INVESTIGATION AND DEVELOPMENT OF A CONTROL AND MONITORING SYSTEM TO DETECT POSSIBLE FAULT IN DISTRIBUTED STORAGE BATTERY FOR ELECTRIC VEHICLE

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A project report submitted in partial fulfilment of the requirement for the award of Master of Engineering (Electrical)

Faculty of Engineering and Science
Universiti Tunku Abdul Rahman

December 2017
DECLARATION

I hereby declare that this project report is based on my original work except for citations and quotations which have been duly acknowledged. I also declare that it has not been previously and concurrently submitted for any other degree or award at UTAR or other institutions.

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Date : 5 Dec 2017 ________________________________
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Supervisor : Professor Dr Chew Kuew Wai

Date : 5 Dec 2017
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For the benefit of mankind
ACKNOWLEDGEMENTS

All praise to Allah that we praise Him, we ask for help and forgiveness from Him. We ask for protection from our badness and our bad actions. I believe that there is no God to be worshipped unless Allah and no companion for Him and I believe that Mohammad is Allah’s messenger for us.

“O to believed people, piety to Allah with the real piety and do not you die unless in Islam” (QS Ali Imran, 102)

“O to all people, piety to Allah which made you from one soul and created from this one soul his partner and made you so many men and women. Let piety to Allah with His name you always ask and preserve relationship between all of you. Indeed Allah always takes care and sees you.” (QS An-Nisaa, 1)

Indeed the best words are Book of Allah (al Quran), the best guidance are Mohammad (pbuh) guidance, be careful with new thing in religion, because every new things are heresy, every heresy is error and every error is in hell fire.

I would like to thank all people which helped me to settle my final year project, especially to my supervisor Prof Dr Chew Kuew Wai. I also want to thank to my wife, Nor’Asyifa Bt Asmat due to her cooperation to take care our kids during my study especially during final year project. I also want to say thank you to my friend, Faiz Bin Mahmood for his guidance for me to study about drawing, equipment selection, testing, programming and running the module.

Thank you.
In the system for electrical vehicle, battery system is one of most important equipment because battery system provides electrical energy for entire electric and electronics equipment.

Like other equipment, battery also faces the breakdown due to wear and tear for the materials inside the battery. When battery system stops producing or have problem to produce electrical energy to electric vehicle, it makes problem for all electrical and electronic equipment. The examples of problems are the electric cannot be started, car cannot in full speed, radio system malfunctions and etc.

The research focuses on battery condition, which battery system starts having problem to supply electrical energy for electrical vehicle. The areas of research are State of Health (SOH), State of Charge (SOC), Voltage (V), Current (I) and Temperature (T)

The research also develops a system that can monitor and control the battery system which consists of two batteries. The control system detects every parameter and displays the parameters to user. The control system also takes some initiatives to counter parameter drop especially for Voltage drop. Voltage is the main factor to know the battery condition. The control system boosts the voltage if voltage drop happen during operation.
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<td>anno domini</td>
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<tr>
<td>$\phi$</td>
<td>magnetic flux, Wb</td>
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<tr>
<td>HEV</td>
<td>hybrid electric vehicle</td>
</tr>
<tr>
<td>EVs</td>
<td>electric vehicle</td>
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<tr>
<td>PHEV</td>
<td>plug hybrid electric vehicle</td>
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<tr>
<td>SOC</td>
<td>state of charge</td>
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<td>SOH</td>
<td>state of health</td>
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<tr>
<td>$V_i$</td>
<td>input voltage</td>
</tr>
<tr>
<td>$V_o$</td>
<td>output voltage</td>
</tr>
<tr>
<td>$V_{dc}$</td>
<td>direct current voltage</td>
</tr>
<tr>
<td>$D$</td>
<td>duty cycle</td>
</tr>
<tr>
<td>$I_o$</td>
<td>output current</td>
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<tr>
<td>RPM</td>
<td>rotation per minute</td>
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<tr>
<td>Wh/Kg</td>
<td>watt per kilogram</td>
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<tr>
<td>C-Rate</td>
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<td>DOD</td>
<td>depth of discharge</td>
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<tr>
<td>PWM</td>
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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Since 1600 A.D, the rate of pollution to environment was increasing rapidly due to usage of fossil fuel especially in industry. Starts from 1700 A.D, coal were used as fuel to move locomotive especially in Britain. The industrial revolution in Europe especially in Britain, France and German made coals were used extensively especially in transportation industry. Coals also used for electricity when electricity was found by scientist. Coals were used to generate steam in coal power plant to supply electricity to consumer especially in industry. The petroleum based engines were used extensively in daily life after diesel engine was discovered by Rudolf Diesel in 1892. The engine which uses petrol as fuel also invented by Nikolaus August Otto in 1876 made petrol used in daily life extensively.

Due to effect to environment by usage of coal and petroleum based as fuel to engine and electricity, scientists are looking new alternative energy that are greener, safer and cleaner to environment. This is important to preserve environment so that earth is still safe for the next generation.

Scientists look various ways to replace fossil fuel as energy for transportation and electricity. They look for the source of wind, heat, bio mass, sun and others to replace fossil fuel. Some sources show promising to the research and others still not showing the promising to environment.
There are two types of battery which common be used in daily life. First is start lighting ignition battery and second is deep cycle battery. Battery type which is used based on application. The first type of battery is start lighting ignition battery. This type of battery normally used in petroleum based vehicle. The type of engines which use this battery is heavy fuel oil engine, petrol based engine and diesel based engine. Battery is used in order to start the engine. After engine already started, engines take the responsibility to move the vehicle and to recharge back by using alternator. This system is battery energy saving but complex due to need to have combination engineering discipline to make vehicle works. The engineering disciplines are electrical, mechanical and chemical engineering disciplines. The second type of battery is deep cycle battery. This type of battery is used in full electrical vehicle. For this electric vehicle, battery is not used to start the engine. The petroleum based engine is replaced by motor. The function of electric motor is to transfer electrical energy to be kinetic energy.

For the start lighting ignition battery, cranking ampere is high to start the engine. The anode and cathode sizes are not big compare to deep cycle battery. It is because the battery only is being used to start the engine.

For the deep cycle battery, cranking ampere is higher in order to make motor rotates continuously. So the sizes for anode and cathode must be big enough to cover the rotation of motor.

There are three types of Electric Vehicle in the market. First is Hybrid Electrical Vehicle (HEV), second is All Electrical Vehicle (EVs) and third is Plug In Hybrid Electric Vehicle (PHEV). HEV and PHEV are moved by the internal combustion engine and motor combination. This combination makes the HEV and PHEV can select weather to use engine or motor. Engine fuel for HEV and PHEV are petrol based or diesel based. The motor for HEV and PHEV is moved by battery. For these type of vehicle, battery charged back by using alternator. Engine started by using battery. Once engine already started, driver can choose whether to use engine or motor to move the vehicle. This can be done by using selector switch. The advantages for these systems are the usage of petrol or diesel can be saved, maintenance for mechanical equipment can be reduced and have backup if anything
happen to the system. So it is means these systems use two sources of fuel, diesel or petrol and battery. The EVs uses only electrical energy to move vehicle from one point to other point. This type of vehicle has electrical motor as ‘engine’. Battery powers the motor. EVs also uses alternator to recharge back to battery. This system is crucial to be monitored especially in voltage and current to make sure battery is not flat during operation. Battery can be assumed as fuel for the vehicle.

