FUZZY LOGIC IN BATTERY ENERGY STORAGE SYSTEM (BESS)

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DEDICATION

I dedicate this project report to my family and friends. My feelings of gratitude first go to my ever-supportive parents whose cheerful and constantly encouraging words have always driven me to put in my best efforts. Their push for tenacity was a vital motivation all along the process. To my special siblings who never left my side, I am indeed grateful.

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ABSTRACT

The battery energy storage system (BESS) is a portable device that consists of batteries, controllers, sensors, relays, and other elements that are vital for battery charging and electricity supply operations. A BESS can be used in on or off grid applications to supply electricity as the main source or a back-up source of energy, and to eliminate power factor surcharge by utility companies. This research seeks to design, apply, and validate the use of fuzzy logic controller as a battery management system to regulate the simultaneous charging and discharging processes of batteries. In this project, BESS hardware is constructed to include two 24V battery sets, an electrical load, proper electrical connections, switches, relays, current sensors, voltage measurements, LED indicators, and a microcontroller. Fuzzy logic controllers, one for each battery set, are designed, simulated, and analyzed in MATLAB before implemented in the actual BESS hardware. The experiment involves repeatedly running the BESS for several hours, through a number of charging and discharging cycles, and analyzing current and voltage measurements. By comparing the performances of the fuzzy logic controllers and that of a conventional sequential algorithm, it can be concluded that the fuzzy logic controller can be applied as a safe and efficient battery management system and may improve the battery life in a BESS

ABSTRAK

Sistem simpanan tenaga bateri (BESS) adalah peranti mudah alih yang terdiri daripada bateri, pengawal, sensor, geganti, dan elemen lain yang penting untuk pengecasan bateri dan operasi bekalan elektrik. Sistem simpanan tenaga bateri (BESS) dapat digunakan dalam aplikasi dalam atau luar jaringan untuk membekalkan elektrik sebagai sumber utama atau sumber tenaga alternatif. Penyelidikan ini bertujuan untuk merancang, menerapkan, dan mengesahkan penggunaan pengawal logik fuzzy sebagai sistem pengurusan bateri untuk mengatur proses pengecasan dan penyahcasan bateri secara serentak. Dalam projek ini, perkakasan sistem simpanan tenaga bateri (BESS) dibina untuk merangkumi dua set bateri 24V, beban elektrik, sambungan elektrik yang betul, suis, geganti, sensor arus, pengukuran voltan, petunjuk LED, dan mikrokontroler. Pengawal logik fuzzy, satu untuk setiap set bateri, dirancang, disimulasikan, dan dianalisis dalam MATLAB sebelum dilaksanakan dalam perkakasan sistem simpanan tenaga bateri (BESS) yang sebenarnya. Eksperimen ini melibatkan berulang kali menjalankan sistem simpanan tenaga bateri (BESS) selama beberapa jam, melalui sejumlah kitaran pengecasan dan penyahcasan, dan menganalisis pengukuran arus dan voltan. Dengan membandingkan prestasi pengawal logik fuzzy dan algoritma urutan konvensional, dapat disimpulkan bahawa pengawal logik fuzzy dapat diterapkan sebagai sistem pengurusan bateri yang selamat dan efisien dan dapat meningkatkan daya tahan bateri dalam sistem simpanan tenaga bateri (BESS).

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LIST OF ABBREVIATIONS

ANN	-	Artificial Neural Network
GA	-	Genetic Algorithm
PSO	-	Particle Swarm Optimization
MTS	-	Mahalanobis Taguchi System
MD	-	Mahalanobis Distance
TM	-	Taguchi Method
UTM	-	Universiti Teknologi Malaysia
XML	-	Extensible Markup Language
ANN	-	Artificial Neural Network
GA	-	Genetic Algorithm
PSO	-	Particle Swarm Optimization

LIST OF SYMBOLS

δ	-	Minimal error
D, d	-	Diameter
F	-	Force
v	-	Velocity
p	-	Pressure
I	-	Moment of Inersia
r	-	Radius
Re	-	Reynold Number

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CHAPTER 1

INTRODUCTION

1.1 Background

A battery is an electrochemical cell (or sealed and protected material) that can be electrically charged to provide a static power potential or electrical charge, which can then be released when required. Until the advent of electric turbines and power grids in the late 19th century, batteries were considered to be the main source of electricity. For the first time in 1749, Benjamin Franklin used drums in his experiments with electricity to explain a collection of connected capacitors.

Transfer of electrons, oxidation and reduction reactions, and two chemical reactions form the basis for standard battery activity. In general, a part of a battery is an anode, while another is a cathode, and there is also an electrolyte. An electrolyte is an electrochemical reaction catalyst that, when ions migrate from one electrode to another, results in a charging and discharging activity. This chemical reaction creates a possible charging distance (i.e. voltage) between the cathode and the anode, as the anode builds up electrons.

