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JUDUL: ENERGY MANAGEMENT OF BATTERY TO DC MOTOR

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ENERGY MANAGEMENT OF BATTERY TO DC MOTOR

AHMAD SYAHIR BIN ZAINAL

A report submitted in partial fulfillment of the requirements for the award of the degree
Bachelor of Mechanical Engineering

Faculty of Mechanical Engineering
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NOVEMBER 2008

SUPERVISOR'S DECLARATION

We hereby declare that we have checked this project and in our opinion this project is satisfactory in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering

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I hereby declare that the work in this thesis is my own except for quotations and summaries which have been duly acknowledged. The thesis has not been accepted for any degree and is not concurrently submitted for award of other degree.

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To my beloved father, mother and my family

Hj Zainal Bin Ahmad Nor

Hjh Siti Isha Binti Tumin

Ms. Nur Aatira Binti Zainal

Ms. Nur Aafifa Binti Zainal

Mr. Syaiful Adli Bin Zainal

Mr. Ahmad Yatimi Bin Zainal

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My heartfelt thanks go to my beloved parents and my family who always supported me and willing fully sacrifice themselves just to see me succeed. Last but not the least, all the glory belonging to Allah. He is worthy of all praise.

ABSTRACT

An electric vehicle (EV) is vehicles that use an electric as its power source. Electricity can be generate by many ways like solar, wind and water. An EV will produce almost zero emission. An EV used a direct current (DC) motor as exchange with the internal combustion engine (ICE) in conventional vehicle and in hybrid electric vehicle (HEV). A battery electric vehicle (BEV) is just using battery as its power source which is different from HEV that are using ICE as a generator and as a secondary power source that still produce pollution in the air. The energy for BEV is generated by battery to DC motor. This part is known as energy management of battery to DC motor. There is method to estimate the state of charge (SOC) from a battery. In this project, an experiment have be done using 5 horsepower (HP) DC motor and a lead-acid battery to estimate the SOC by using an open circuit voltage (OCV) of a battery. For charging profile, a data is produced by using a 12V 20A charger that is connected to a series of battery. A simulation for determining SOC of a battery to DC motor also have be done by using a MATLAB software version 7.6.0 (R2008a). By an experiment, result of charging and discharging profile are plotted into a graph and by a simulation using MATLAB software, graph of discharging profile is plotted and by analyzed the result, prediction of journey have been made and battery lifetime also can be determined. With this both result, a comparison have been made to both result and an algorithm is been produced consisting of an energy management of a battery to DC motor. With this algorithm, an estimation of the energy left in the batteries that have been supply to different load of DC motor should be easier. The new design of a battery charger also been introduced in this thesis. By using a L200 component, the charger system should be an intelligent circuit with additional features.

ABSTRAK

Kenderaan elektrik (EV) ialah suatu kenderaan yang menggunakan tenaga elektrik sebagai sumber tenaga utama. Tenaga elektrik boleh dihasilkan daripada pelbagai cara seperti tenaga suria, angina dan air. EV hampir tidak mengeluarkan sebarang pencemaran terhadap alam. EV menggunakan motor DC sebagai ganti kepada *internal combustion engine* (ICE) yang digunakan dalam kenderaan konvensional dan kenderaan elektrik hibrid (HEV). Kenderaan elektrik berbateri (BEV) hanya menggunakan bateri sebagai sumber tenaga utama dimana berbeza dengan HEV yang menggunakan ICE sebagai *generator* dan sebagai sumber tenaga kedua yang masih menghasilkan pencemaran di dalam udara. Tenaga di dalam BEV dihasilkan dari bateri ke motor DC. Bahagian ini dikenali sebagai pengurusan tenaga dari bateri ke motor DC. Ada satu cara untuk mengukur *state of charge* (SOC) daripada bateri. Dalam projek ini, satu eksperimen telah dilakukan dengan menggunakan 5 *horsepowe*r (HP) motor DC dan *lead-acid* bateri untuk mengukur SOC melalui *open circuit voltage* (OCV) daripada bateri. Untuk profil mengecas, data diperolehi dengan menggunakan pengecas 12V 20A yang disambungkan kepada satu siri bateri. Simulasi untuk mengukur SOC daripada bateri ke motor DC telah dilakukan menggunakan perisian MATLAB versi 7.6.0 (R2008a). Melalui satu eksperiment, satu keputusan profil pengecasan dan pengediscasan telah dihasilkan dalam satu bentuk graf dan melalui simulasi dengan menggunakan perisian MATLAB, hanya graf pengediscasan dapat dihasilkan dan dengan menganalisa keputusan tersebut, ramalan tentang jarak perjalanan dapat dibuat dan jangka hayat bateri turut dapat ditentukan. Dengan kedua-dua keputusan ini, satu perbandingan telah dilakukan melauli kedua-dua keputusan ini dan satu *algorithm* telah dapat dihasilkan tentang pengurusan tenaga daripada bateri ke motor DC. Dengan terhasilnya *algorithm* ini, pengukuran tenaga yang masih berbaki di dalam bateri yang telah diberi ke bebanan yang berlainan di dalam motor DC sepatutnya menjadi lebih mudah. Rekaan baru sirkit pengecas bateri juga telah diperkenalkan di dalam tesis ini.

Dengan menggunakan komponen L200, system pengecas sepatutnya menjadi sirkit yang pintar dengan penambahan ciri-ciri lain.

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LIST OF SYMBOLS

P_m	Mechanical output power
ω_m	Omega, nominal speed in rad/s
N_m	Nominal speed in rpm
π	Pi, valued at 3.142
K	Constant
T_m	Mechanical load torque

LIST OF ABBREVIATIONS

EV	Electric Vehicle
SOC	State of charge
HEV	Hybrid Electric Vehicle
BEV	Battery Electric Vehicle
ICE	Internal Combustion Engine
AC	Alternating Current
DC	Direct Current
OCV	Open circuit voltage
V	Voltage
R_s	Series resistances
C	Capacitance
R_0	Overvoltage resistance
Pb	Lead metal
PbO_2	Lead (IV) oxide
H_2SO_4	Sulfuric acid
$PbSO_4$	Lead(II) sulfate
H_2O	Water
NiMH	Nickel/metal-hydride
NiOOH	Nickel oxyhydroxide
HP	Horsepower

W	Watt
A	Ampere
Rpm	Rotation per minute
Rad/s	Radian per second
Ah	Ampere-hour
Min/s	Minute/s
SG	Specific gravity

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

An electric vehicle (EV) is the vehicle that use different source of energy from the conventional vehicle. Power source of an EV gained from the electricity to supply the energy to vehicle sub-system. An EV is produce to achieve zero emission vehicles. A conventional vehicle produce a lot of environment pollution and this number are raising rapidly as millions of people gain access to public and personal transportation. Due to the oil price that now is unreasonable raise cause by lack of the petroleum from all over the world, the automobile manufacturers find a ways to using others energy as change to the petrol [1]. One of the energy that have being found is using the electricity since 1931 in Paris [2]. Nowadays, the automobile manufacturers working harder to improve the current EV to become more reliable and have a friendly use functions. Many of the automobile manufacturers have produced an EV such as Daimler-Chrysler, Ford, and General Motors that initially use Plumbum-acid batteries. Toyota and Honda will use nickel metal-hydride batteries and Nissan will demonstrate vehicle using Li-ion batteries as the energy [1]. As in the conventional vehicle, fuel gauge is use to determine fuel left in the vehicle. In EV, the estimation of battery state of charge (SOC) is important to determine the energy left in EV to predict journey that can reach by an EV before empty and need to be charge [3]. Energy from the electricity is supplied by a series of battery pack place in an EV. An EV divided by two categories that are Hybrid Electric Vehicle (HEV) and Battery Electric Vehicle (BEV) [4].

HEV is an electric vehicle using both the petrol or diesel and battery as a power source so hybrid mode can be change anytime necessary. In HEV there are also two kind of HEV. Series HEV and parallel HEV.

Figure 1.1 shows a series HEV. The electric motor will be connecting to drive train and vehicle will driven by electric motor. If the state of charge (SOC) at minimum stage, an Internal Combustion Engine (ICE) will turn on and charging the battery. An ICE will turn off when SOC fully recharge. In SHEV, there is no mechanical connection between ICE and chassis. The advantage of SHEV is the ICE is running at an optimal and combination of speed and torque all the time SHEV being operate. This can reduce the fuel consumption and having a high efficiency. Even though, the SHEV also have a disadvantage. Because of there are two energy conversions install in SHEV, much energy loss due to inner resistance and friction during the transportation of the energy between ICE and wheels [5].

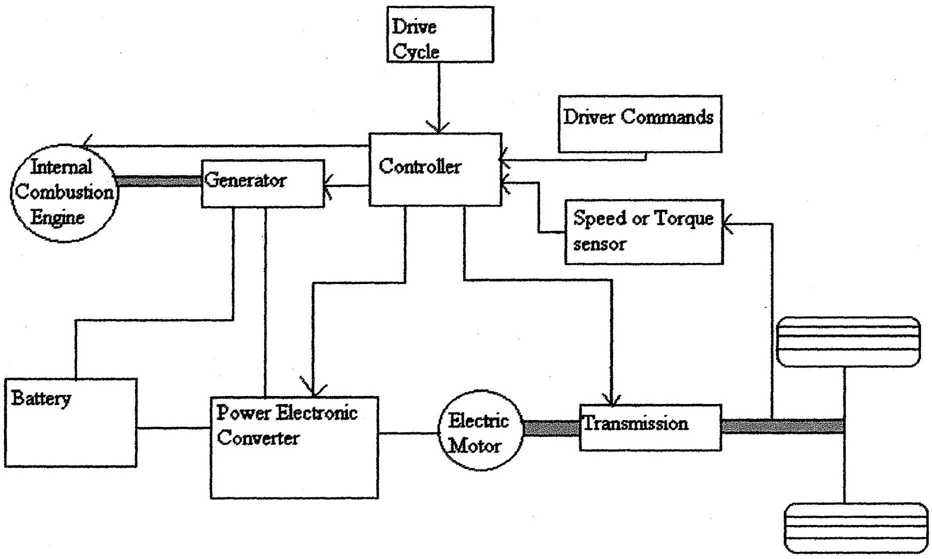

Figure 1.1. Series Hybrid Electric Vehicle [5].