There are some limitations for EVs car. First is this type of car cannot be moved far away from charging station. Second is time taken to fully charge the battery is longer compare to fill the full tank the diesel or petrol for petroleum based engine. Third is battery can condemn due for long time usage and time taken to replace battery is long. Fourth is this type of battery is difficult to be acquired.
1.2 Research Objectives

The objectives for this study are to study and investigate the battery:

- To study the battery working principle
- To study the characteristic of battery such as SOC, SOH, Specific Energy Density and etc.
- To study the effect if two batteries or more are not balanced, theory behind this
- To study the relationship between input voltage ($V_i$), output voltage ($V_o$), duty cycle ($D$), output current ($I_o$) and rotation per minute (RPM)
- To develop the boost converter that can maintain RPM and $V_o$ if $V_i$ drop happens
1.3 Problem Statement

For the EVs, the power source is from battery. This is important to monitor the condition of battery so that battery can perform in healthy state. If batteries get problem, the EVs cannot be moved from one point to other point. The nominal voltage for one battery is 12 Vdc. The battery threshold voltage needs to be known so that the battery condition can be monitored. The voltage is important factor to determine the condition of battery. The voltage determines the State of Health (SOH) and State of charge (SOC).

Based on the research, the voltage threshold is 8 Vdc. If voltage is below than 8 Vdc, battery is considered condemned and cannot be used to move the EVs. The battery required for this study is two units. Due to nominal voltage for electronic components is 12 Vdc, these batteries need to be separated so that these battery work at specific load. Due to the voltage threshold is 8 Vdc, the battery voltage need to be monitored so that voltage can be maintained in working range. If battery voltage below than 8 Vdc, the boost converter needs to take action to boost the voltage up.
CHAPTER 2

LITERATURE REVIEW

2.1 Introduction To Energy

Energy is a form that can work for the system. For example to rotate the motor, electrical energy is required to be changed to be magnetic energy and then to be mechanical energy. The energy cannot be created and cannot be deleted. The energy only can be transformed from one type to other type by using some mechanisms required.

There are so many types of energy. For examples are electrical energy, kinetic energy, potential energy, magnetic energy, thermal energy, light energy, sound energy, renewable energy and chemical energy. These types of energy have their own functions to environment and require some techniques to get benefit from them. For example is light energy. Photovoltaic cells are required in order to grab the light energy. First the light energy needs to be changed to electrical energy. After changed, electrical energy can be stored in battery as a store. If water needs to be boiled, this electrical energy stored in battery needs to be changed to heat energy by using heating element or water heater. This electrical energy also can be changed back to light energy by using monitor or screen.

The example of chemical energy storages are battery and petroleum. The chemical energy inside the petroleum can be converted to heat energy first via combustion process and converted again to kinetic energy via piston rod.
2.2 Energy For Transportation

Energy is used to transport or move one object from one place to other place. To transfer one object, certain amount of energy is required to counter the weight and gravity force. If one object is heavy, it requires more energy to move from one place to other place compare to one object is light. The gravity force also plays important role to determine the amount of energy required. For example at moon, the amount of energy required to transfer one object is six times less compare to the amount of energy required on earth.

The name of energy to transfer one object from one place to other place is called kinetic energy. The kinetic energy is closely related to potential energy. The kinetic energy is about movement action. The potential energy is about energy inside the object which can make movement.

The kinetic energy is closely related to velocity and weight for one object, based on formula $E=0.5MV^2$. The amount of $E$ is higher if $M$ and $V$ getting higher. The potential energy is closely related to height and weight for one object, based on formula $E=PHG$. The amount of $E$ is higher if $P$ and $H$ is higher.

In transportation industry, there are so many sources of energy which already used to move one object from one place to other place. In maritime industry, the energy were used are wind energy, potential energy and kinetic energy. In land transportation industry, the kinetic energy from animals is the first used by man to move. For the modern era, the types of energy which used are energy from coal, energy from petroleum and energy from electrical.

2.3 Introduction To Battery

Battery is the equipment which can supply electrical energy for electrical and electronic equipment. The current from battery flows from anode terminal to cathode terminal. The process to produce current is called electrochemical process. This
process happens in battery. This process makes electron flows from cathode as negative terminal to anode as positive terminal. The basic principle is the voltage different between anode and cathode must be enough so that current can through from anode to cathode. This current flows from anode to load first via connector and then back to cathode to complete the flow. The basic formula which can be used is $V=IR$. $V$ is Voltage, $I$ is Current and $R$ is Resistor.

There are three important components for one battery. First is anode, second is cathode and third is electrolyte. These three items have their own functions to make sure current flow from anode to cathode. Anode is as a positive terminal for battery. Cathode is as a negative terminal for battery. Electrolytic is as a medium for electron to flow from cathode to anode. The movement principle for electron is reverse to current. The selection for anode and cathode is based on how reactive the anode and cathode is. Anode terminal must be built from material which more reactive compare to material for cathode.

### 2.4 Type of Battery

Basically, there are two types of battery. They are non-rechargeable battery and rechargeable battery. The criteria for non-rechargeable or rechargeable battery are based on type of chemical reaction inside the battery. For non-rechargeable battery, the chemical reaction cannot be reversible. After one time used, this type of battery will be useless can need to be removed in proper way. For rechargeable battery, the chemical reaction can be reversible by apply the electric to the cell. It means the condition inside the battery is reconditioned back. The common example for non-rechargeable battery is alkaline battery. The common example for rechargeable battery is lithium ion battery.

There are so many variations for battery based on characteristics. The important characteristics are Voltage ($V$), Current ($I$), Ampere Hour (AH), weight, dimension, type of usage, specific gravity and electrolyte type. All of these characteristic have their own functions for battery.
Voltage is the term used to show the potential difference between two points. If the voltage is higher, battery can produce more amount of current to the load. Voltage standards for battery come in various values. There are 1.5 V, 3 V, 6 V, 9 V, 12 V, 24 V and 48 V. Current is the amount of current flows from anode terminal to cathode terminal through load. Current needs to be known to make sure cable is enough to bring the current to flow. If cable is not big enough, cable can damage due to undersize. So, cable needs to be ensured that follow specification. Ampere Hour is the term used to show how much a battery can be recharged for the specific time. For example is 1 AH. It means this battery can be recharged as 1 Ampere per Hour. If battery A is 2 AH and battery B is 1 AH, it means the charging rate for battery A is higher compare to battery B. Weight is the term used to show how heavy one battery is. It is important to make sure the support for battery can support battery without collapse. Specific Gravity is the term used to show how well the electrolyte liquid is. If the Specific Gravity shows the value below than 1, the electrolyte needs to be changed. It is because electrolyte cannot keep the electrons anymore. There are two types of electrolyte. First is dry cell and second is wet cell. This is to show that this battery needs maintenance or does not maintenance. For battery which requires maintenance, the electrolyte level needs to be maintained in order to keep battery in good condition.
Diagram 1: Diagram of dry cell battery

Diagram 2: Diagram of wet cell battery
2.4.1 Non Rechargeable Battery & Rechargeable Battery

Non rechargeable battery type is battery that cannot be recharged back once battery already used. The electrochemical process cannot be reversed due to some parts already gone during battery usage. The types of rechargeable batteries are alkaline battery, aluminium battery and zinc chloride battery. Normally this type of battery is cheaper compare to rechargeable type.

