdidapati. Teknologiselbahanapidianggapsalahsatudaripada DG yang paling berpatutan yang bebasdaripadaapa-apaperubahaniklim. Biasanya grid tradisionaldigunakanuntukmembekalkantenagaelektrikkepadapenggunatetapimelaluiproje kiniterdapatkelebihanpada grid utamaiaituduajenis DG disambungkankepada grid utama. Sambunganjenisinidipanggilsistem "Microgrid"(MG). Kedua-duajenis DG yang bersambungdengan grid utamaadalahselbahanapidanpenyimpananbateri. Di sanalahakanterdapatduarekaanlitariaitu yang pertamaadalahselbahanapidisambungkanke grid utamadanrekabentuk yang keduaialahpenyimpananbateridisambungkanke grid utama. Litarinidirekadenganmenggunakanperisian MATLAB Simulink dankeputusan data simulasi yang ditunjukkanialahkeluarankuasa, tigafasavoltandantigafasaaruselektrik.

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LIST OF ABBREVIATIONS

DG	-	Distribution Generation
MG	-	Microgrid
PCC	-	Point of Common Coupling
SD	-	Separation Device
AFC	-	Alkali Fuel Cell
PEMFC	-	Proton Exchange Membrane Fuel Cell
PAFC	-	Phosphoric Acid Fuel Cell
BMS	-	Battery Management System
MGCC	-	Microgrid Central Controller
PV	-	Photovoltaic
BESS	-	Battery Energy Storage System
VRLA	-	Valve-Regulated Lead Acid
UPS	-	Uninterruptible Power System

LIST OF SYMBOLS

H_2	-	Hydrogen gas
H^+	-	Hydrogen ion
e	-	Electron
O_2	-	Oxygen gas
O	-	Oxygen ion
V	-	Voltage
I	-	Current
kW	-	Kilowatt
RMS	-	Root Mean Square
Vp-p	-	Voltage phase to phase
DC	-	Direct Current
AC	-	Alternate Current
P	-	Active Power
Q	-	Reactive power

CHAPTER 1

INTRODUCTION

1.1 Motivation

In developing countries, the usage and demand for energy is increasing rapidly due to the increase of human population and improvement in standard living. The necessity of technology in urban area helps the power consumption to increase respectively. The use of the fuel cells as a new alternative is the best solution to accommodate this situation.

Fuel cells has the advantage that is can be installed anywhere since it did not need large space. Constant supply of hydrogen supply as the fuel is the only thing needed to power up the fuel cells. Through this project, this two types of DG that is fuel cell and battery storage are used in connecting with MG.

MG is a power system that consists interconnected load and DG, which operates in high voltage or low voltage [1]. MG is greater than traditional grid this is due to the ability of the system to operate on its own when fault happens to the main grid. Hence, the source of power to the consumers would not be interrupted since it has backup system.

1.2 Problem Statement

Combining DG into the existing network can help improve the consistency of the system. A common problem in industries when using traditional grid is the grid is only one way of flow electricity and communication. Instead of using the traditional grid, in this project, MG is used to replace the traditional grid. However, MG operations have to satisfy quality requirements in terms of the frequency and voltage. To overcome this problem, energy storage systems for short and long term storage are used with MG. Fuel cell is implemented in DG so that the system can work functionally.

The MG is used to ensure there is no interruption happened as in traditional grid if fault happen. DG implemented in MG will be the backup to supply the power to the load if the power source from the grid is not functioning.

1.3 Objectives

The objectives of this project are;

i. To study the operation of DG, MG and battery storage in the three phase system network.

ii. To design the circuit of fuel cell, battery storage and MG system by using MATLAB Simulink software.

iii. To analyse the performance of fuel cell and battery storage system of microgrid by using MATLAB Simulink Software

1.4 Scope

The modelling and analysis of the fuel cell along with battery storage connected to MG are all carried out by using MATLAB, Simulink. This project research will cover the purpose on the operation of fuel cell and battery storage The observation of the changing voltage, current and power are all discussed by taking out the simulation of the graphs.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

To overcome the environmental issues and rapidly increasing power demand, various renewable and non-renewable energy sources getting attention. One of it is fuel cell system. The advantages of fuel cell are pollution free and high efficiency technology for MG distribution systems. In this section, all the main part such as fuel cell, MG and battery storage will be discussed. The design, configuration and operation of the MG, fuel cell and battery storage will be explained.