Figure 1.2 shows a parallel HEV (PHEV). PHEV can be driven with both of ICE and electric motor (EM) at the same time. This can make a PHEV to choose the combination freely so the PHEV will be applied by the required torque at each time. To combine these two ICE and EM is to use the EM alone at lower speed and leave ICE to work at high speed so the EM will be more efficient than the ICE. When ICE is in operate mode, an EM will act as a generator and charge the battery. When the power demand is low, only the ICE will be use. When PHEV being accelerated and use high speeds, the EM will be operate as a complement to ICE that will give extra power if needed. An ordinary ICE is inefficient when operate at low speed so better to use EM at low speeds [4].

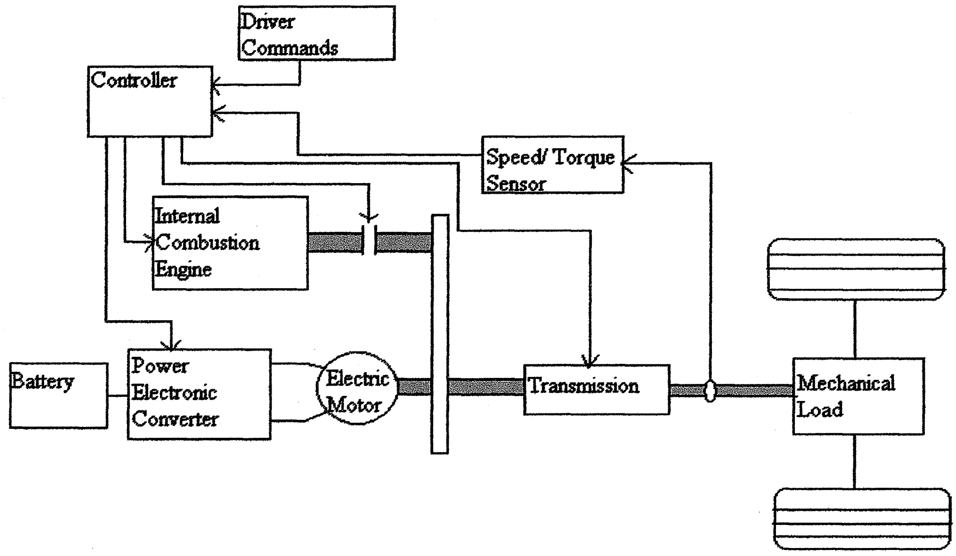

Figure 1.2. Parallel Hybrid Electric Vehicle [4].

Figure 1.3 shows a Battery Electric Vehicle, an EV that using pure electric as a power source. Because of the power source is using 100% energy from the battery, BEV produce zero emission pollution. In BEV, motor will be connecting directly to the drive train. Battery is connected to the motor. Here, if the motor using is from the Alternating Current (AC) motor, BEV will need a Direct Current (DC)/Alternating Current (AC) converter to change the signal from DC to AC so the motor can operate smoothly [6].

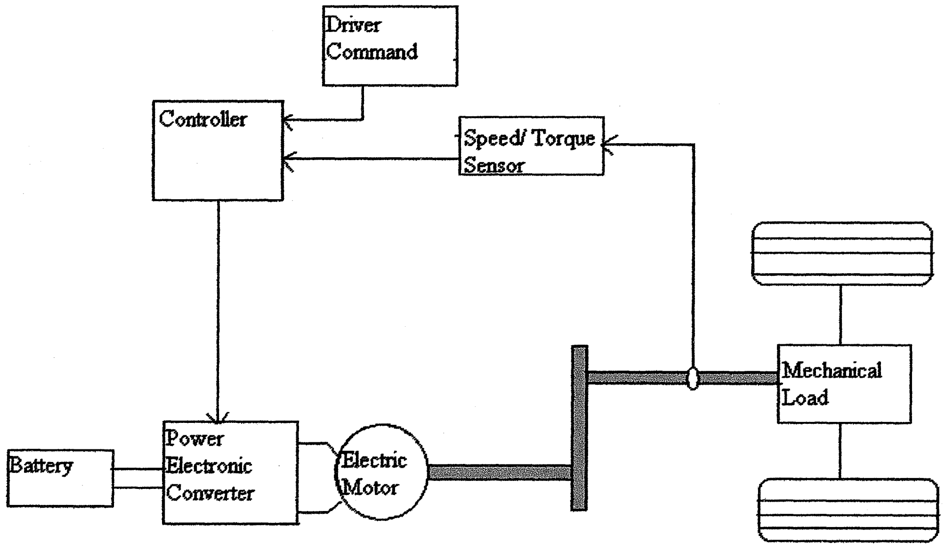

Figure 1.3. Battery Electric Vehicle [6].

1.2 PROJECT BACKGROUND

An EV has not been denied as one of the alternative effort to reduce the environment pollution and cost that cause by a conventional vehicle. For an EV, estimation of SOC is the important subject to be discussed. Methods for estimate SOC have been done by [7] but this estimation is for Hybrid Electric Vehicle. An estimation of SOC for lead-acid batteries also has been done by Ahmad Fasih [8]. Estimation of the SOC for HEV is not a crime but the HEV still producing pollution and using a diesel as its power source. World has tell that the petroleum producing is reducing each year and even each month so, if the method of estimation SOC is for HEV then when the time has come this method is not yet being approve if this method can be use by EV. This thesis will define the energy management of BEV. This thesis want to define if the method of estimation SOC for the HEV can also being applied to the BEV with various type of load use.

1.3 PROJECT OBJECTIVE

The objective of this project is to develop an algorithm for the energy management of Battery to DC motor based on the energy needed by the DC motor.

1.4 PROJECT SCOPE

Objective of this thesis is to develop an algorithm for energy management of BEV. Thus, this thesis will consist:

1) Monitoring the state of charge (SOC) of battery for predictive battery lifetime for different DC motor used.
2) Improving charger system to be more effective.
3) Design intelligent charger controller.

1.5 THESIS OUTLINE

Chapter 1 is about the introduction to the Electric Vehicle that used a DC motor as a replace of an engine in conventional vehicle and the purpose of this thesis written to give an explanation about this project.

Chapter 2 represented the battery modeling, the equation that will use to complete this project and an overview on battery management of electric vehicle. This chapter also will show on how the estimation of Voc and SOC will be determined.

Chapter 3 described the methods that are used to determine the Voc of the battery and from this data, estimation of SOC can be done. This chapter also show the experimental and simulation method.

Chapter 4 shows the result get from both of experiment and simulation method, compared and will be discuss to get the algorithm of energy management of battery to DC motor.

Chapter 5 presents the summary and conclusions to complete this project.

CHAPTER 2

OVERVIEW OF ENERGY MANAGEMENT OF ELECTRIC VEHICLE

From the research, estimation of the SOC is done by using the extended Kalman filter (EKF) for the HEV [7]. So, this project wants to estimate the SOC by different energy of battery and different kind of DC motor by using the experiment and simulation using MATLAB software.

2.1 THE BATTERY

Battery is important in the BEV because it supply the energy to move the vehicle and make it works. Thus, battery management is very important for energy management in BEV.

2.1.1 Battery Management

The automotive is a passive standalone and very important component in the Electric Vehicle (EV). Precise monitoring and active control of the battery are needed in the energy management and powertrain hybridization. The battery monitoring are known as a continuously calculating application-relevant battery state quantities based on sensed physical quantities, typically current, voltage, and temperature. "Configurations of this type have been common for traction batteries for some time, but have more recently been introduced for demanding 12V SLI battery applications as well. Examples for active control measures are state-of-charge (SOC) control by discharge/charge management and thermal management that maintains upper and lower temperature thresholds and limits temperature gradients within the battery.

Together with subsystems involving elements such as sensors, monitoring algorithms, and cooling fans, the battery then forms an energy storage system that interacts with the vehicle in a complex manner". This is meant that state of charge (SOC) is important to determining rate capacity of batteries. The SOC also needed to determining end of the charging and discharging the batteries. To determining the SOC, there are various methods such as direct measurement, specific gravity (SG) measurement, voltage based SOC estimation and also current based SOC estimation. The SOC calculation is important for the batteries in the battery management so the power that will be deliver to the load in the maximum state.
But to determine the state of charge, preferred to use this equation that are determine from estimating the open circuit voltage. That is [1].

$$SOC(\%) = 84 \times OCV - 98.4 \tag{1.1}$$

To make it easier, the table have been develop to determine the SOC much more quicker than using the equation [9]

Table 2.4: Determining SOC base on OCV [9]

Open circuit voltage (OCV)	**State of Charge (SOC)%**
12.6 V	100
12.4 V	75
12.2 V	12.2
12.0 V	12.0
11.9 V	11.9

2.1.2 Battery Modeling

For the simulation of energy consumption of electric vehicles, precise battery models are required. The biggest challenging problem in modeling a battery source is come from the non-linear characteristics of the equivalent circuit parameters that require lengthy experimental and numerical procedures. This is because the battery has its own internal parameter. The battery modeling has 3 basic types of battery modeling. The ideal model of a battery circuit diagram as shown in Figure 2.5 basically ignores the internal parameters and simple where this model is primarily made up of only a voltage source [1].

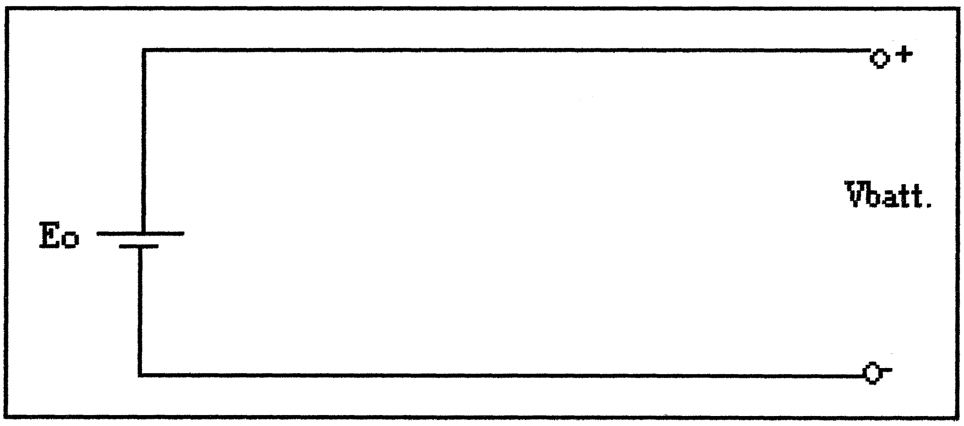

Figure 2.5: The Ideal Battery Model [1].