Rechargeable battery type is batter that can be recharged back once battery already used. The electrochemical process can be reversed back due to some parts are still exist during battery usage. The types of rechargeable batteries are lead acid battery, nickel cadmium battery, nickel zinc battery, lithium ion battery and nickel metal hydride battery.

2.4.1.1 Alkaline Battery

Alkaline battery is a type of non-rechargeable battery that common used in daily life. The reason this type of battery called alkaline battery is because of the alkaline electrolyte is made from potassium hydroxide. The advantages of alkaline battery are it has higher density and longer lasting compare to other battery. The anode is made from manganese dioxide and the cathode is made from manganese zinc. This alkaline battery was sold as 10 billion worldwide. This type of battery was developed for the first time Waldemar Jungner in 1899 and more developed by Thomas Alva Edison. This type of battery which uses zinc and manganese dioxide was invented by Lewis Urry in 1950. Finally this type of battery was patented by Karl Kordesch on 9 October 1957. This type of battery also has disadvantages due to have mercury content. The anode and cathode are consumed during discharge. The alkaline electrolyte is not used during reaction. The capacity of battery is strongly dependent to load. If the load is high, the capacity will low and vice versa.
Diagram 3: Diagram of alkaline battery

2.4.1.2 Aluminium Battery

Aluminium battery is a type of battery which produces electricity with the chemical reaction between oxygen and aluminium. Actually the aluminium battery is among the best battery because this type of battery has the highest energy density compare to other battery. The problem for this type of battery is cost for anode terminal is so high it has side effect to environment. This type of battery was restricted only for military application. The advantage for this type of battery is the life span can up to eight times compare to lithium ion battery.

The method to recharge the battery is to replace anode terminal with the new anode.
2.4.1.3 Zinc Chloride Battery

Zinc chloride battery is a non-rechargeable battery which uses zinc and manganese to create electricity by using electrochemical reaction. This battery is also dry cell battery. This type of battery is always used in low drain or intermittent equipment such as remote control, radio and flash light. The other word is this type of battery is always used in light duty application. The disadvantage for this type of battery is easily to corrode. The anode terminal is zinc and the cathode terminal is Chloride.
2.4.1.4 Lead Acid Battery

Lead acid battery is a common example for rechargeable battery. This lead acid was created by Gaston Plante and this battery is the most classic type for rechargeable battery. The disadvantage for this type of battery is this battery has less efficiency compare to other battery. It means that, this type of battery requires more space and weight in order to produce same power rating with other battery. Despite that, this type of battery also has advantage. The advantage for this type of battery is it can produce high surge current in a short range of time. Other advantage is the cost for this type of battery is relatively cheaper compare to other batteries. This type of battery is common used in daily life. This type of battery uses lead acid as electrolyte. This electrolyte needs to be top up when the real amount inside the battery is less than required. The top up can be done by using flute water. The disadvantage for this type of battery is the life span is less compare to other batteries.
Diagram 6: Diagram of lead acid battery

2.4.1.5 Nickel Cadmium Battery

Nickel Cadmium battery is a type of rechargeable battery. It uses nickel oxide hydroxide and metallic cadmium as terminals for battery. The advantages of this type of batter are good cycle life and high performance at low temperature. The other advantage for this type of battery is battery still can provide full capacity even though the charging is not enough. The battery also used in light duty such as clock, emergency lighting and etc.
Nickel zinc battery is a type of rechargeable battery. This type of battery uses nickel and zinc as terminals. This type of battery was created by Thomas Alva Edison in 1901. This type of battery later was improved Dr James J Drumm to be used in railway line. The advantage for this type of battery is this battery opens circuit when fully charged. This battery is also suitable to electronics equipment because of voltage stability. This battery has low internal resistance compare to other types of battery. This nickel zinc battery does not use metal hydrides, cadmium, lead or mercury which is difficult to recycle. Zinc and nickel are the elements which easy to recycle. The nickel zinc battery does not use flammable active material. It means that this battery is not easy to burn. This battery also reduces the factor to dendrites problem. Other advantages for this type of battery are has very high energy density, low discharging rate, can be discharge up to 100% and recharged back without problems.
2.4.1.6 Lithium Ion Battery

Lithium ion battery is a type of rechargeable battery that commonly used in electronic equipment. The working principle is the lithium ion moves from anode terminal to cathode terminal during charging and moves from cathode terminal to anode terminal during usage time. This type of battery uses intercalated lithium compound for material of electrode compare to metallic lithium which used in non-rechargeable battery.

Lithium ion battery is the common in home electronics. The advantages of this type of battery are has high energy density, tiny memory effect and also low self-discharge. Lithium ion battery is getting popular and now is replacing lead acid battery.

There are so many types for lithium ion battery. There are Lithium Cobalt Oxide, Lithium Iron Phosphate, Lithium Ion Manganese Oxide, Lithium Nickel Manganese Cobalt Oxide, Lithium Nickel Cobalt Aluminium Oxide and Lithium Titanate.
2.4.1.8 Nickel Metal Hydride

Nickel Metal Hydride battery is type of rechargeable battery. The positive terminal or anode is made from Nickel Oxide Hydroxide and the negative terminal or cathode is made from Hydrogen Absorbing Alloy. The energy capacity for nickel Metal Hydride battery can be double or triple compare to Nickel Cadmium battery. The development of Nickel Metal Hydride battery started from at Battelle Geneva Research Centre in 1967. The development of this type of battery was sponsored by Volkswagen AG and Daimler-Benz. The specific energy for this type of battery can up to 50 Wh/Kg, power density can up to 1000 W/kg and life cycle can be 500 charges. The research later continued by Philips Laboratories and CNRS. A successful battery finally demonstrated by Buschow and Willems in 1987. They approached battery by using mixture of La0.8Nd0.2Ni2.5Co2.4Si0.1 that retained 84% capacity of charge after 4000 charge-discharge cycles. Other approach to use mischmetal rather than lanthanum was introduced. The Nickel Metal Hydride came into market in 1989. The Nickel Metal Hydride structure and composition improved by Ovonic Battery Corporation in 1998.
2.5 Important Characteristic

For battery, there are several important characteristics in order to know the performance of battery. The examples of important characteristics are Voltage, Current, Power, Specific Energy Density, State of Health (SOH), State of Charge (SOC), Temperature, Cell Balancing, Charging Rate (C-Rate), Internal Resistance and Life Cycle. These characteristics are important to know the suitable application, durability, temperature, charging time and condition of battery. Every battery has their own characteristics and these characteristics differ from each other. The factors for different characteristics are from the method of construction, material usage and size of material.