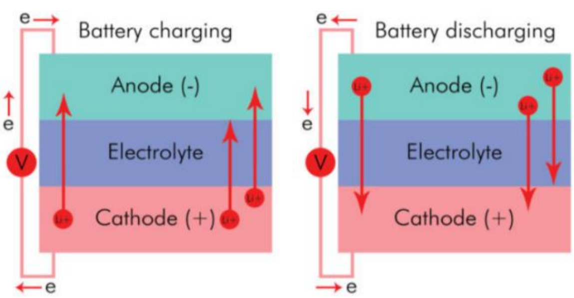

Figure 1.1 Battery charging and discharging process

A current flow is caused by attaching a load with a wire to the terminals of the battery, which discharges the battery from the anode to the load, and then to the cathode, as electrons flow (i.e., the current). As the movement of these ions occurs, the battery chemistry changes until the anode is no longer supplied with electrons, which results in the battery being discharged, as depicted in Figure 1.1.

The battery energy storage system (BESS) is an electrical energy storage system produced using specially built batteries. The basic idea is that it is possible to use those saved resources at a later time. Extensive research in this field has resulted in developments in batteries that have developed the idea of the battery energy storage system (BESS) into a commercial reality. The battery energy storage system (BESS) plays an important role in the incorporation and enhancement of the usage of renewables.

Charging a battery and charging period is non-linear and takes a lot of time, making it difficult to achieve the maximum energy storage performance with traditional control methods. Energy storage is recognised as a key component for substantiality of renewable energy, and is now an objective of government and private initiatives [1]. Batteries offer a strong solution to energy storage in industries like automobiles, robots and telecommunications. The charging and discharging of a battery can cause battery damage and can also reduce battery life, if not properly managed. Zhou Runhua, from real-time news portal Caixin Global, reported in April 2019 that at least 3 electric vehicles had exploded in China on suspicions of a battery failure. [2].

Battery management devices enable the monitoring and control of battery output. Many battery control parameters can be used [3], such as:

i. The battery voltage
ii. Current
iii. State of charge (SOC)
iv. State of Health
v. Depth of discharge (DOD).

In order to design and pick a parameter to optimise the battery storage device, battery management is very critical. Precise battery status estimation, for parameters such as State of Available Power (SoAP), State of Health (SOH) or State of charge (SOC), is still a challenging task. The algorithms in the particular application must work correctly over the years [4]. Although a battery becomes increasingly pertinent over time, there are still many issues with recognising and managing it. One significant problem among them is determining the battery level [5].

The parameter evaluation strategy is very critical since the parameters can influence the project. It is also obvious that the total battery residual capacity will affect the battery's instantaneous maximum output [6]. There are several difficulties: voltage calculation, current and power limits, charging profile regulation, battery balance, and battery voltage and temperature monitoring.

A precise initial SOC value is required for the Coulomb counting method and depends to a great extent on the efficiency of the current sensors. However, the main downside of this approach is that an open-loop approximation is needed, and errors may be substantial due to disruptions and uncertainties [7]. The use of neural networks, Kalman filters and fuzzy logic may be a good way to monitor the charging or discharging of the battery, but a very hard-to-use device needs to be provided for the integrated system [8].

The charging rate is shown in Amps as the battery per unit time added while charging (i.e., Coulombs/sec, which is a unit of Amps). However, the charge/discharge rate is more commonly specified by calculating the time taken to discharge the entire battery. The battery is only "theoretically" discharged at its highest level, since it is difficult to completely discharge most practical batteries without destroying or reducing their lifespan.

There are a number of limitations and requirements associated with each battery's loading and discharge conditions. For each type of battery, the voltage and current of the charging cycle are different. A battery charger or charger controller designed to handle one battery type cannot usually be used with another.

To ensure the optimum recharge and discharge status of the battery, a fuzzy control technique is developed. Trial and error is one method to design the fuzzy logic control rule [9]. Fuzzy logic is based on the experimental results of experts in the relevant application area. Hence the use of fuzzy rules and inference engines helps fuzzy controllers to make decisions similar to humans while working in the field.

1.2 Problem Statement

To ensure the capacity of nano-gel batteries using current and voltage, measurement of the accuracy of each battery is required. This is a challenge because different characteristics during charging and discharging are generated by current and voltage. Relays are needed to operate under the state of the batteries to control the system of charging or discharging based on the capacity of the batteries.

The temperature of a battery is very critical for preserving the output of the battery during charging and discharging. The temperature affects the lifetime of a battery. One solution for avoiding overcharge is to employ a battery management control device, which can be done through the knowledge of the available energy in the battery.

The current and voltage levels should be running at the Battery Energy Storage System (BESS). Different characteristics during charge and discharge are generated by current and voltage. Overcharging can reduce battery life and cause substantial battery damage.