The circuit diagram as shown in Figure 2.6 is the linear model that is similar to an ideal battery with open-circuit voltage E_0 and equivalent series resistances R_s. The terminal is the V_{batt} and can be obtain from the open-circuit tests. This model is the most commonly used battery model.

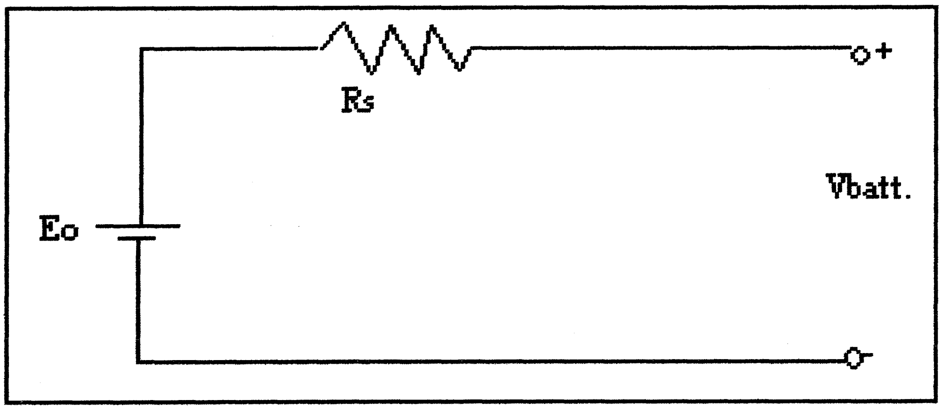

Figure 2.6: Linear Battery Model [1].

The thevenin model as shown in Figure 2.7 consists of electrical values of the open-circuit voltage (E_0) internal resistance(R), capacitance(C) and the overvoltage resistance (R_0). The capacitor C is the capacitance of the parallel plates and resistor R_0 is the non-linear resistance from the plate to electrolyte.

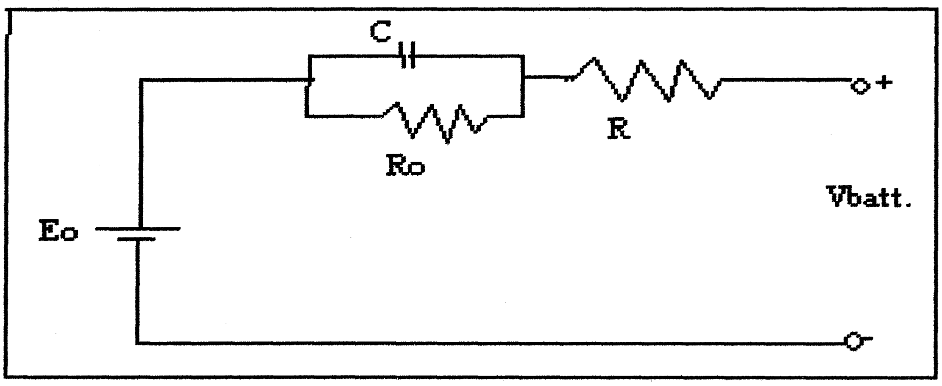

Figure 2.7: The Thevenin Model [1].

For the model, assumption have be made that all of the components are constant but in real application, they depend on the battery conditions.

2.2 BATTERY OR CELL VOLTAGES

For the battery or cell voltages, the common used now by almost all the vehicle is lead-acid battery and Nickel-metal hydride battery.

2.2.1 Lead-acid Battery

In the lead-acid battery contain electrodes of lead metal (Pb) and lead (IV) oxide (PbO_2) in an electrolyte of about 37% *w/w* (5.99 Molar) sulfuric acid (H_2SO_4). In the discharged state both electrodes turn into lead(II) sulfate ($PbSO_4$) and the electrolyte loses its dissolved sulfuric acid and becomes primarily water. Due to the freezing-point depression of water, as the battery discharges and the concentration of sulfuric acid decreases, the electrolyte is more likely to freeze.

The chemical reactions are (charged to discharge) [10]:

Anode (oxidation):

$$PbO_2 + SO_4^{-2} + 4H^+ + 2e^- = PbSO_4 + 2H_2O \ (1.685V) \qquad (2.2)$$

Cathode (reduction):

$$PbO_2 + SO_4^{-2} = PbSO_4 + 2e^- \ (0.356V) \qquad (2.3)$$

2.2.2 Nickel-metal hydride battery

Nickel/metal-hydride (NiMH) batteries offer significantly higher shallow-cycle life and energy density, compared to AGM batteries. Technological issues are primarily their limitations at extreme temperatures (cold cranking, hot charge acceptance). The potential for further cost reduction is limited.

The negative electrode reaction occurring in a NiMH battery is [10].

$$H_2O + M + e^- = OH^- + MH \quad (2.4)$$

The electrode is charged in the right direction of this equation and discharged in the left direction. On the positive electrode, nickel oxyhydroxide (NiOOH) is formed,

$$Ni(OH)_2 + OH^- = NiO(OH) + H_2O + e^- \quad (2.5)$$

The "metal" M in the negative electrode of a NiMH battery is actually an intermetallic compound [10].

2.3 DC MOTOR

As a change of internal combustion engine (ICE) in the conventional vehicle, an electric vehicle using a DC motor. The operation is quite similar with the conventional vehicle. If the pedal be push by the driver, electronic control module (ECM) will receive a signal and apply current and voltage to the electric motor from the battery system. Then the motor will apply torque to the EV wheels [1]. Mechanical output power can be finding from the equation below [12].

Mechanical output power,

$$P_m = T_m * \omega_m \quad (2.6)$$

$$= T_m (\pi * N_m/30)$$

where,

ω_m = Nominal speed in rad/s

N_m = Nominal speed in rpm

Normally, power in an electric motor is given in horsepower unit, HP. Thus, power need to be calculated by watt unit, W and to change from HP to W is show in equation (2.7).

$$\text{Power (W)} = \text{Power (HP)}/746 \tag{2.7}$$

From the mechanical load torque, constant K can be determining,

$$T_m = K^* \omega_m \tag{2.8}$$

This equations are important in an electric motor either it is a DC motor or an AC motor and will be using in the simulation with Mathlab for complete this project.

CHAPTER 3

EXPERIMENT AND SIMULATION OF BATTERY TO DC MOTOR USING MATHLAB

3.1 EXPERIMENT METHODS

To implement an algorithm for energy management of battery to a DC motor, an initial step is to done the experiment and then will be compared to the simulation with Matlab. If results from an experiment are compatible with simulation, then the algorithm developed is successful. This is step for an experiment.

3.1.1 Charging Battery

1. All battery is uncap and arranged in parallel(charger is in off mode)
2. Cable is connecting from charger to the batteries. The polarities have to be attention. Positive terminal with positive cable and negative terminal with negative cable.
3. Charger to be set in 12V and current apply is set to 20A. Current apply is advised to be same as discharging to avoid damage of battery.
4. Charger will be on and every 20mins, the charger will turn off and voltage of each batteries taken by using voltmeter.
5. This step repeated until the open circuit voltage is 12.5V.

3.1.2 Discharging Battery

1. Batteries arranged in parallel
2. Batteries are connected to a DC motor as it is instruct in the manual instruction of DC motor.
3. Motor will be run and every 10mins, open circuit voltage will be taken by using voltmeter and current also be determined by using ammeter to know how much current from battery to DC motor.
4. Open circuit voltage is taken till the voltage drop to 11.9V
5. With the data of open circuit voltage, state of charge can be determined and the battery lifetime can be predicted.

3.2 SIMULATION USING MATHLAB

Using Mathlab software is to done a simulation and be compared to experiment to find out it is compatible or not. Here, is the step of using Mathlab software to done the simulation with reference from Mathworks.

Before it, a little calculation need to be show because the parameter in Mathlab is depends on this calculation.

3.2.1 Mathematical Calculation

To using a DC motor in Mathlab, certain parameters need to be calculated like mechanical output power, Pm and mechanical load torque, Tm.
This simulation is using 5HP DC motor and 1750rpm for its nominal speed.

