DECLARATION

I declare that this thesis entitled "Energy Management For A Series Hybrid Electric Vehicle (HEV)" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ______________________________

Name : MOHAMAD KAMAL HILMI B. MOHD RAFI

Date : 19 JUNE 2012

DEDICATIONS

Specially dedicated to my beloved father and mother for their supports in aspect of financial and motivation. Also thanks to my siblings and friends for all of the encouragement and support to complete this project.

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Thanks to Allah for giving me a good health to complete my final project. This project would not have been possible without the support of many people. I would like to thanks my supervisor En. Mohd Rusllim Bin Mohamed who was abundantly helpful and offered invaluable assistance, support and guidance.

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I also want to express my love especially for my parents for their understanding and endless love through the duration of my studies.

Once again, thank you all very much from the bottom of my heart. Without you, I could never have done it successfully.

ABSTRACT

The studies for hybrid electrical vehicle (HEV) have attracted considerable attention because of the necessity of developing alternative methods to generate energy for vehicles due to limited fuel based energy, global warming and exhaust emission limits in the last century. HEV incorporates internal composition engine, electric machines and power electronic equipments. In this study, overview of HEVs with a focus on hybrid configurations and energy management strategies are presented. This project is to be carried out by perform a demonstration of small scaled hardware that will used remote control (RC) parts as components to this project. First phase of the project will be focusing on software that will monitoring the speed of DC motor and perform a close loop that will estimate the energy requirement in certain condition. While the second phase of the project will be focusing on hardware development integrating with energy management software. The ratings of the battery and engine and the power output that will be delivered by each source under the expected condition will be considered in this paper. In this paper, the software and hardware that will be used and integrated will mention. An in house series hybrid electric vehicle will develop and in other word this paper presents the small scale of Series Hybrid Electric Vehicle (SHEV).

ABSTRAK

Kajian untuk kenderaan elektrik hybrid (HEV) telah menarik perhatian kerana keperluan membangunkan kaedah alternatif untuk menjana tenaga bagi kenderaan kerana tenaga bahan api terhad, pemanasan global dan had pelepasan ekzos di abad yang lalu. HEV menggabungkan enjin komposisi dalaman mesin elektrik dan perlatan elektronik kuasa. Dalam kajian ini, gambaran HEV dengan fokus pada konfigurasi hibrid dan strategi pengurusan tenaga dibentangkan. Projek ini akan dijalankan dengan melaksanakan demosntrasi perkakasan berskala kecil. Fasa pertama projek ini akan memberi tumpuan kepada perisian yang akan memantau kelajuan motor DC dan melaksanakan gelung rapat yang akan menggarkan keperluan tenaga dalam keadaan tertentu. Manakala, fasa kedua projek ini akan memberi tumpuan kepada pembangunan menyepadukan perkakasan dengan perisian pengurusan tenaga. Penilaian bateri dan enjin dan keluaran kuasa yang akan disampaikan oleh setiap sumber di bawah kedaan yang dijangka akan dipertimbangkan dalam kertas kerja ini. Dalam kertas ini, perisian dan perkakasan yang akan digunakan dan bersepadu akan disebut. Kenderaan Hibrid Siri akan dibangunkan dalam kata lain kertas kerja ini menbentangkan skala kecil Siri Hibrid Elektrik Kenderaan

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LIST OF ABBREVIATIONS

HEVs	-	Hybrid Electric Vehicle
SHEVs	-	Series Hybrid Electric Vehicle
PHEVs	-	Parallel Hybrid Electric Vehicle
DC	-	Direct Current

CHAPTER I

INTRODUCTION

1.1 Background of Project

In urban area, due to the beneficial effect on environment, electric and hybrid vehicles are an important factor for improvement of traffic and more particular for a healthier environment. We are quite rapidly reaching the end of the cheap oil era. Therefore the need for alternative energy source is growing and the price competition of alternatives against oil is becoming more and more realistic. Electric and electric hybrid vehicles are offering the best possibility for the use of new energy sources because electricity can result from a transformation with high efficiency of these sources and is always used with the highest possible efficiency in systems with electric drives or components. Some basic considerations about electric and hybrid vehicles today are presented together with the infrastructure developments [2].

A hybrid electric vehicle is propelled with stored energy from a battery or flywheel, plus energy produced by burning fuel in an engine. The cost of the energy consumed, as well as the quantity of air pollutants released, can be reduced by optimizing the ratings of the battery and engine and the power output that will be delivered by each source under the expected driving conditions. Life-cycle cost can be minimized by running the engine at a constant speed and power, and by avoiding deep discharges of the battery.