2.5.1 Specific Energy Density

The definition of specific energy is energy over unit mass. This is used to measure the amount of energy inside of one material. Types of energy which can be measured are Helmholtz free energy, Gibbs free energy, specific enthalpy energy, specific internal energy, heat energy and electrochemical energy. Sometimes, this type of energy can be used to measure the kinetic energy and potential energy in one body.
The unit for specific energy is Joule per Kg or J/Kg. It means if the specific energy is 1 J/Kg, the energy inside the body which weight 1 Kg is 1 Joule. The higher the specific energy, the energy contained in one body. In SI base unit, the unit is m²/s². It is also can be derived from other quantity to get e=E/m. For food and beverage industry, the unit used is Kcal/g. It means Kilocalorie per gram. It shows how much calorie in 1 gram of food. In electrical engineering, the unit used is Kwh/Kg. It means Kilowatt hour per Kilogram. It shows how much Kilowatt Hour in 1 Kg. BTU/lb is used in imperial country. It shows how much British Thermal Unit in 1 pound. To measure the body tissues absorbs energy from radiation, the Gray and Sievert units are used. Specific Strength is the energy contained in one body that can withstand the centrifugal force without fly away due to rotation.

The concept of specific energy in battery is acquired from chemical term. The unit used is molar rather than kg. The molar unit is special unit used for chemical engineering. Molar actually is not dimension unit. It counts the pure no or no of molecule, because the molecule is concerned rather than volume or weight.

Energy density is the quantity of energy that contained in one body per unit volume. It differs to specific energy, because it more precise. The density of energy is concerned to measure energy inside one material.

2.5.2 State Of Health

State of Health (SOH) is the characteristic to determine the condition for battery. It is important characteristic to know the battery still in good condition or already bad condition and needs to replace. This SOH is the term used for battery. The unit to figure the SOH can be written as percentage point. For examples are 100%, 80% and other values.

The values for SOH during manufacturing time typically always 100% or more than 90%. But this value decreases over the time. The factors to determine the
rate of decreases is determined by temperature, relative humidity, battery usage, load condition and etc.

SOH determined by battery management system to know the value of SOH. And then the SOH is compared to the threshold SOH to determine whether this battery is suitable to work or cannot work. This determination also can be made to know the life time for battery. If battery passes the SOH test, battery released for market.

There are some parameters which used to determine the SOH by battery management system. Manufacturer sets the standard for SOH based on parameters to determine whether battery passes or fail SOH test. The parameters are internal resistance, capacity, self-discharge, ability to receive charge and number of charge-discharge cycles.

2.5.3 State Of Charge

State of Charge (SOC) is an important characteristic to determine the amount of charge inside the battery. This is important to know the battery can be used or cannot be used. If battery cannot be used due to charge inside battery is not enough, battery needs to be recharged back by using charger. Unit for SOC is percentage point. For examples are 100%, 80% and etc. The alternate way to determine the condition of battery is Depth of Discharge (DOD). The DOD is reverse way with SOC. For example if SOC is 100%, DOD is 0%. If SOC is 70%, DOD is 30%. The objective to use SOC is to determine the current condition for battery. The objective to use DOD is to determine the lifetime for battery after repeated use.

The SOC cannot directly be measured, but some parameters are used to determine the SOC. There are two methods, first is online and second is offline. For offline method, battery charged in constant rate until fully charged. The unit counting that can be used is Coulomb-counting. But this method is expensive and can disturb the functionality of battery. Normally this method can be used in lab. In online
technique, there are five parameters to determine the SOC. The parameters are chemical, voltage, current integration, Kalman filtering and pressure.

For chemical method, only wet cell battery type can be tested by using this type of testing. The test is done by taking the specific gravity from electrolyte. The condition of electrolyte is important to know the condition of SOC. If the condition of electrolyte is good, the electrolyte can keep charge for the long time. If the condition of electrolyte is not good, electrolyte cannot keep charge for the long time. The instrument used to determine specific gravity is hydrometer. To determine the specific gravity, it is important to measure the volume of electrolyte and then weigh it. After that, ratio is taken by comparing the volume over weight. The SOC can be known by looking the table.

For voltage method, voltage is taken from battery to know the SOC. This voltage method can be used during online. For example if maximum voltage is 12 Vdc and the taken voltage is 10 Vdc. The percentage of SOC can be known by using ratio Voltage taken / Voltage Original. Based on this ratio, the percentage of SOC is 10V / 12V = 83.33%. This method is famous method because can be done during operation without dismantle battery.

For current integration method, current is taken from battery and then integrated to time to know the SOC. The problem for this method is other battery is required as standard. The other battery also needs to be make sure is 100% SOC. If the standard battery is not 100% SOC, the measurement can be not accurate.

The other technique that can be used is Kalman filtering. Battery can be modelled to electrical components which used by Kalman filter to predict the over-voltage and current.

The other technique that can be used to determine SOC is by using pressure method. The problem for this technique, this technique only can be used onto Nickel Metal Hydride battery. The pressure inside NiMH battery increases when battery is charged. Pressure gauge can be installed to determine the pressure inside the battery.
2.5.4 Temperature

Temperature is an important factor to determine the condition of battery. Battery has the temperature range to operate. If the temperature is too low or too high, battery cannot operate in optimum condition. The discharging process is more crucial compare to charging process and special precaution must be taken to battery. Temperature is too low or too high reduces the rate for battery to accept charge. So battery needs to be set in suitable temperature before start charging.

Older types of battery such as lead acid and NiCd are more tolerate to high temperature rather than to newer types of battery such as Li-Ion. This tolerate condition make them easy to be charged below freezing but in the charging rate needs to be reduced.

All types of battery are good charging in moderate temperature. For lower temperature charging, the rate of charging needs to be reduced due to the rate of mixture between of oxygen and hydrogen also reduced. If charging rate is high, pressure inside cell leads to venting. The venting phenomena makes voltage drop. Reduce the charging rate during low temperature can avoid pressure build up inside cell. Nickel based charger can offer protection to the battery during charging at low temperature. To make sure all types of battery can be charged at fast rate, manufacturer attaches together with thermal blanket. The function of thermal blanket is to make sure the environment temperature for battery is stable and in moderate temperature range. The thermal blanket adjusts the environment temperature to make sure the environment temperature is suitable.

Lead acid battery is tolerance to low temperature due their sluggish behaviour. The voltage produced by lead acid is determined by temperature. For example the voltage is low when high temperature and the voltage is high when low temperature. When lead acid battery charged at not constant temperature, the charger should be able to adjust the voltage to reduce the effect of stress to battery. Freeze lead acid battery can make permanent damage to this type of battery. It is because lead acid battery is water type electrolyte. If battery freezed during discharge condition,
electrolyte inside the battery tends to increase in volume and causes damage to battery case. It makes battery to leak.

The temperature for Li-Ion battery is charged at fast rate is from 5°C to 45°C. The Li-Ion battery charging current should be reduced if the temperature is below than 5°C. Due to reduction of diffusion rate at anode, battery should not be charged.

The worst enemy to all types of battery is heat. Heat can make damage to battery. If nickel-based battery is charged at high temperature, it reduces generation of oxygen. When oxygen generation reduces, it also reduces the acceptance of charge. The heat makes charger thinks that battery is fully charged whereas battery is not fully charged.

Heat also makes other types of battery are not fully charged. The heat reduces acceptance of charge for battery. Charging and discharging the battery at high temperature makes gas to be generated and then makes cylindrical cell to vent. Capacity for battery also loses if battery is charged at high temperature.