1.3 Research Goal

The goal of the research is to design the Battery Energy Storage System (BESS) with a fuzzy logic controller using MATLAB/Simulink. Through current and voltage behavior on the system, the battery performance can be monitored and controlled. Battery performance will impact the fuzzy logic rules. Battery Energy Storage System (BESS) hardware is constructed to include two 24V battery sets.

1.4 Objective

The objectives of the research are:

i. To control the charging and discharging processes of a Battery Energy Storage System (BESS) using battery voltage and current measurements.
ii. To build the Battery Energy Storage System (BESS) with a fuzzy logic controller.
iii. To compare the performance of conventional sequential algorithm and fuzzy logic controller.

1.5 Scope of the Project

i. Develop a Battery Energy Storage System (BESS) that consists of two 24V 4Ah battery sets of nano-gel batteries.
ii. Simulate the Battery Energy Storage System (BESS) using Matlab/Simulink.
iii. To monitor and control the charging and discharging process of the batteries using a conventional sequential algorithm and a fuzzy logic controller (FLC)
iv. Compare the performance of conventional sequential algorithm and fuzzy logic controller (FLC)

1.6 Project Planning and Progress

In order to achieve the goals in this project, several tasks are needed to be completed, as illustrated in Figure 1.2. This project report is divided into three groups, which are research, planning, and implementation. The concept of battery management, and methods used to charge or dicharge batteries using fuzzy logic, need to be understood before designing and developing the relevant software and hardware. A particular fuzzy logic controller needs to be used to develop the software and hardware, in order to optimise the project.

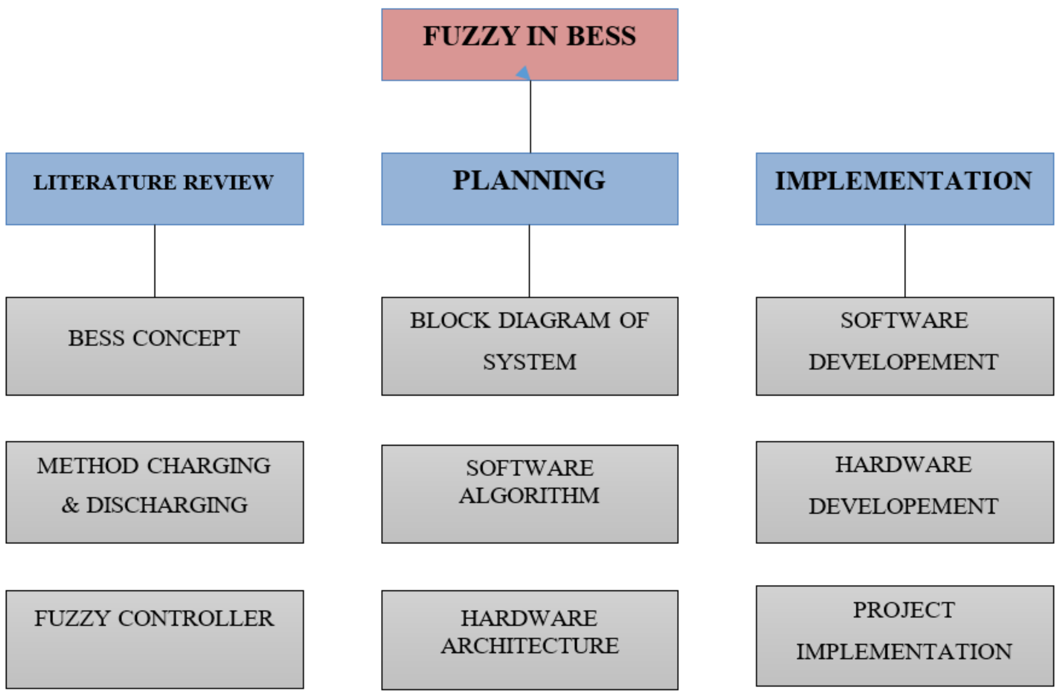

Figure 1.2 Planning summary of the project

1.7 Outline of the Project

This report contains five chapters:

Chapter 1

This chapter covers the introduction of the battery energy storage system, battery, problem statement, objective and the scope.

Chapter 2

This chapter contains a literature review on fuzzy logic controllers, battery management using fuzzy logic, and the battery charge and discharge process. Previous works and brief related works on the battery management method are also discussed.

Chapter 3

This chapter presents a detailed model of the battery energy storage system using Proteus and MATLAB/Simulink. The details of fuzzy rules implementation, and the hardware used in the system are also explored.

Chapter 4

The outcomes of the simulation and the results which have been evaluated are shown here. Discussions are then presented on the results.

Chapter 5

This chapter talks about the proposed work and future work to enhance or further improve on this project.

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