$P(Watt) = 5HP*746$

$P = 3730W$

$3730W = Tm(\pi*1750/30)$

$Tm = 20.354N\text{-}m$

$K = 20.354N\text{-}m/(\pi*1750/30)$

$K = 0.11106$

3.2.2 Step For Simulation.

1. Load DC motor power from DriveParameters library or if there is any manual specification, can be load itself.

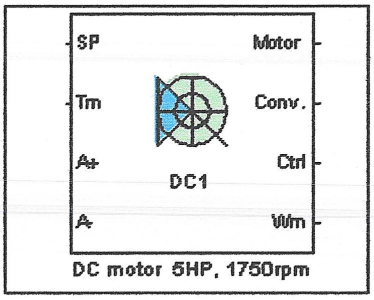

Figure 3.8: DC motor for simulation in Mathlab

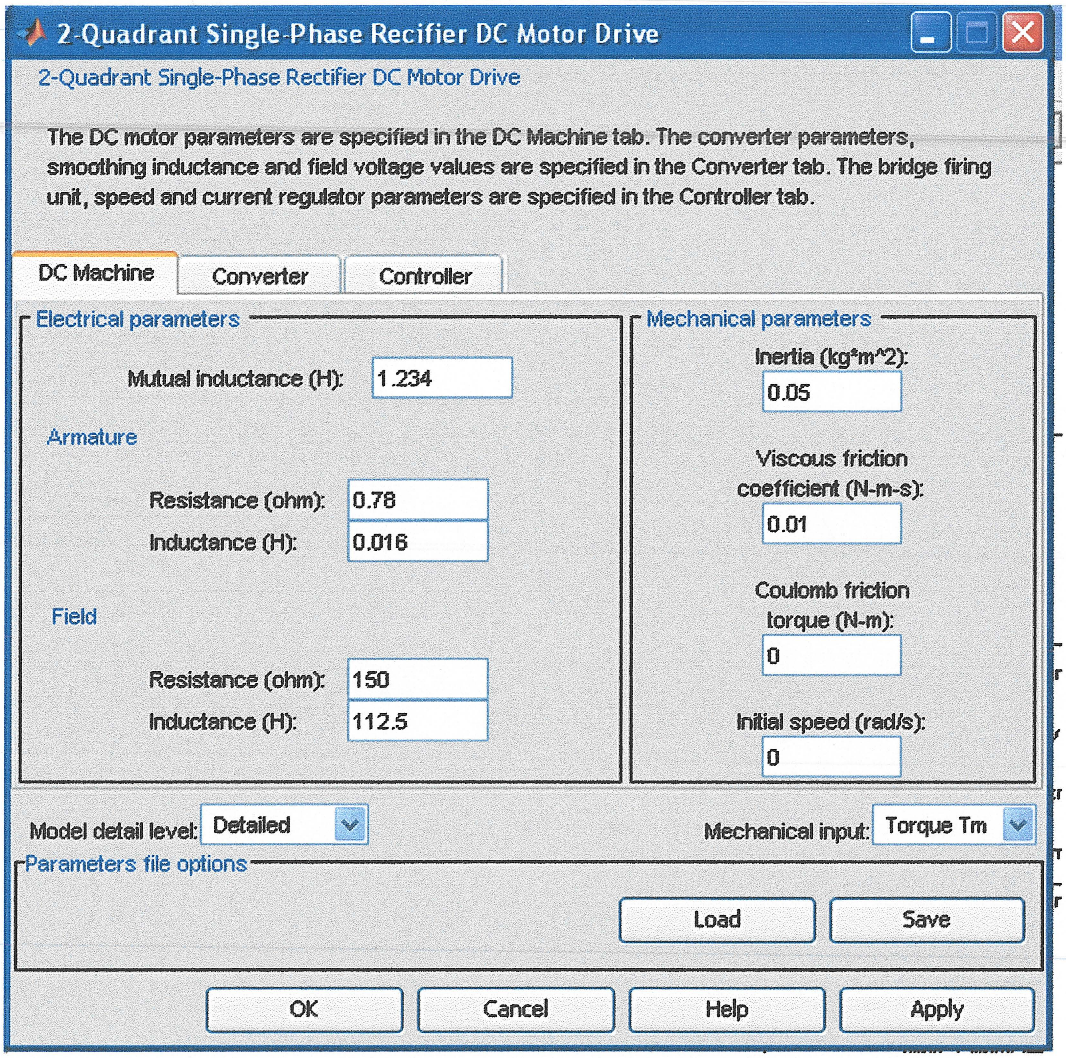

Figure 3.9: Parameters for DC motor in Mathlab

2. Insert motor speed reference. Refer to the power motor used. Different motor power will need different speed reference.