The main issue for HEV design is controlling the energy transfer from sources to the loads with minimum loss of energy which depends on the driving cycles. HEVs include more electrical apparatus such as electric machines, power electronics, electronic continuously variable transmissions, embedded powertrain controllers, advanced energy storage devices and energy converters as compared to the conventional internal combustion engine vehicles (ICEVs). The powertrain configuration of HEV can be divided into three types, series, parallel and series-parallel. The series hybrid is the simplest kind of HEV [3]. Its engine mechanical output is first converted into electricity using a generator. The converted electricity either charges the battery or can bypass the battery to propel the wheels via the same electric motor and mechanical transmission.

The cost of energy consumed as well as the quantity of air pollutants released can be reduced by optimizing the ratings of the battery and engine and the power output that will be delivered by each source under the expected driving conditions [4]. Therefore, the study of the energy management of hybrid electric vehicle is compulsory to upgrade the performance of the battery and also performance of the battery also performance of the vehicles.

1.2 Problem Statement

Growing concerns about oil prices and environmental protection have forced the automotive industry to accelerate the pace of the development of hybrid electric and fuel cell vehicles for mass marketing. Hybrid electric vehicles (HEVs) seem to be the most economically viable solution so far and probably for the next decade [1], [2]. As hybrid electric vehicles (HEVs) are gaining more popularity in the market, the rule of the energy management system in the hybrid drivetrain is escalating [8]. Performance of the hybrid electric vehicle always focuses on sources, the powerful of the battery and also the internal combustion engine (ICE). However, the more power of the source, the more expensive the vehicle. So, to overcome this problem, an energy management on this hybrid electric vehicle has to propose so that energy that was produced either by the battery or internal combustion engine can be managed. For example, the cost of the energy consumed as well as the quantity of air pollutants released can be reduced by optimizing the ratings of the battery and engine and the power output that will delivered by each source under the expected driving conditions.

1.3 Objectives

The objectives of this project are:

1. To design and develop an energy management system of series HEV.
2. To develop an in-house HEV unit in series configuration, electronic system and demonstrate the operation.

1,4 Scope of Project

This project is about an energy management system of series HEVs that is focused on software development include programming the microcontroller and hardware development to show the series HEVs configuration system and demonstrate the energy management. A Radio Controlled Nitro Car is used as an in house model of a vehicle and electronic systems are designed to show the energy management in series HEVs.

1.5 Project Outline

This project consists of five chapters including this chapter. The content of each chapter can be outlined as follows:

Chapter 2 provides a literature review, background, previous research done by other researchers in the same area and relevant issues to Series Hybrid Electric Vehicles and also the energy management. The principle designs of a hybrid electric vehicle have been considered especially on series configuration and some studies of the components have been mentioned in this chapter.

Chapter 3 describes a broad description of the research methodology in this project. This chapter begins with description of theoretical studies focusing on energy management of series hybrid electric vehicle methods including the use of the RC nitro car compartment. This chapter state the three phase of the methods in order to create the energy management of series hybrid electric vehicle. The software and circuit diagram of the electronic system including the integration between the software and hardware have been showed in this chapter.

Chapter 4 presents the result and discussion of this project based on the energy management created by integration between the software and hardware. The movement of the car recovered in two conditions, accelerating and decelerating where presented by electronic component and shows the series configuration hybrid electric vehicle. The result of this project recovered only in that two conditions and discussion of each condition have followed.

Chapter 5 provides a general conclusion based on this project status. The improvement for further studies on energy management of series hybrid electric vehicle is established. Future works for completing the study are highlighted. Other research opportunities for future work are presented.

CHAPTER II

LITERATURE REVIEW

2.1 Introduction

This chapter describes some literature related on Hybrid Electric Vehicle (HEV) have conducts by others researcher related in this project. This project require a full understanding about the Hybrid Electric Vehicle especially in series configuration system, so overview from previous study really help in understanding the concept and idea of the whole project.

Nowadays, HEVs become more popular among giant company and has increase in the level of research and development being conducted into the field in order to yield greater performance benefits. There are number of papers investigating areas for improvement and providing possible solutions as well as looking at the current state available technologies in order optimize performance.

2.2 Principle design of a Hybrid Electric Vehicle

There are several previous studies conducted into the current state of HEVs to give a general idea of what is presently achievable. Two examples are "Electric and Electric Hybrid Vehicle Technology A Survey" [3] and the "Ultracapacitors For Electric, Hybrid and Fuel Cell Vehicles" [4], both papers give a useful overview on the principles design of a HEVs as well as the different configurations and components involved. Some useful information about different configuration of HEVs and list of battery options with advantages and disadvantages as well as a table of characteristic such as specific energy, specific power and energy density [3]. There is also a brief discussion of possible motor selections. The second paper [4] covers similar studies with some focus on the background of the problem. This project generally focused on the series configuration system, this paper [5] said that the series hybrid is a combination of energy sources. The traction is obtained by only one central electric motor or by wheel hub motors. The total energy source results from the combination of two or more energy sources. The rated power of the engine-generator group can be designed on very different ways depending on the applications characteristics.