2.2 Microgrid

MG is a system that connect houses, factories and other buildings to power central sources [2]. A normal grid or traditional grid will connect to the houses, factories or other building but when there is maintenance work need to be done, all of the connected building will be cut off from receiving the supply. This is a situation that can be corrected by connecting the building using MG.

2.2.1 Microgrid Design

MG is a system that have low voltage or medium voltage distribution network that surround by DG, energy storage systems and loads, operating as a single controllable system [3]. Basically MG can be power on in case of emergency such as lightning strike or storms, without disturbing the supply to the loads. This is due to the connection of the load with the DG. DG is a used for capacity support, voltage support and regulation, and line loss reduction [3].

DG usually made of many new technologies such as fuel cell, photo-voltaic systems and several kinds of wind turbines. This DG will be the backup whenever the load is cut off from the main grid.

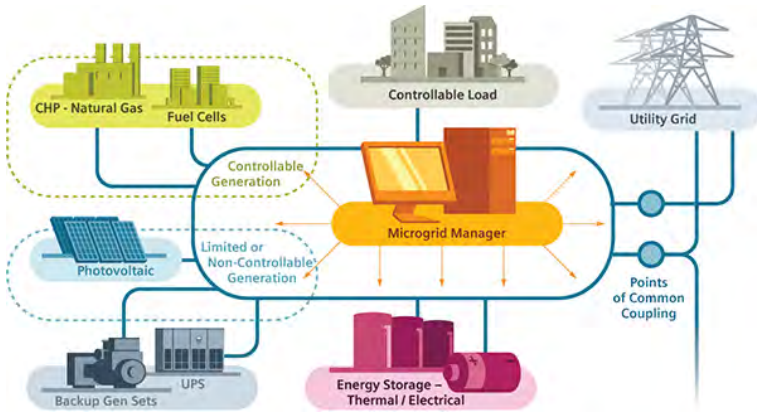

Figure 2.1: A microgrid overview[3]

2.2.2 Microgrid Operation

Figure 2.2 shows the MG operation. In the figure, it shows a group of feeders connecting to each other. There is a single point of connection to the main distribution utility called point of common coupling (PCC). PCC is the point in the electric circuit where a MG is connected to a main grid [4]. There is also a point called SD that is Separation Device which can disconnected MG immediately whenever fault happens in

the distribution grid. The figure below shows in feeders 1 and 2, it has local generation which is require because it have sensitive loads. There is also loads that do not have any local generation that is traditional load, connected to Feeder 3[4].

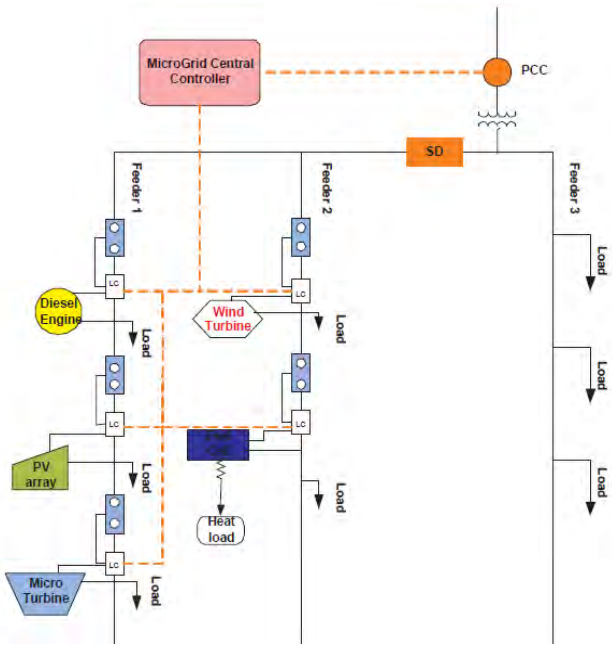

Figure 2.2: Operation of microgrid

2.3 Fuel Cell

Fuel cell is a device that converts chemical energy from fuel into electricity. Electricity was form through a chemical reaction of positive charged hydrogen ions with oxygen or other oxidizing agent [5]. Fuel cells was first invented in 1838, but, the world only know its existence until more than a century later through NASA space programs which to generate power for satellites and space capsules. Ever since then, fuel cells were broadly used in many applications which focused as a primary and backup power for industries, residential and commercial buildings. The ability to be installed in remote and inaccessible areas makes it possible for the used in powering vehicles such as forklift, buses, boats, submarines, automobiles and motorcycles.