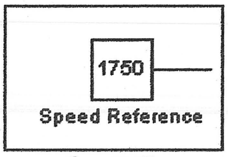

Figure 3.10: Speed reference for DC motor based on the motor rpm

3. Load value of constant K in the linear load torque from mechanical load torque calculation.

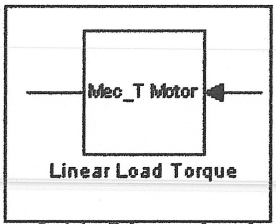

Figure 3.11: Linear load torque

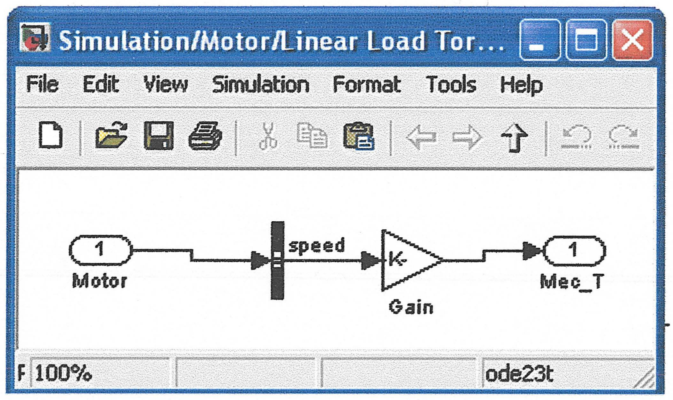

Figure 3.12: Constant K in linear load torque block diagram

4. Load battery specification from battery library or manual specification if have any.

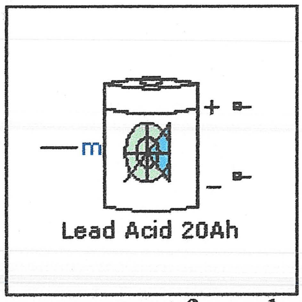

Figure 3.13: Battery component from electric drives library

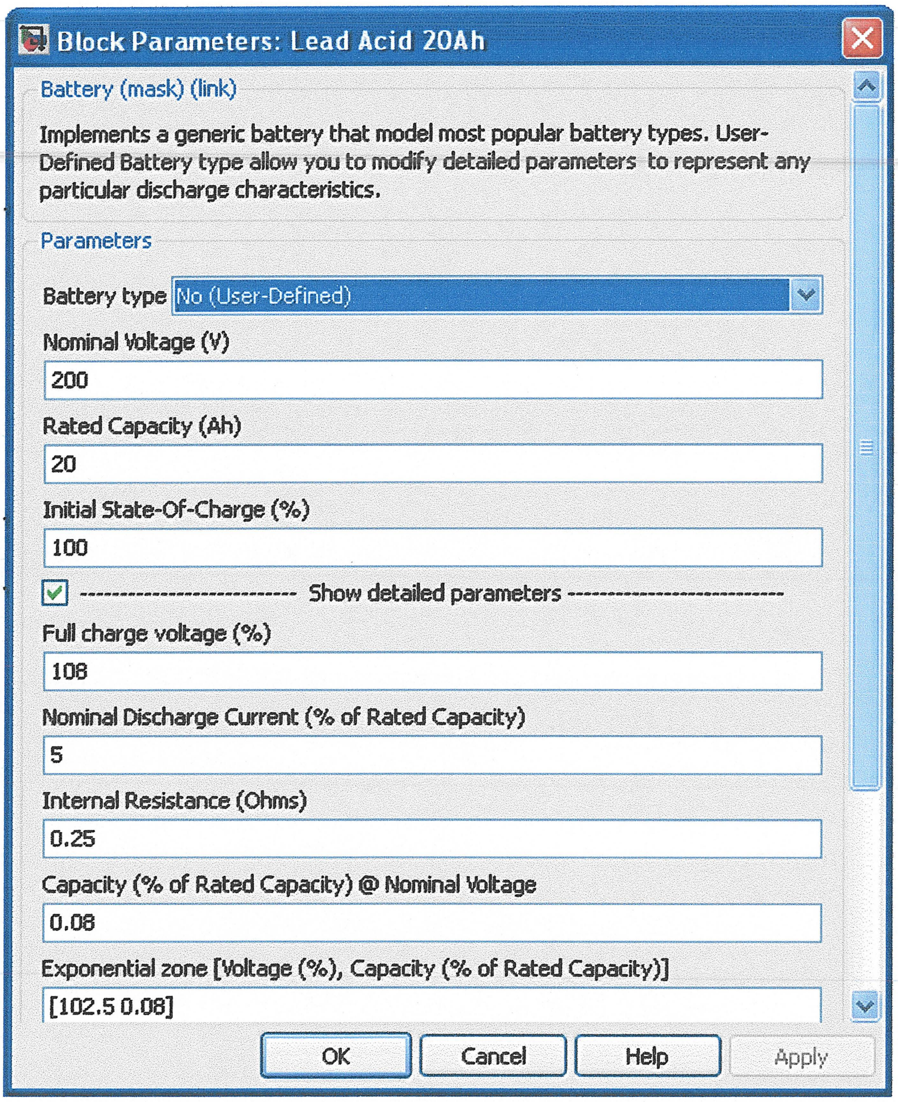

Figure 3.14: Parameters in battery from electric drives library

5. Load current based on the motor power needed.

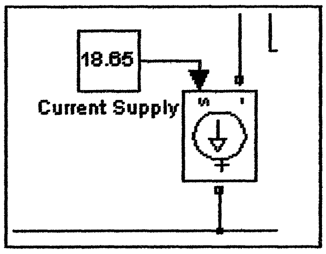

Figure 3.15: Current supply in block diagram

6. Run the simulation and from the simulation, state of charge graph will appear and battery lifetime will be known.

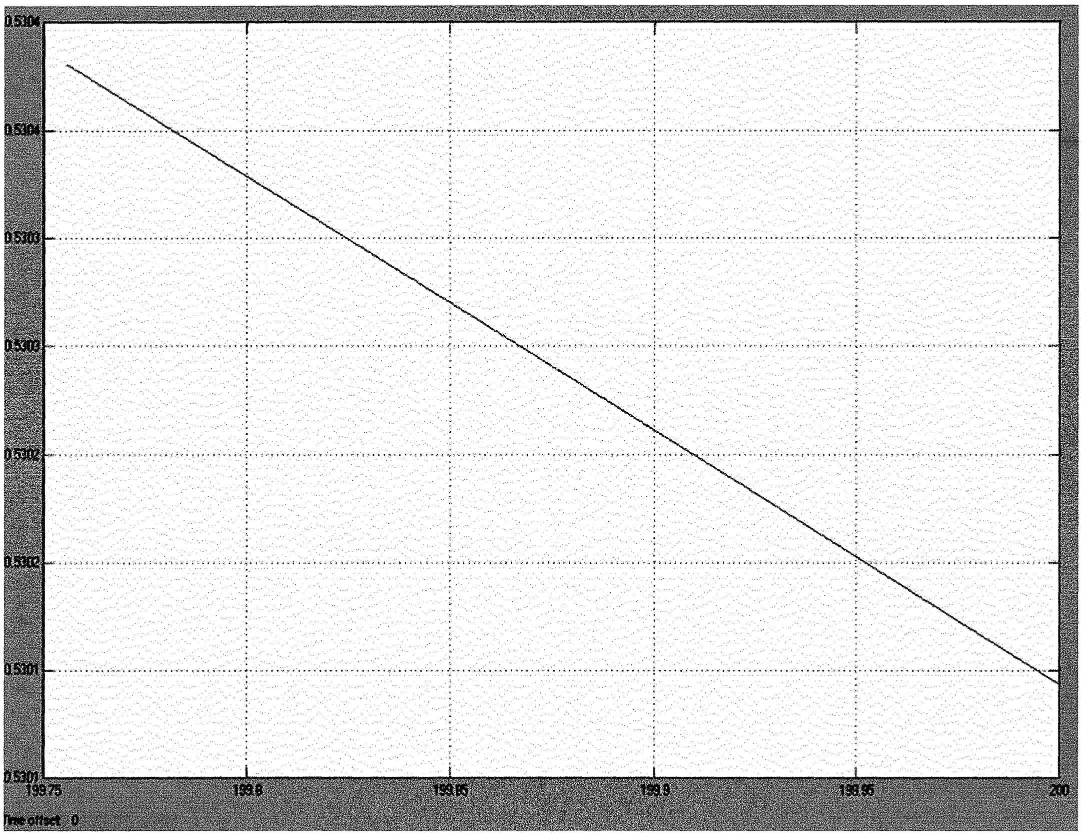

Figure 3.16: Result from the simulation by Mathlab

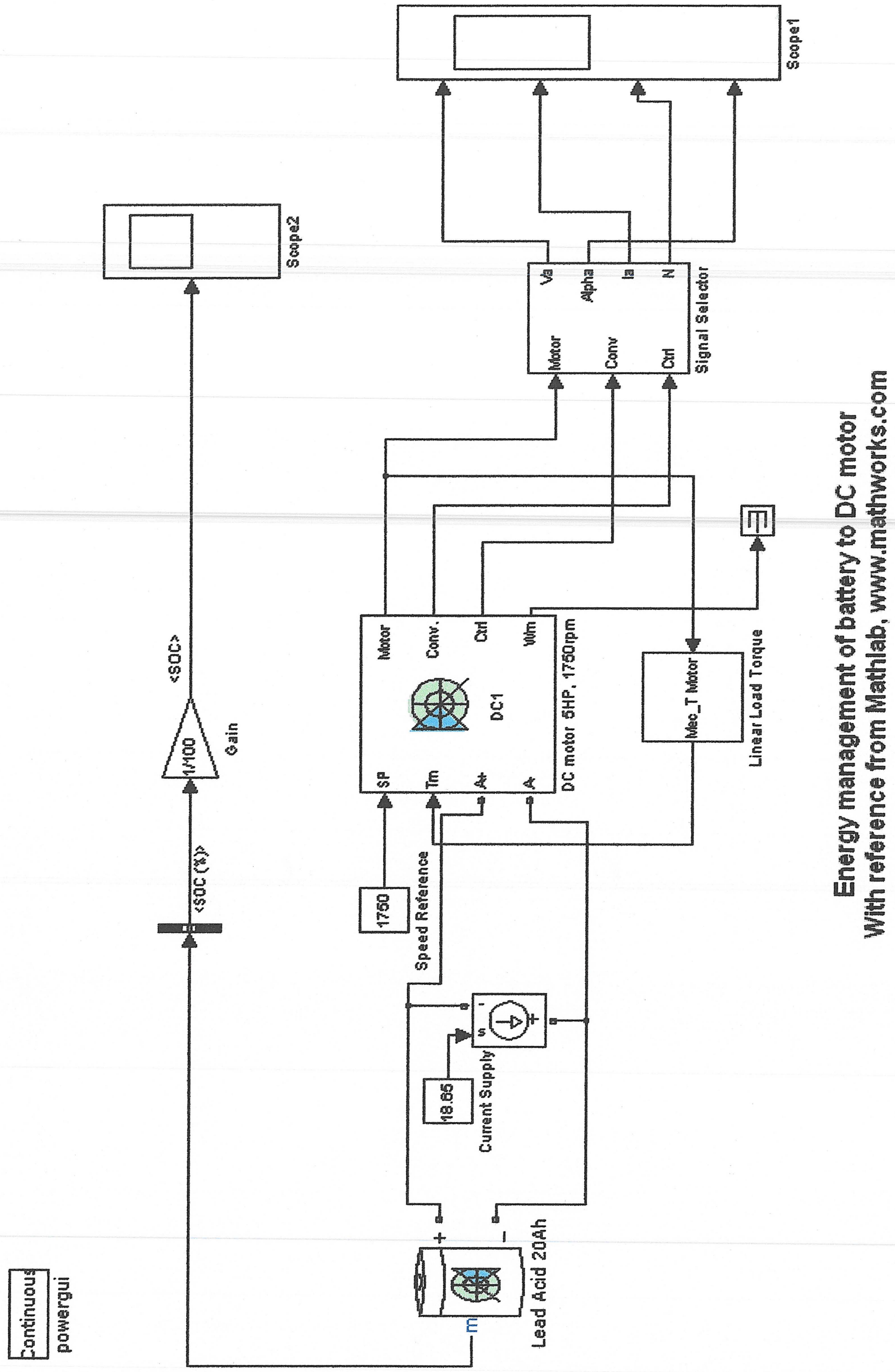

Figure 3.17: Simulink model for battery to DC motor.

Figure 3.17 shows a simulink model using block diagram which reference is **from** www.mathworks.com**, using a battery and supply the energy to DC motor. An** algorithm has been developed by using this simulink model. Different batteries and volt can be applied in this simulink model.

CHAPTER 4

STATE OF CHARGE ESTIMATION USING OPEN CIRCUIT VOLTAGE

4.1 EXPERIMENTAL RESULT

State of charge can be estimate using the experimental method. By using 3 packs of lead acid batteries, the open circuit voltage can be determined and yet the SOC value will be determine.

Table 4.18: SOC Table Base On OCV for Various Temperature [11].

Electrolyte Temperature (Fahrenheit)	Electrolyte Temperature (Celsius)	100% SOC	75% SOC	50% SOC	25% SOC	0% SOC
120°	48.9°	12.663	12.463	12.253	12.073	11.903
110°	43.3°	12.661	12.462	12.251	12.071	11.901
100°	37.8°	12.658	12.458	12.248	12.068	11.898
90°	32.2°	12.655	12.455	12.245	12.065	11.895
80°	26.7°	12.650	12.450	12.240	12.060	11.890
70°	21.1°	12.643	12.443	12.233	12.053	11.883
60°	15.6°	12.634	12.434	12.224	12.044	11.874
50°	10.0°	12.622	12.422	12.212	12.032	11.862
40°	4.4°	12.606	12.406	12.196	12.016	11.846
30°	-1.1°	12.588	12.388	12.178	11.998	11.828

20°	-6.7°	12.566	12.366	12.156	11.976	11.806
10°	-12.2°	12.542	12.342	12.132	11.952	11.782
0°	-17.8°	12.516	12.316	12.106	11.926	11.756

Table 4.18 shows the state of charge of lead-acid battery with different temperature. The usual condition of SOC is 80F or 26.7C as been highlighting above. By using table 4.18, SOC can be determined more quickly in the experiment. Determination of SOC in experiment is using interpolation with this table.

Figure 4.19 shows parallel batteries while in charging process. Open circuit voltage is determined by using a voltmeter on its terminal in each of the batteries. Open circuit voltage can be determined in each of the battery and with the OCV, state of charge of the battery is determined.

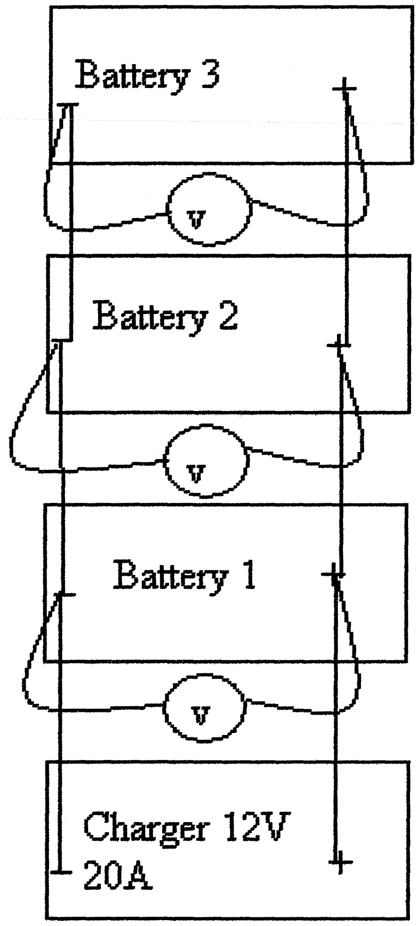

Figure 4.19: Parallel Batteries Charging

Table 4.20: Parallel Batteries Charging (quantity of 3)

Time(min)	Open Circuit Voltage(V)			I_1	I_2	I_3	State of Charge(%)		
	V_1	V_2	V_3				V_1	V_2	V_3
20	11.95	11.93	11.87	20.0	8.3	2.5	8.82	5.88	0.00
40	12.04	12.01	11.91	20.1	9.4	2.3	22.06	17.65	2.94
60	12.10	12.07	11.95	20.0	10.6	2.3	30.56	26.39	8.82
80	12.16	12.12	11.98	20.2	11.6	2.5	38.89	33.33	13.24
100	12.20	12.16	12.01	20.8	12.3	2.6	44.44	38.89	17.65
120	12.22	12.18	12.02	20.2	12.4	2.7	47.22	41.67	19.12
140	12.29	12.24	12.06	21.0	11.4	2.8	55.95	50.00	25.00
160	12.31	12.27	12.09	20.8	12.7	2.9	58.33	53.57	29.17
180	12.37	12.33	12.12	21.3	12.9	3.0	65.48	60.71	33.33
200	12.41	12.38	12.17	20.8	13.4	3.2	70.24	66.67	40.28
220	12.45	12.42	12.20	20.9	13.6	3.2	75.00	71.43	36.10
240	12.47	12.44	12.22	20.1	11.3	2.0	77.50	73.81	47.22
260	12.50	12.47	12.24	19.8	13.5	3.2	81.25	77.5	50.00
280	12.56	12.54	12.27	20.2	12.6	3.5	88.75	86.25	53.57
300	12.56	12.53	12.28	20.1	12.6	3.4	88.75	88.75	54.76
320	12.58	12.56	12.32	19.4	10.9	3.1	91.25	85.00	59.52
340	12.62	12.61	12.54	20.5	14.5	8.8	96.25	95.00	86.25
360	12.65	12.63	12.61	20.8	14.4	9.0	100.00	98.75	95.00

Table 4.20 is the results of experiment by using parallel batteries consists 3 batteries of lead-acid battery. By checking the battery voltage every 20 mins, determination of state of charge can be calculate and the current applied also been determine.