### 2.5.5 Indication

Battery indicator is an indicator that gives information about battery. The type of indication is visual inspection for State Of Charge (SOC). This indicator is important for electric vehicle. The function of battery indicator is to indicate the condition of battery visually. The parameter that is used for indication is voltage. Voltmeter was used to indicate the amount of voltage for battery. Colour code is used to replace voltmeter for easier indication. The other type of indicator is light. Light is used as signal to indicate the condition of battery. The concept of light is similar to colour code. The other equipment that used together with voltmeter is ammeter. Ammeter is used to measure current from battery. For electric vehicle, some buzzer is also used to give alarm if SOC for battery is below than threshold.
2.5.6 Cell Balancing

Cell balancing technique is a technique to distribute the charging to all batteries. This technique only can be used if batteries are more than two. The benefits of this technique are the life span for battery can be prolonged, the capacity for batteries can be balanced, voltage differences can be reduced and to avoid short circuit between batteries. Battery balancing is done by battery balancer. Balancer is always used in lithium ion battery pack for electronic components.

Typically, every battery has its own capacity and SOC. The factors that make different capacity are manufacturing, assembly and temperature variances. Due to every battery has its own capacity, a battery balancer is required to stabilize the SOC for every battery. Without an effective balancing technique, every battery which smallest capacity of SOC can damage due to overcharge. Without an effective balancing technique, every battery which largest capacity of SOC cannot be fully charged due to undercharge. With proper technique, the balance circuit should be arranged so that battery which smallest capacity of SOC is same with the battery which has largest capacity of SOC. It means that, energy is transferred from or to individual cell until balance condition achieved.

Complete battery management system is include all parameters such as charging rate, temperature and other features to make life longer for battery.

2.5.7 Design of Converter

Converter is equipment that can change the amount of voltage from one value of voltage to be other value. The type of current that can be regulated is Direct Current (DC). There are three types of converter. First is boost converter. The function of boost converter is to boost voltage to be required value if voltage is not enough. Second is buck converter. The function of buck converter is to buck voltage to be required value if voltage is over. Third is buck-boost converter. The function of
buck-boost converter is to buck the voltage if voltage is over and boost the voltage if voltage is not enough. It means that buck-boost converter has dual functions. There are a few methods that can be used to regulate the voltage. The common method is by using Pulse Width Modulation (PWM). PWM is method to regulate voltage by using time. By controlling the voltage time, voltage can be regulated.

### 2.5.8 Charging Rate

Charging rate or also known as C-Rate is a unit to measure how fast battery can be recharged in a specific time. For example if C-Rate for battery is 1C, it means battery can be recharged as 1 A in 1 hour or 1AH. It is important to know the characteristic for battery to determine the time for fully charging. Every battery has own charging capacity. The capacity of battery can be measured directly by using battery analyser. During battery discharged rate is measured by analyser at calibrated current. For lead acid battery, commonly is 1.75 V per cell, NiCd and NiMH battery commonly is 1.0 V per cell and for Li-Ion battery commonly is 3.0 V per cell. To measure the capacity of battery, test can be done by using charging rate and discharging rate. For example of C-Rate is 1C, battery is fully charged in 1 hour. So at this time, battery capacity is 100%. And then battery is discharged, time to fully discharged is taken. Let say the battery is fully discharged in 30 minutes or half hour, it means the capacity of battery is 50%. Every battery has own capacity, some batteries are overrated and some batteries are underrated. Based on research, it is better to charge battery at lower C-Rate rather than higher C-Rate. The reason is because, if battery is fully charged at higher C-Rate, not all charges absorbed by battery. Some charges turn to heat. To increase the capacity of battery, it is better to charge battery at lower C-Rate even though it takes longer time.

Every type of battery has its own capacity. The lead acid battery is rated by 0.2C and 0.05C. The NiCd battery is rated by 10C.
### 2.5.9 Internal Resistance

Internal resistance is resistance that exists inside the battery. This resistance is important to make sure battery is not short circuit. Internal resistance also plays the function to determine how much current can be supplied to the load. Lower internal resistance makes better performance for battery. Performance of battery is determined by battery performance. The common value for internal resistance is milliohm. Internal resistance also produces heat inside battery.

Lead acid battery has very low internal resistance compare to others. Lead acid battery also works well to high current burst for a few seconds. The problem of lead acid battery is cannot withstand with high current in long time. There are two main factors that increase the internal resistance inside battery. First is sulfation and second is grid corrosion. Other factor that increases internal resistance is temperature.

Crystalline formation is the main factor that increases internal resistance in nickel based battery. This crystalline formation can be reduced by deep cycling.

The internal resistance inside Li-ion battery increases with usage and aging but can be slowed via top up the additive to electrolyte.

Alkaline and carbon zinc batteries relatively have higher internal resistance compare to other types of battery. This feature makes these types of batteries cannot be used in low current application such as flashlight, remote control and etc.

There are two methods to measure internal resistance. First method is direct current (DC) measuring and second method is alternate current (AC) measuring. For DC current measuring, voltage drop is measured by given current. For AC current measuring, voltage drop also measured but with additional reactance.

The reason for different value of internal resistance for different type of battery is because different material. Some material has very low internal resistance. Some material has low internal resistance. Some material has middle internal
resistance. Some material has high internal resistance. Some material has very high internal resistance.

2.5.10 Life Cycle

Every battery has own life cycle. The duration for life cycle depends on some factors. The factors are type of battery, material of battery, charging rate, environment, voltage and condition of battery.

For non-rechargeable battery, it only can be used once. After this type of battery is used, it cannot be recharged back. It is because the condition of battery cannot be reversed.

The other factor is material of battery. Some materials are good quality and can lasting for the long time. Some materials are not good in quality and only cannot lasting for the long time.

Charging rate or C-Rate also plays important factor that prolong battery usage. It is better to charge battery at lower C-rate rather high C-Rate even though time taken is longer for low C-Rate.

If battery needs to be preserved for the long time, it is better to keep in suitable environment. Life cycle can short if battery is kept in unsuitable temperature and relative humidity. Too warm or to cold environment is not good for battery. High relative humidity makes low insulation to battery. Low insulation makes short connection between anode and cathode terminal. Short circuit makes explosion to battery.

If battery voltage is different with load or charger, it can damage battery. For example if battery wants to be fully charged, the nominal voltage on battery is 12Vdc and nominal voltage on charger is 240Vac, the different voltage makes over voltage and lastly damages the battery. If voltage on battery that wants to be used is 12 Vdc
and voltage on load is 4 Vdc, it makes under voltage and can damage load because the difference of voltage is big. So the voltage value is important value for circuit.

Condition of battery is one factor to determine the life cycle for battery. For example, the life cycle for battery is short if battery corrodes. It is because corrosion converts active material to be inactive material. The factor of corrosion is humidity. The presence of water or humidity makes metal corrodes. When metal corrodes, the chemical condition inside the metal is different. This chemical condition cannot work for chemical reaction to generate electricity. Some methods can be used to avoid corrosion in order to preserve battery.
CHAPTER 3

METHODOLOGY

3.1 Introduction

Some experiments were done for sample balancing testing, passive balancing testing and active balancing testing. For sample and passive balancing, some testing already done to know the relationship between input voltage (Vi), output voltage (Vo), rotation per minute (RPM) and output current (Io). This is important to know the interrelation between of them.