Besides that, the second paper [5] said that one of the alternative energy storage methods is ultracapacitors. In its discussion, based on nowadays technology, available HEVs made more relevant due to the increased market penetration over those 10 years. This provides a useful insight for car manufacturers in adopting hybrid technology as well as their preferred architectures and component choices.

After several years, extensive research has been done on PHEVs and HEVs. As it has two sources of energy for example engine and battery, some researchers have presented a few energy management strategies and optimized them using various optimization techniques. Dominik Karbowski [12] has investigated about the control strategy for transmission of parallel PHEV using global optimization technique based on Bellman principle. Its main objective was to reduce the losses in engine, motor, and battery. Then the results were compared with the default control strategy of PSAT for different distances travelled by PHEV. While, paper study by Aymeric and

Sylvain [13], they used DIRECT algorithm to obtain some optimized parameters for rule-based control strategy for transmission of parallel PHEV. They also analyzed the impact of distance travelled by PHEV on these parameters. Both papers showed that drive cycle and distance travelled impact their results significantly.

2.3 System Configuration

The definition of the HEVs is so general that it anticipates future technologies of energy sources [5]. As proposed by Technical Committee 69 (Electric Road Vehicles) of the International Electrotechnical Commission, a HEVs is a vehicle in which propulsion energy is available from two or more kinds or types of energy stores, sources or converters, and at least one of them can deliver electrical energy. Based on this general definition, there are many types of HEVs, such as the engine and battery, battery and fuel cell, battery and capacitor, battery and flywheel and battery and battery hybrids. However, the above definition is not well accepted. Ordinary people have already born in mind that a HEVs is simply a vehicle having both an engine and an electric motor. To avoid confusing readers or customers, specialists also prefer not using the HEVs to represent a vehicle adopting energy source combinations other than the engine and battery hybrid. For example, they prefer to call a battery and fuel cell HEVs simply a fuel cell EV. As we prefer general perception to lose definition, the term HEVs in this paper refers only to the vehicle adopting both the engine and electric motor for the drive train, while the engine and battery hybrid is the energy source. Traditionally, HEVs were classified into two basic kinds, series and parallel. Recently, with the introduction of some HEVs offering the features of both the series and parallel hybrids, the classification has been extended to three kinds, series, parallel and series–parallel. In the year 2000, it is interesting to note that some newly introduced HEVs cannot be classified into these three kinds. Hereby, HEVs are newly classified into four kinds:

1. Series hybrid
2. Parallel hybrid
3. Series–Parallel hybrid
4. Complex hybrid

Series hybrid electric vehicles (SHEV) involve internal combustion engine (ICE), generator, battery packs, rectifier, capacitors, converters and electric motors as shown in Fig. 2.1. Based on papers [18], [19], [20], [21], [22], [23],[24], SHEV has no mechanical connections between ICE and wheels.

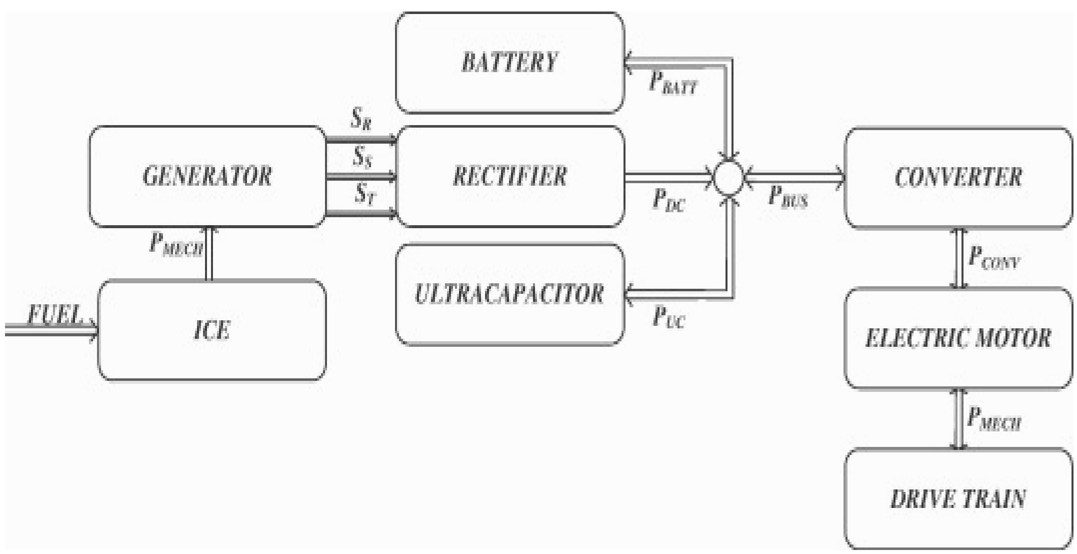

Figure 2.1: The power flow of SHEV powertrain [18].