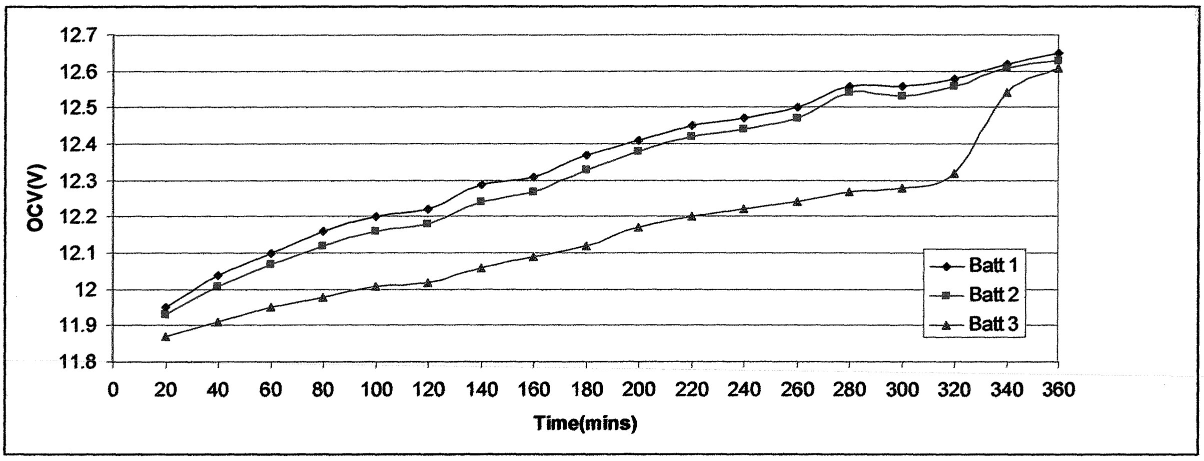

Figure 4.21: Time versus Open Circuit Voltage (OCV) while charging

In Figure 4.21 shows a graph plot from the result in table 4.20. By using the determination of OCV from the batteries, state of charge of battery can be plotted into a graph. Battery open circuit voltage is increasing corresponding with time. This mean in every 20 mins, charger will constantly supply power to the battery while charging. Between these three batteries, as it show battery 1 has a high performance.

This is not because using a different kind of battery or different type of battery, but it is because battery 1 is having more energy than the other 2 battery. The increasing of OCV of battery also depends on how much energy left in the battery. If the batteries still have a lot of energy in itself, charging process will be faster and can decrease the amount of time for charging the battery.

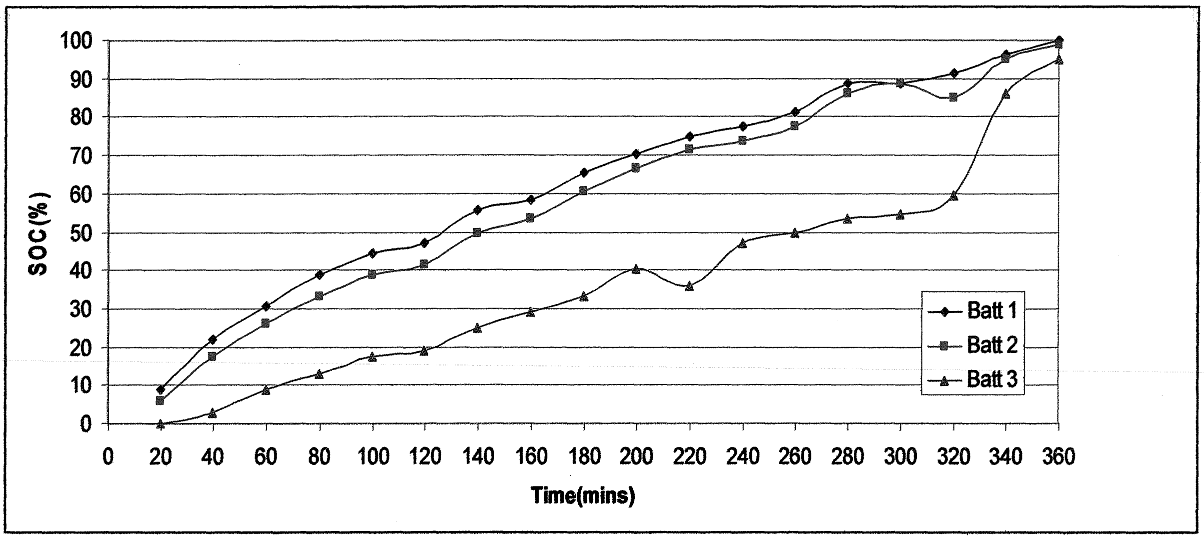

Figure 4.22: Time versus State of charge (SOC) while charging

In Figure 4.22, graph plot of state of charge by using the open circuit voltage have been produce. Thus, the graph shows charging of battery need 360 mins to charge the battery from 0% of SOC to 100% SOC. For determining state of charge of battery, amount of current applied also cause effect in time of charging process. Battery 1 have been supplied with approximately 20A of current. Thus, this makes battery 1 state of charge increase faster than the other 2 batteries.

Battery 2 been supplied with average of 14A to 8A of current. In the graph that has been plotted, there is not much different between these two batteries. For a battery 3, current supplied much more lower that is between 2A to 9A. With this result, it shows battery 3 have a slower charging process cause by current applied are too small. For charging process, amount of current applied is important to have a fast charging process.

4.1.1 Charging Profile

After doing the experiment then the determination of state of charge can be found. As it can see that the table above is the result of the experiment. Because of the batteries use are the wet low maintenance batteries, thus the table that being used is like the table in Table 4.18. This kind of charging can determine how far the vehicle can go and how much time that are needed to recharge the battery back. Assume the standard temperature of battery charging is 80^{o}F and applying the current 20A. If the battery state of charge of the battery is just 75%, that means the open circuit voltage of the battery is 12.450V. Therefore, to recharge it back to 90% of state of charge it needs 100 mins (app 1 hr and 40 mins) and to recharge it to 100% state of charge it needs 140 mins (app 2hrs 20 mins).The lower the state of charge will need more time to recharge it back.

4.1.2 Prediction Journey by State-of-Charge

By this calculation also prediction on how far the journey that the vehicle can go can be done. As an example, if 100% state of charge of battery can go about 100km so if the vehicle need to go to 45 km of journey, it needs 45% of state of charge. If the batteries indicate the 75% state of charge, then the vehicle can reach that place but if the state of charge is only 25%, then the vehicle just can reach 25 km. Thus, it needs another 20% state of charge more. To get another 20 km journey, it have to stop and recharge in about 40 mins and continue the journey to that place and then recharge it to 100% state of charge in about 360 mins (app 6 hrs). To avoid the battery damage, the minimum of open circuit voltage that can remain is 11.90V only.

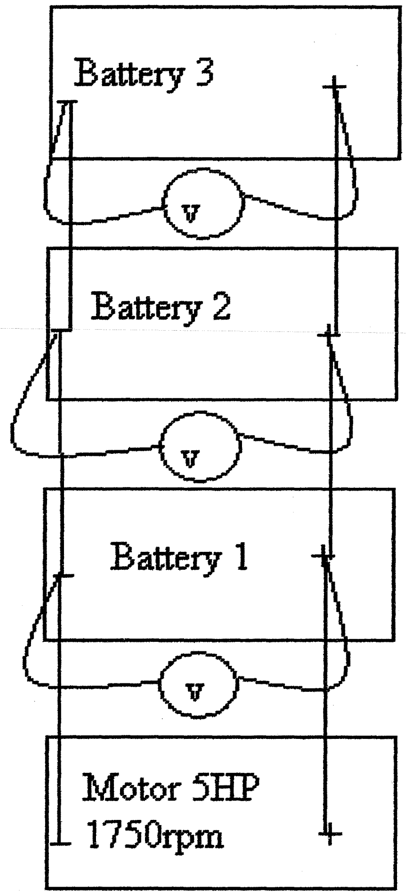

Figure 4.23: Parallel Batteries Discharging

Figure 4.23 shows parallel batteries been discharging by a motor with a power of 5 HP and with the nominal speed of 1750 rpm. As same with the charging process, the open circuit voltage of each battery has to be determining using voltmeter in order to know its state of charge. The voltmeter has to be in parallel to take a data for open circuit voltage.

Table 4.24: Discharging batteries using power motor 5.0HP 1750rpm

Time(min)	Open Circuit Voltage(V)			I_1	I_2	I_3	State of Charge(%)		
	V_1	V_2	V_3				V_1	V_2	V_3
10	12.05	12.53	12.58	48.0	1.2	0.6	23.53	85.00	91.25
20	11.45	12.46	12.56	43.2	1.7	0.8	0.0	76.25	88.75
30	10.80	12.39	12.54	42.7	3.3	1.4	0.0	67.85	86.25
40	9.17	12.32	12.51	36.3	12.2	2.6	0.0	59.52	82.5

Table 4.24 is the result from experiment by discharging process using a DC motor 5 HP to know the energy in the battery that have been supplied to DC motor. In discharging process every 10 mins, data in open circuit voltage taken. Same as charging process, an OCV is needed in order to know the energy capacity that's it in state of charge of the battery. By using the DC motor also, one's battery lifetime will be discovered.

In real world of engineering, a vehicle that using a DC motor must have an alternator to always charging and discharging process while still running. The alternator will make a generator to supply power when state of charge of battery become lower and it will turn off when battery have been recharge. This experiment to approving that the algorithm developed is right by not using an alternator and to discover the battery lifetime.

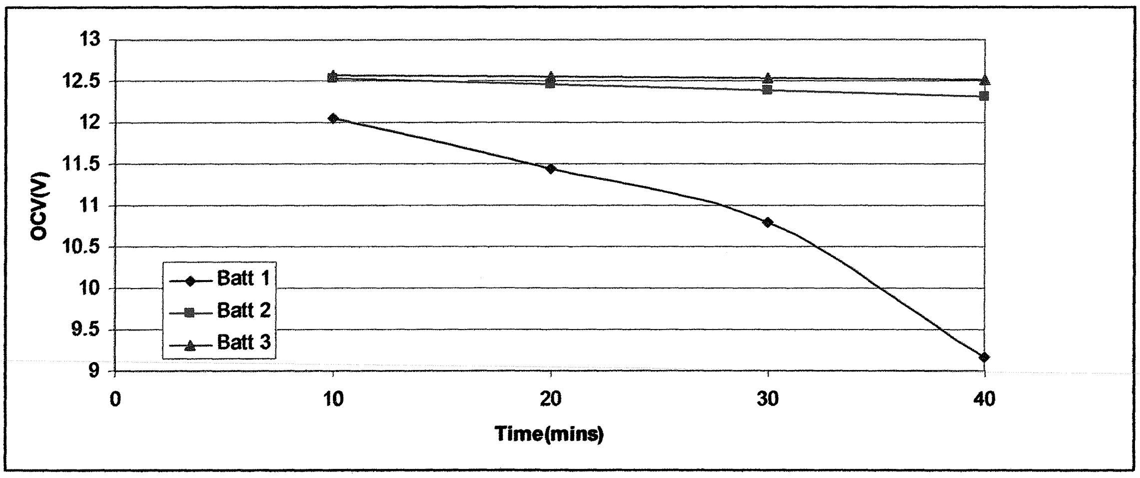

Figure 4.25: Time versus Open Circuit Voltage (OCV) while discharging

In Figure 4.25, graph shows determination of OCV of battery while discharging it. From the graph of OCV, SOC can be determined and knows the battery lifetime. For the open circuit voltage, all of the batteries have a same OCV, 12.7V. Same as the charging process but this time, battery 1 have a faster discharging process. In 10 mins, battery 1 started to drop from 12.7V to 12.0V while the other batteries still in the good condition.