2.3.1 Fuel Cell Modelling

Fuel cells have variety of different types. Each of it consist of an anode, a cathode and electrolyte which allow positive charged hydrogen ions to move between the two sides of fuel cell. To generate positive hydrogen ions and electrons, each anode and cathode contain catalysts which caused the fuel to oxidized. After the oxidation reactions, the hydrogen ions are drawn to the electrolyte. Simultaneously, through an external circuit, electrons are also drawn from the anode to the cathode. This helps produced a direct current electricity. Hydrogen ion, electrons, and oxygen reacts with each other at the cathode to form water[6].

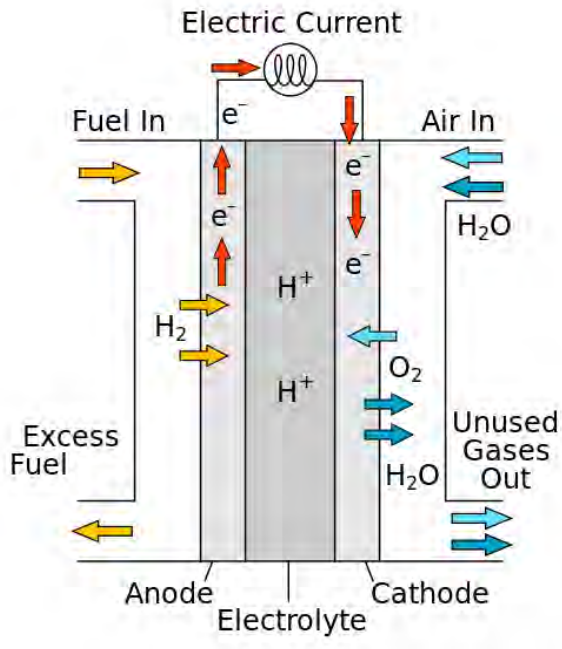

Figure 2.3: Construction of fuel cell

The two half reaction occur in the fuel cell are:

At anode: $H_2\,(g) \rightarrow 2H^{++}\,2e^-$ (2.1)

At cathode : $\frac{1}{2}O_2\,(g) + 2H^+ + 2e^- \rightarrow H_2O$ (2.2)

Overall reaction: $$H_2(g) + \frac{1}{2}O_2(g) \rightarrow H_2O \quad (2.3)$$

2.3.2 Fuel Cell Characteristic

There are many types of fuel cell line such as Alkaline Fuel Cell (AFC), Proton Exchange Membrane Fuel Cell (PEMFC) and Phosphoric Acid Fuel Cell (PAFC). These fuel cells generate direct current. According to the power rating, there are numerous way of a fuel cells was chosen. 1KW fuel cells has the output voltage range 25-50V while 30KW and above of fuel cells can have output voltage range 200-400V. Fuel cells are in a development stage as stated in [7]. Below are the assumptions about the operating characteristics:

1. Fuel cell with type of PEMFEC has low temperature and have partial oxidation, it takes minor time to start-up while a high temperature fuel cell will takes 3 to 4 hours to start up. This show that fuel cell with low temperature is more suitable for start-stop operation since the start up time takes small amount of time.

2. Although fuel cell can do nearly instant load changes, it has a limit in the fuel processing system which has a certain time of lag due to the chemical reactions occur.

3. As the number of moving parts are low, fuel cells have the potential for high in reliability. Life length of fuel cells is given as 40000 h for the stack and at least twice the number of hours for the system.

2.4 Battery Storage

In recent years, due to large integration of Renewable Energy Sources like microturbine and fuel cell unit into the MG, the supplication of Battery Storage (BS) has surge greatly. The BS has considerable interest and advantages in the MG-based