3.2 System Design

This system is designed to monitor voltage at Li-ion battery. The regulator for this system regulates voltages which already measured. Once this system detected any voltage drops which happen at Li-ion battery, boost converter takes some necessary actions to regulate voltage so that output voltage still maintain at 12 Vdc. Output voltage needs to be maintain at 12 V dc so that load voltage is not interrupted. If load voltage is interrupted, it disturbs operation for the entire of vehicle. The effects which can be happen to the vehicle are power cut-off, vehicle cannot be full speed and electronic system is disturbed.
3.3 Equipment Selection And Working Principle

The selection of equipment is important to make sure that all equipment can work together in order to get optimum performance and result. Technical specifications for all equipment need to be studied so that all equipment can be suited.

There are two major aspects which involve for this project. First is hardware part and second is software part. These two parts play important rule to make sure this system works properly.
3.3.1 Arduino Uno Rev3

Arduino Uno Rev 3 is a microcontroller which controls the operation for entire of circuit. This Arduino is like ‘brain’ to the system. This controller consists of two major parts. First is hardware part and second is software part. This Arduino operates
on 5 Vdc. In hardware part, it has three major components. First is analogue input, second is digital input or output and third are others. All parts have their own function to operate. For example for analogue input, it only can receive input from analogue type. For digital input or output, it only can receive input from digital type. But this digital input or output needs to be configured to make sure it operates in input or output.

Photo 2: Arduino Uno Rev3

3.3.2 240 Vac To 12 Vdc Rectifier

The function of rectifier is to change the type of voltage and current from AC type to be DC type. This is important step because input voltage is Vac and output voltage is Vdc. Electronic equipment cannot be operated in Vac and only can be operated in Vdc. There are two major parts for this rectifier. First is transformer and second is rectifier. The function of transformer is to transform the value of voltage. The
methods which can be used are step up and step down. If voltage needs to be increased, step up transformer can be used. If voltage needs to be decreased, step down transformer can be used. The method needs to be used is depend on amount of voltage that required for load. The basic principle for this operation is \( P_1 = P_2 \) and \( P = VI \). It means that input power and output power is same. If voltage adjusted, current also automatically adjusted. The cable size depends on current. The second part for this system is rectifier. This rectifier has circuit to change AC type to DC type. The rectifier needs completely change the AC type to DC type without any disturbance and distortion. It is important to make sure electronic components in this circuit work properly.

Diagram 11: Diagram of 240 Vac to 12 Vdc converter

3.3.3 12 Vdc To 5 Vdc Chopper

Chopper is the circuit that changes the amount of voltage from 12 Vdc to 5 Vdc. The chopper only changes the DC. Chopper cannot work to change the amount of AC type. The reason chopper changes the amount of voltage is some equipment especially are Arduino Uno Rev3, current detectors, temperature detectors and liquid crystal display use 5 Vdc as the amount of input voltage. This equipment cannot use 12 Vdc as power source level. If they use 12 Vdc, over voltage can happen and damaging the equipment. The method of operation for this chopper circuit uses
PWM method. It means that output voltage is determined by timing on operation. The timing is controlled by PWM to produced desired output voltage.

Diagram 12: Diagram of 12 Vdc to 5 Vdc converter

3.3.4 Voltage Divider

Voltage divider is important to divide the voltage from 12 Vdc to be appropriate voltage. The original input voltage sensed by Arduino Uno Rev 3 is 12 Vdc. This 12 Vdc needs to be changed to 5 Vdc. It is because the maximum input voltage that can be detected by Arduino Uno Rev 3 is 5 Vdc. If more than 5 Vdc, Arduino Uno Rev 3 get damaged. The method to divide the input voltage is using potentiometer and resistor. The resistor and potentiometer need to be arranged so that voltage can be divided properly between potentiometer and resistor. The potentiometer and resistor are arranged in series. Based on series connection characteristic, voltage is different but current is same.

Diagram 13: Diagram of voltage divider
3.3.5 Boost Converter

Boost converter is important to boost the voltage if voltage is not enough or below than 12 Vdc. Boost converter boosts the voltage to make sure output voltage is not below than 12 Vdc. The output voltage needs to be maintained around 12 Vdc to make sure operation for electrical vehicle runs smoothly. There are some problems if under voltage happens to the load. For examples are vehicle cannot be started, vehicle cannot be full speed, some functions are disturbed and etc. The method of operation for booster is by using PWM method. The method of operation for PWM is by using timer. The timing determines the output voltage.

![Diagram of boost converter](image)

Diagram 14: Diagram of boost converter

3.3.6 Liquid Crystal Display

The function of liquid crystal display (LCD) is to display the input voltage and result for this control system. The input voltage is detected by Arduino Uno Rev 3 first and then displayed by LCD. Once output voltage is produced by boost converter, output voltage is detected by Arduino Uno Rev 3 and then displayed by LCD. The input voltage for LCD is 5 Vdc and it gets power supply from 12 Vdc to 5 Vdc chopper.
3.3.7 Temperature Sensor

Temperature sensor is a device to get temperature data from battery. Temperature sensor is attached to the body of battery in order to get temperature. It is important to know the condition for battery body. This temperature sensor is powered by 5 Vdc. This sensor has 3 connections. First connection is for 5 Vdc, second connection is for data and last connection id for ground. The data connection is connected to the Arduino Uno Rev 3 via digital input pin. It is because the data type is digital. The digital data is read by Arduino Uno Rev 3. The temperature data also is displayed by LCD.
3.3.8 Current Sensor

The function of current sensor is to measure the amount of current. It is important to know how much current which already produced by battery. This system also can be damaged if over current happens. The current sensor is powered by 5 Vdc. The current sensor has 3 connections. First terminal is for 5 Vdc, second terminal is for +ve and last terminal is for –ve. Current sensor detects voltage from battery and then measures the current by using resistors configuration inside the current sensor. The current sensor needs to be configured to set the current range. Normally there are 3 ranges for current setting. First is 5 A, second is 15 A and third is 30 A.
3.4 Software Configuration

Software is important as a standard of procedure to instruct and control the operation of control system. There are so many types of language that available in the market. For examples are C programming language, FORTRAN programming language and assembly language. The characteristics for every language are different for each other. Some languages are difficult to write but easy in configuration setting. Some languages are easy in writing but tedious to write the instructions. The software used is C programming language. The C programming language is chosen due to compatibility to Arduino Uno Rev 3. It is important the working schedule is correct due to avoid errors. There are 2 types of errors. First is syntax error, which is about writing error. Second is working error, which is about the way of process. For syntax error is easy to be detected. But for working error is difficult to be detected. The flow chart needs to be checked and to be made sure that is correct before program writing can be done. There are two sets programming were used. First is to passive balancing and second is active balancing.
CHAPTER 4

RESULTS AND DISCUSSION

4.1 Power Supply

Input voltage should show the value of 240 Vac. This is standard value for Malaysia electrical rules and regulations. The standard technical specification for Malaysia electrical is 240 Vac, 50 Hz. This standard was inherited from British when British conquered Malaya, Sabah and Sarawak before.

Step down transformer changes the value from 240 Vac to be 12 Vac. The formula that be used by transformer is $P_1 = P_2$. The specific formula is $P = VI$. By adjusting the amount of turn ratio, voltage value can be adjusted by using $VI/N$.