As time increasing, the OCV of battery 1 is drop until it comes to minutes of 30, the OCV of battery 1 drop rapidly. Battery 2 and battery 3 is maintaining the OCV of the batteries. Battery 2 was having OCV of 12.32V at 40 mins and battery 3 having an OCV of 12.51V at 40 mins.

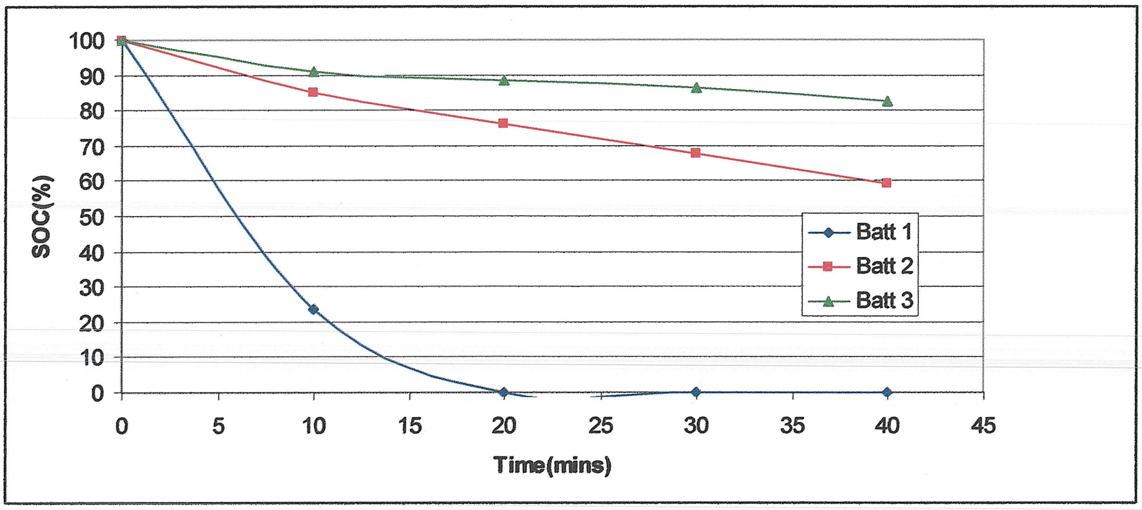

Figure 4.26: Time versus State of Charge (SOC) while discharging

In Figure 4.26 shows graph of SOC by determination of OCV. This is the discharging profile for the motor with 5 HP but the batteries used are fast to discharge. Battery used is fast to discharge because it doesn't have the alternator that can alternate used of the generator and battery power. In discharging process also the currents apply is important parameter that needs to be considered. For battery 1, there is almost 50A of current that applied. This cause state of charge of the battery decrease rapidly. While the other two batteries just being applied of not much than 10A applied of current. The graph also shown in 10mins it can discharge 0.6V.

It means the motor needed 10mins to discharge from 100% state of charge to 20% state of charge. This is because the current that supplied out are much bigger that is 40A and above. With this result, the battery lifetime can be determined. The importance of this experiment has been explained earlier. Simulation and experiment have to be compatible to approve the algorithm developed is right. With the Figure 4.26, it shows the 0% of state of charge drop at 20 mins.

4.2 SIMULATION USING MATHLAB SOFTWARE

By a simulation, state of charge can be determined and the parameter of battery can be change due to the voltage and current apply that needed by a DC motor and the battery.

Thus, the experiment do not necessarily been done until the confirmation of DC motor and battery used is confirm by a person in charge of that project. Result of the simulation is shown in Figure 4.27

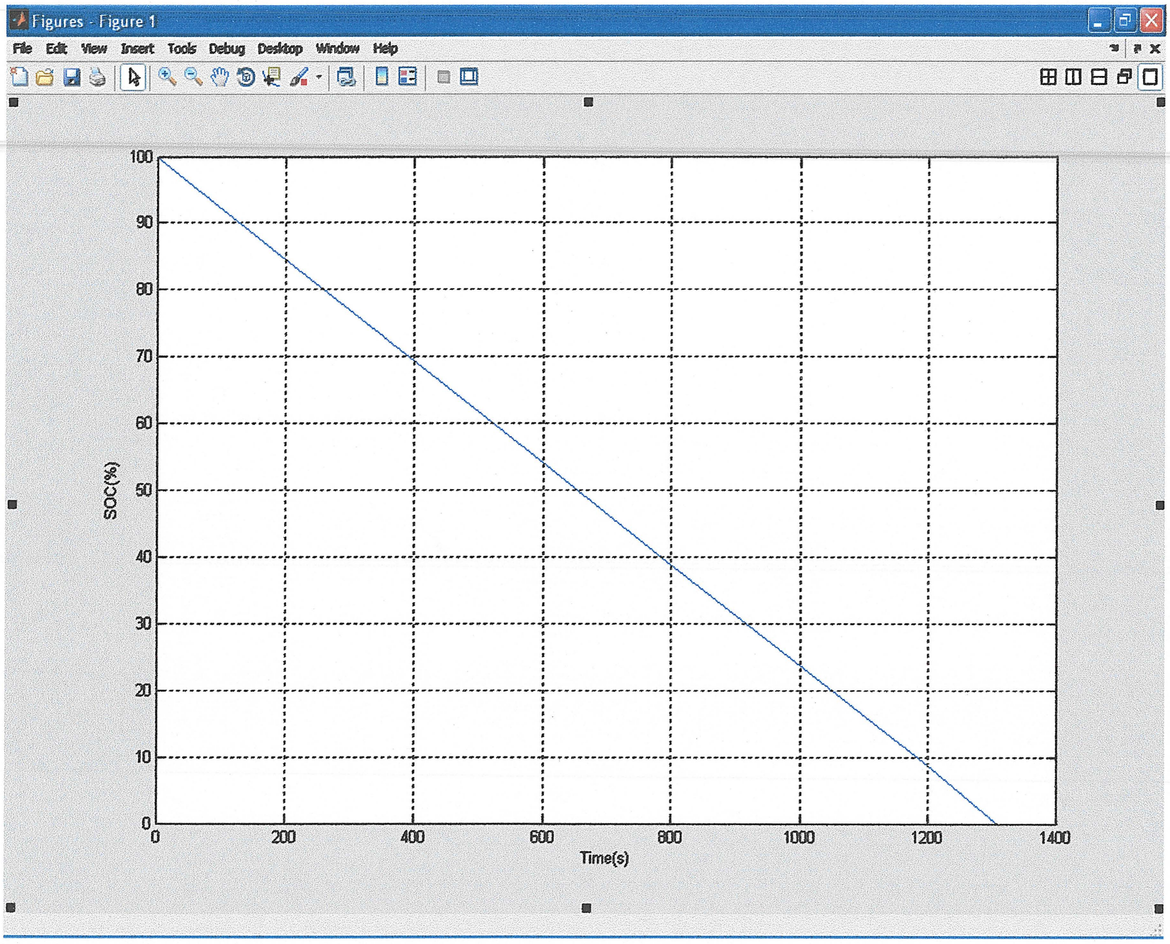

Figure 4.27: Time Versus State of Charge (SOC) By Using Mathlab

Figure 4.27 shows a graph plot by a simulation from Mathlab. In this Figure, 0% of state of charge is on 1300 s that's approximately 21.67 mins. By an experiment, 0% of state of charge is at 20 mins. A slightly different values come by experiment and simulation is caused by temperature while doing an experiment not been adjust to be always in 80F. Thus, it caused a different value in data collection.

With this result, it shows the algorithm of a simulation and by doing an experiment can be compatible and the algorithm is working perfectly.

4.3 DESIGN OF INTELLIGENT CHARGER CONTROLLER

Intelligent charger controller consists of sensor that can detect when to stop the charging process. This is important in order to take care of the battery thus it can avoid damage for the battery itself. Figure 4.27 shows the design of new charger.

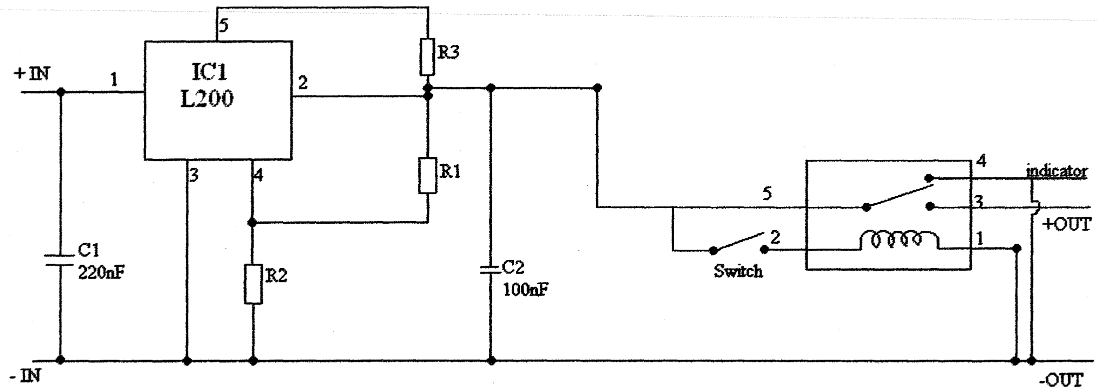

Figure 4.28: Design Of New Charger Based on Relay Circuit

Figure 4.28 shows a new design of charger by using a relay circuit as its controller. When switch on the switch, charger will start charging batteries. Thus, when SOC of battery reach the state as a person want, then it will turn off and indicator. To make this charger working perfectly, additional component such as a timer or sensor can be added as one person like. It depends on a humans need. L200 is a main chip of the circuit. This is how the circuit will work. At pin 5, it will provide output power and all current will go through R3. Pin 2 is connect to internal voltmeter that control voltage between pin 5 and pin 2 to make sure voltage drop not exceed than 0.45V.

Current will be overflow if its drop more than 0.45V. Pin 4 connect to another internal voltmeter that control for pin 4 and pin 3. If there are too much current flow, than L200 has to drop the voltage to pin 5 and this will cause the output power is lower than we need. Thus, this can make charging process pending. C1 and C2 is to smoothing the volt flow from input to input because L200 has a feedback loop. It takes reading from voltage depend on voltage response. If C1 and C2 not be used, there will be an oscillation on the output voltage.

CHAPTER 5

CONCLUSION AND FUTURE WORKS

5.1 CONCLUSION

For the result from experiment, state of charge of battery for 0% is 20 mins and by an algorithm after run the simulation, state of charge of battery for 0% is 21.67 mins. By this result, a conclusion can be made that the algorithm for the energy management of Battery to DC motor based on the energy needed by the DC motor have been successful develop by monitoring the state of charge of battery which is by using an open circuit voltage for an experiment. In this project, the battery that are used in this project actually cannot be using as power supplier to DC motor in long term management because in a real world, an electric vehicle that using a DC motor as an exchange of the engine have one more component known as an alternator. This alternator will switch on the generator when state of charge of a battery is low and this generator will provide power to the DC motor and when battery is fully recharge, the generator will be turn off and power is provide by the battery again. But result from this project can be used for other type of battery and power of DC motor. This project also wants to monitor the battery lifetime if DC motor using different horsepower. With the design of new charger that can improving charger controller system also can give a contribution to an automotive-electrical field.

5.2 FUTURE WORKS

As a recommendation, new charger design can be combine with another electronic circuit to make it efficiently. That electronic circuit is known as a microcontroller. With a microcontroller, relay, timer and indicator with a charger circuit, more effective charger can be produce where it can charge the battery while supply the energy to DC motor in an Electric Vehicle. Before this, the charging method only can be done when we off the vehicle and charging it. With this recommendation, the drivers have an opportunity to choose how much SOC that are needed to complete a journey. Charging battery by using a lead-acid battery or using a DC/AC converter is commonly used and be used in this project. There are many ways to generate electricity such as solar, wind and water. For future works, charging the battery is not using a lead-acid battery or AC/DC converter but will be upgrade by using a solar panel or wind turbine to recharging a series of battery pack in the battery system. While an EV moving, wind or solar will generate an energy to helps charger to recharge batteries in EV. With this combination, an EV really achieves the zero emission because using 100% renewable energy for an EV and hope that one of real Electric Vehicle can be produce by UMP using the method and project that UMP students have contribute.

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APPENDICES A

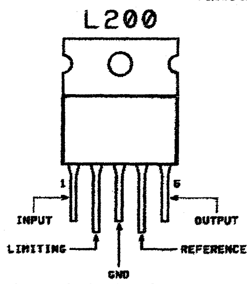
CHARGER REFERENCE 1

What you need to make the charger
You need the following parts:

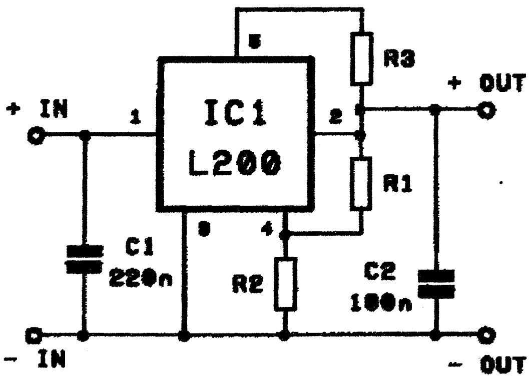
- an L200 chip
- an AC/DC converter
- a strip board and wires
- a few resistors (including one variable resistor) and capacitors
- a box to put it all in, preferably aluminum
- connectors for your battery and the AC/DC converter
- **various screws to put everything together**

You need the following tools:

- a soldering iron
- a multimeter (well, probably just a voltmeter would do)
- a drill to put holes in your box
- **various files, screwdrivers, and wrenches**



The main body of the L200 chip (made by SGS-Thomson) is about 1cm on a side, and it has 5 pins and a tab for attaching to a heat sink. The chip as used in the circuit below acts as a voltage regulator with current limiter. The current limiting aspect is important in order to keep the current within the range that the AC/DC converter can safely deliver.



The capacitors C1 (of 220 nanoFarad) and C2 (of 100 nanoFarad) smooth out the input and output voltages. This is important because the L200 has a feedback loop where it takes voltage readings that depend on its output and then changes its output in responce. This can induce some oscillations in its output. The size of the capacitors is appropriate for smoothing out this frequency. R2 should be an 820 Ohm resistor. R1 should be a variable resistor, with maximum value somewhat larger than the computed ideal resulting from the second equation. It's best if it can be adjusted very finely, as you want to be precise about the output voltage of your charger. The value of R3 sets the maximum current the circuit will produce (up to about 2A). The relevant equations are:
Vout (in volts) = 2.77 * (1 + R1 / R2)
R1 = (Vout/2.77 - 1) * R2
R3 (in Ohms) = 0.45 / Imax (in amps)
where Vout is the voltage drop across the output (between + OUT and - OUT, this is the voltage applied to your battery), and Imax is the maximum charging current. To determine what Imax should be, find the manufactorer's charging recommendations for your battery. Some batteries, like my Hawker Cyclon don't need to have the current limited when they are being charged with constant voltage. Still, you have to pick some value, and you'll want it to be less than than the 2A max that the L200 will deliver and less than the max current your AC/DC converter is rated for (which is clearly written on the converter). I used a resistance of about 0.5 Ohms to limit it to about 1A, as the AC/DC converter I used (see below) is rated for 1A.
You can see that with this circuit you'll get an output voltage anywhere between about 3V and 33V. Thus, practically speaking, it can be used as a charger for either a 6V or 12V battery depending on how you set the resistor R1, and which AC/DC converter you use.

APPENDICES B

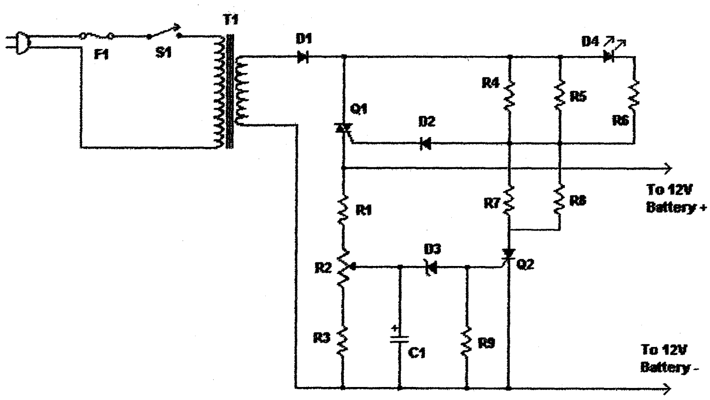
CHARGER REFERENCE 2

Automatic 12V Lead Acid Battery Charger

Author	Views	Views Today	Rank	Comments
	56,945	137		90

This charger will charge any 12V lead acid battery including flooded, gel and AGM. It is fully automatic and will charge at a rate up to about 4A until the battery voltage reaches a preset point at which it will switch to a very low current float charge. If the battery voltage drops again the charger will begin charging until the voltage once again reaches the cut off point. In this way it can be left connected to a battery indefinitely to maintain full charge without causing damage. An LED indicates when the battery is fully charged.

Schematic



Parts

Part	Total Qty.	Description	Substitutions
R1, R3	2	330 Ohm 1/4W Resistor	
R2	1	100 Ohm 1/4W Pot	
R4, R5, R7, R8	4	82 Ohm 2W Resistor	
R6	1	100 Ohm 1/4W Resistor	
R9	1	1K 1/4W Resistor	
C1	1	220uF 25V Electrolytic Capacitor	

D1	1	P600 Diode	Any 50V 5A or greater rectifier diode
D2	1	1N4004 Diode	1N4002, 1N4007
D3	1	5.6V Zener Diode	
D4	1	LED (Red, Green or Yellow)	
Q1	1	BT136 TRIAC	
Q2	1	BRX49 SCR	
T1	1	12V 4A Transformer	See Notes
F1	1	3A Fuse	
S1	1	SPST Switch, 120VAC 5A	
MISC	1	Wire, Board, Heatsink For U1, Case, Binding Posts or Alligator Clips For Output, Fuse Holder	

Notes

1. R2 will have to be adjusted to set the proper finish charge voltage. Flooded and gel batteries are generally charged to 13.8V. If you are cycling the battery (AGM or gel) then 14.5V to 14.9V is generally recommended by battery manufacturers. To set up the charger, set the pot to midway, turn on the charger and then connect a battery to it's output. Monitor the charge with a voltmeter until the battery reaches the proper end voltage and then adjust the pot until the LED glows steadily. The charger has now been set. To charge multiple battery types you can mount the pot on the front of the case and have each position marked for the appropriate voltage.
2. Q1 will need a heatsink. If the circuit is mounted in a case then a small fan might be necessary and can generally be powered right off the output of D1.
3. T1 is a transformer with a primary voltage appropriate to your location (120V, 220V, etc.) and a secondary around 12V. Using a higher voltage secondary (16V-18V) will allow you to charge 16V batteries sometimes used in racing applications.
4. If the circuit is powered off, the battery should be disconnected from it's output otherwise the circuit will drain the battery slowly.

Related Circuits

6V to 12V Converter, Portable CD Player Adapter For Car, Car Battery Charger, Automatic 12V Lead Acid Battery Charger, Solid State Tesla Coil/High Voltage Generator, 12VDC To 120VAC Inverter, LASER Power Supply, Power Supply, High Current Power Supply, Dual Polarity Power Supply, High Voltage High Current Power Supply, Transformerless Power Supply, Fixed Voltage Power Supply, Voltage Inverter, Voltage Inverter II, Automatic Load Sensing Power Switch