The function of rectifier is to change the type of AC to be DC. Input voltage 12 Vac is changed to be 12 Vdc. 12 Vdc power supply is used by battery and boost converter.

The function of 5V chopper is to change the value of 12 Vdc to be 5 Vdc. It is important to make sure that appropriate level for equipment. 5 Vdc power supply is used by Arduino Uno Rev 3, current sensor, temperature sensor and LCD.
4.2 Battery Monitoring

Battery needs to be monitored every time to know the condition of battery. 3 items are monitored from battery. First is voltage, second is current and third is temperature. 3 items need to be monitored to make sure battery still working during operation. For voltage monitoring, before battery into Arduino Uno Rev 3, voltage divider is used to convert 12 Vdc to be 5 Vdc. It is because the maximum battery that safe for Arduino is 5 Vdc. So it means that 12 Vdc from battery is equivalent to 5 Vdc to Arduino Uno Rev 3. Once input voltage is sensed by Arduino Uno Rev 3, Arduino Uno Rev 3 processes the data and reflects to data. For example, if Arduino Uno Rev 3 senses 7 Vdc, Arduino Uno Rev 3 instructs PWM to switch on 42% so that boost converter supports 5 Vdc. Arduino Uno Rev 3 only feedbacks to voltage. Arduino Uno Rev 3 does not feedback to current and voltage. Current is varied if voltage is varied based on \( V=IR \). Resistant value is fixes. The value for temperature is constants. The temperature is only used to monitor the condition of battery. Normally battery’s temperature is constants.

4.3 DC To DC Boost Converter

DC to DC boost converter is used to boost voltage if input voltage from battery is not enough to 12 Vdc. 12 Vdc is voltage for battery. Battery is required to supply 12 Vdc to make sure that electrical and electronic equipment inside electrical vehicle work properly. DC to DC boost converter boosts only the required voltage by controlling ON OFF time from PWM. For example, if input voltage from battery is 6 Vdc, Arduino Uno Rev 3 instructs PWM so that PWM switches on MOSFET by 50%. When MOSFET is switched on by 50%, boost converter boosts voltage as 6 Vdc. The total output voltage from boost converter and input voltage is 12 Vdc. Attached is the photo:
4.4 DC Motor

DC motor is used as a load to work. DC motor can give the output in term of Output Voltage, Output Current and Rotation Per Minute (RPM).
4.5 **LCD Result**

The function of LCD is to display the voltage value of battery and the output voltage for boost converter. The total value for input voltage for battery and output voltage for boost converter is 12 Vdc. The total value must not more than 12 Vdc. The output
value for boost converter reflects to input voltage for battery. For example if input voltage for battery is 7 Vdc, the output voltage for boost converter must be 5 Vdc. To instruct the on timing for boost converter, PWM can be used to control the switch timing for boost converter.

Photo 8: LCD result
4.6 Limitation Of Arduino

From the result, the actual value which acquired from Arduino Uno Rev 3 is lower than 12 Vdc. The actual result should be 12 Vdc. This is the limitation for Arduino Uno Rev 3. Arduino Uno Rev 3 cannot read actual value.

4.7 Results For Experiment

After some testing already done by using this control system, result already obtained and plotted on graph. The experiments can be divided into two categories. First is for passive balancing and second is active balancing. For passive balancing, some experiments already done to show the relationship between Output Voltage (Vo), Rotation Per Minute (RPM) and Output Current (Io).
The DC to DC boost converter was used as a sample to show the relationship between Vo, Io and RPM. Below are the results which already got after some experiments.

Details for result:
<table>
<thead>
<tr>
<th>Input Voltage (V)</th>
<th>Output Voltage (V)</th>
<th>Rotation Per Minute (RPM)</th>
<th>Output Current (mA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.00</td>
<td>0.00</td>
<td>0</td>
<td>0.00</td>
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</tr>
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</table>

Table 1: Result for sample balancing system
Based on the Graph 1 which already obtained above, it is found that RPM is proportional to the voltage. Based on the formula that was given, RPM is proportional to the voltage. It means if Voltage increases, RPM for motor also increases. The formula used is:

\[ n = \frac{V_m - I_a R_m}{k_b \Phi} \]

Formula 1: Formula for DC motor speed based on Voltage
Based on the Graph 2, it was found that Io is proportional to Vo. It means that, if Vo increases, Io also increases based on this formula. The formula used is:

\[ V = IR \]

Formula 2: Formula for Voltage and Current
Based on the Graph 3, it was found that RPM is proportional to Io. It means that, if Io increases, RPM also increases based on this formula. The formula used is:

\[ n = \frac{(I_o - I_a) (R_m)}{k_b \Phi} \]

Formula 3: Formula for DC motor speed based on Current

Other experiments also been done to show the relationship between Duty cycle (D) and Vo, RPM and Io. The circuit needs to be modified so that D can play important roles to control the RPM, Vo and Io. Below is the photo for circuit:
Photo 10: Circuit configuration to do experiments
Details of result:

<table>
<thead>
<tr>
<th>Duty Cycle (D)</th>
<th>Output Voltage (V)</th>
<th>RPM</th>
<th>Output Current (mA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.00</td>
<td>0</td>
<td>0.00</td>
</tr>
<tr>
<td>0.2</td>
<td>0.70</td>
<td>3431</td>
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</tr>
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<td>0.4</td>
<td>1.96</td>
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<td>0.6</td>
<td>3.60</td>
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<td>3.92</td>
<td>8097</td>
<td>43.90</td>
</tr>
<tr>
<td>1</td>
<td>5.00</td>
<td>8231</td>
<td>45.60</td>
</tr>
</tbody>
</table>

Table 2: Result for passive balancing system

Graph 4: Relationship between Vo and D

Based on the Graph 4 which already obtained, it is found that D plays important role to determine the value of Vo. The formula used is:

\[ Vo = Vi(D) \]

Formula 4: Formula for Duty Cycle (D) to control Vo
Based on the Graph 5 which already obtained, it is found that D plays important role to determine the value of RPM. The formula used is:

\[
\text{RPM} = (\text{RPM}) \times (D)
\]

Formula 5: Formula for Duty Cycle (D) to control RPM
Based on the Graph 6 which already obtained, it is found that D plays important role to determine the value of RPM. The formula used is:

\[ Io = (Ii) (D) \]

Formula 5: Formula for Duty Cycle (D) to control Io

![Graph 7: Relationship between RPM VS Vo](image)

Based on the Graph 7 which already obtained above, it is found that RPM is proportional to the voltage. Based on the formula that was given, RPM is proportional to the voltage. It means if Voltage increases, RPM for motor also increases. The formula used is same with Formula 1:
Based on the Graph 8, it was found that RPM is proportional to Io. It means that, if Io increases, RPM also increases based on this formula. The formula used is same with Formula 3:

The active balancing system already assembled and tested. Attached is the photo from experiments:
Photo 11: Data collection from experiment
Details for experiments:

<table>
<thead>
<tr>
<th>Input Voltage (V)</th>
<th>Duty Cycle</th>
<th>RPM</th>
<th>Output voltage (V)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
<td>0.25</td>
<td>7200</td>
<td>5.00</td>
</tr>
<tr>
<td>0.50</td>
<td>0.24</td>
<td>7200</td>
<td>5.00</td>
</tr>
<tr>
<td>1.00</td>
<td>0.23</td>
<td>7200</td>
<td>5.00</td>
</tr>
<tr>
<td>1.50</td>
<td>0.22</td>
<td>7200</td>
<td>5.00</td>
</tr>
<tr>
<td>2.00</td>
<td>0.21</td>
<td>7200</td>
<td>5.00</td>
</tr>
<tr>
<td>2.50</td>
<td>0.20</td>
<td>7200</td>
<td>5.00</td>
</tr>
<tr>
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<td>0.19</td>
<td>7200</td>
<td>5.00</td>
</tr>
<tr>
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<tr>
<td>5.00</td>
<td>0.00</td>
<td>7200</td>
<td>5.00</td>
</tr>
</tbody>
</table>

Table 3: Results for active balancing system

Graph 9: Relationship between Vi VS D

Based on the result that already obtained from the experiments, D will be adjusted automatically if Vi drops. The reason is because to maintain the RPM and Vo so that electric vehicle still working even though the Vi is reduced. Based on the data that
already obtained, if Vi is 0V, the maximum D that can be achieved is 0.25. So the value for D is between 0 and 0.25. If Vi maintains 5V, D still maintain 0 because boost converter does not need to work to support voltage. The formula used is:

\[ D = 1 - \frac{V_i}{V_o} \]

Formula 6: D is determined based on Vi

Based on graph 10, RPM still maintain even though D is changing. RPM need to be maintained in order to make sure electric vehicle still working even though Vi drops.
CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Summary

Electric vehicle has bright prospect to replace fuel oil vehicle. Electric vehicle is cleaner and greener compare to fuel oil vehicle. The problem of electric vehicle such as cannot go further is reduced. Battery monitoring system can be developed in electric vehicle to monitor the condition of battery. This monitoring system can give warning signal to user once battery is going problem.

5.2 Recommendation

Battery monitoring system for battery is far away from perfection. So, other study can be done to improve quality, reliability and maintenance rate for battery monitoring system.

5.2.1 Status Signal

Signal for status can be added to the system to improve the battery monitoring system. It is because the signal status is important to give warning if sign of degradation exists. For example if SOC and SOH for battery are lower than threshold.
The signal status can be made from light emitting diode (LED) or buzzer. The preference device is LED. It is because LED consumes power smaller than buzzer. Buzzer consumes much power compare to LED.
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8) (Laifa Taob,c,d,1, Jian Maa,b,1, Yujie Chengb,c,1, Azadeh Noktehdand,e, Jin Chongf, Chen Lua,b,2,2, 2017)
9) (Qingxia Yang,a, Jun Xua, *, Binggang Caoa, Dan Xua, Xiuqing Lib, Bin Wanga, 2016) (Koko Friansa1, Irsyad Nashirul Haq2, Bening Maria Santi3, Deddy Kurniadi4, Edi Leksono5,, 2016)
APPENDICES

APPENDIX A: LEM-200 Technical Data
APPENDIX B: Software configuration

For passive balancing, details of programming:

```c
int pwm = 3;  // assigns pin 3 to variable pwm
//int pot = A0;  // assigns analog input A0 to variable pot
int t1 = 0;   // declares variable t1
int t2 = 0;   // declares variable t2
void setup()  // setup loop
{
    pinMode(pwm, OUTPUT);  // declares pin 3 as output
//  pinMode(pot, INPUT);  // declares pin A0 as input
}
void loop()
{
    // t2= analogRead(pot);  // reads the voltage at A0 and saves in t2
    // t1= 1000-t2;       // subtracts t2 from 1000 ans saves the result in t1
    analogWrite(pwm, 00);  // sets pin 12 HIGH
//  delayMicroseconds(2000);  // waits for t1 uS (high time)
//  analogWrite(pwm, 100);  // sets pin 12 LOW
//  delayMicroseconds(2000);  // waits for t2 uS (low time)
}
```

For active balancing, details of programming:

```c
// Final Year Project
// Mohammad Izarul Haq
int potentiometer = A0;
int feedback = A1;
int PWM = 3;
int pwm = 0;
```
#include "LCD5110_Graph.h"
LCD5110 myGLCD(5, 6, 7, 9, 8);  // Setup Nokia 5110 Screen CLK=5, DIN=6, DC=7, RST=9 CE=8,
extern uint8_t SmallFont[];     // Small font display
extern uint8_t MediumNumbers[]; // Medium font number display
unsigned long millisPassed = 0;
unsigned long secondPassed = 0;
unsigned long minPassed = 0;
unsigned long previousMillis = 0;
unsigned long previousSecond = 0;
unsigned long previousMin = 0;
void setup() {
  pinMode(potentiometer, INPUT);
  pinMode(feedback, INPUT);
  pinMode(PWM, OUTPUT);
  Serial.begin (9600);
  pinMode (PWM, OUTPUT);
  Serial.println ("Testing"); /\ To show the value in serial monitor
  Serial.print ("Amp In");Serial.print ("\t");Serial.print ("Vin");Serial.print ("\t");
  Serial.print ("Temp In");Serial.print ("\t");Serial.println ("Vout"); //To show the
  Serial.begin (9600);
  myGLCD.InitLCD(); //initialize LCD with default contrast of 70
  myGLCD.setContrast(68);
  myGLCD.setFont(SmallFont); // Set default font size. tinyFont 4x6, smallFont 6x8,
  mediumNumber 12x16, bigNumbers 14x24
  myGLCD.clrScr();
  myGLCD.print("TESTING",CENTER,0);
  myGLCD.print("123",CENTER,12);
  myGLCD.print("Please Wait",CENTER,24);
myGLCD.print("Izarul", CENTER, 40);
myGLCD.update();
delay(2000);
myGLCD.clrScr();

}

void loop()
{
  float voltage = analogRead(potentiometer); // read the input on analog pin 0:
  float voltage1 = voltage * 1.00 * (5.0 / 1023.0); // Convert the analog reading
  float output = analogRead(feedback);
  float output1 = output * 1.00 * (5.0 / 1023.0); // Convert the analog reading

  if (voltage1 < output1)
  {
    pwm = pwm + 1;
    pwm = constrain(pwm, 0, 255);
    // delayMicroseconds(5000); // waits for t1 uS (high time)

    myGLCD.clrScr();
    myGLCD.print("voltage1 = ", 0, 10);
    myGLCD.printNumF(voltage1, 2, 45, 10);
    myGLCD.print("output1 = ", 0, 30);
    myGLCD.printNumF(output1, 2, 45, 30);
    myGLCD.print("pwm = ", 0, 20);
    myGLCD.printNumF(pwm, 2, 45, 20);

    myGLCD.update();
    delay (1500);
  }
}
if (voltage1 > output1)
{
    pwm = pwm-1;
    pwm = constrain(pwm, 0, 255);
    delayMicroseconds(5000); // waits for t1 uS (high time)
    myGLCD.clrScr();
    myGLCD.print("voltage1 = ",0,10);
    myGLCD.printNumF(voltage1, 2,45,10);
    myGLCD.print("output1 = ",0,30);
    myGLCD.printNumF(output1,2,45,30);
    myGLCD.print("pwm = ",0,20);
    myGLCD.printNumF(pwm, 2,45,20);
    myGLCD.update();
    delay (1500);

}

analogWrite(PWM,pwm);