ICE is turned off when the battery packs feed the system in urban driving. Significant amount of energy is supplied from the regenerative braking and the down slope driving. Ultracapacitors are added to the system to extend the lifecycle and the efficiency of the battery. ICE is turned on when the battery energy is low in the country driving. If the power demand of electric motor is the less than output power of generator, the remaining power is used to charge ultracapacitor banks and battery pack. If the power demand of motor is higher than the output power of the generator, the required energy is supplied from ultracapacitor banks and battery pack.

Therefore, engine operates at its maximum efficiency point so the fuel efficiency improves and the carbon emission is less than the other vehicle configurations. It is applied to the commercial vehicles with the improvement of SHEV configurations. SHEV applications include TEMSA – Avenue Hybrid bus, Mercedes – Citaro bus and

Table 1: Benefits of the series hybrid configuration [26].

Features	Optimized efficient power plant	Fast "black box" service exchange possible
	Modular power plant possibilities	Long operational life
	Optimized efficient traction drive line	Mature well proven technology
	Engine down sizing	Excellent transient response
	Space packaging advantages	Zero emission operation possible
Disadvantages	Larger traction drive system	
	Careful design algorithms a prerequisite	
	Multiple energy conversions	
Vehicles systems/applications	TEMSA Avenue Hybrid	Tesla ultra light rail
	Orion VII	Conventional light rail
	Wrightbus electrocity	New Tesla buses

2.3.2 Parallel hybrid electric vehicles (PHEV)

In PHEV, both the mechanical power output and the electrical power output are connected in parallel to drive the transmission as shown in Fig. 3. There are various control strategies used for parallel configuration. In the most common strategy, ICE is basically always in on mode and operates at almost constant power output at maximum efficiency point.

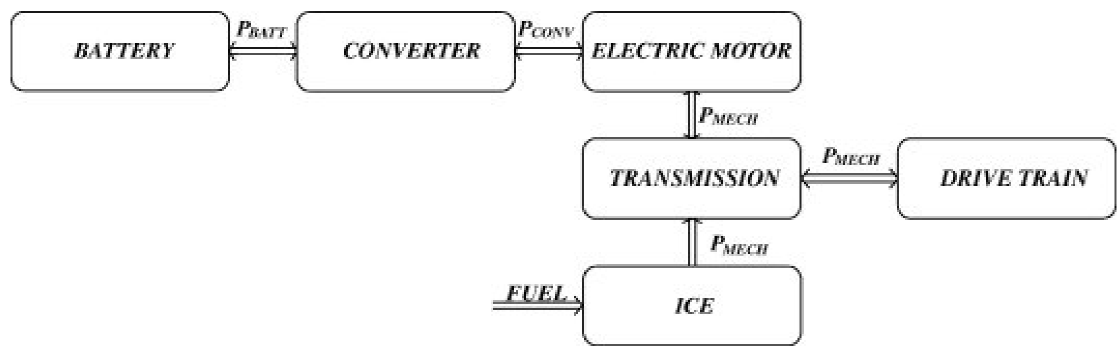

Fig. 2.2: The power flow of parallel HEV powertrain.

If the power requested from transmission is higher than the output power of ICE, the electric motor is turned on, ICE and electric motor supply power to the transmission. If the power requested from transmission is less than the output power of the ICE, the remaining power is used for charging the battery packs. In this configuration, regenerative braking power on a down slope driving is used to charge the battery. Insight model introduced by Honda is a specific implementation of parallel HEV (PHEV). Other examples for PHEV applications are Ford Escape Hybrid SUV and Lexus Hybrid SUV. Benefits of the parallel hybrid configuration are given in Table 3[26].

Table 2: Benefits of the parallel hybrid configurations [26].

Features	Economic gain at high cost
	Retarder option but at complexity risk
	Zero emission operation possible

Disadvantages	Expensive system
	Control complexity
	Careful design algorithms a prerequisite
	High voltages needed for efficiency
	Complex space packaging
	Hino HIMR
Vehicles systems/applications	Bus/heavy truck market

Table 3: A general comparison of SHEV and PHEV Powertrain [26].

Architecture	System voltage	Typical power requirement (kW)	Electric fraction (%)	Relative fuel economy gain (%)
Parallel Configuration	14 V, 42 V, 144 V, 300 V	3–40	5–20	5–40
Series Configuration	216 V, 274 V, 300 V, 350 V, 550 V, 900 V	>50	100	>75

2.3.3 **Combination of parallel and series HEVs**

Combination of parallel and series hybrid configurations into a single package is quickly becoming the standard in passenger vehicle hybridization [27]. As the name implies the combination hybrid configuration is neither fully parallel nor series configuration. Fig. 4 shows the essential of the combination architecture.

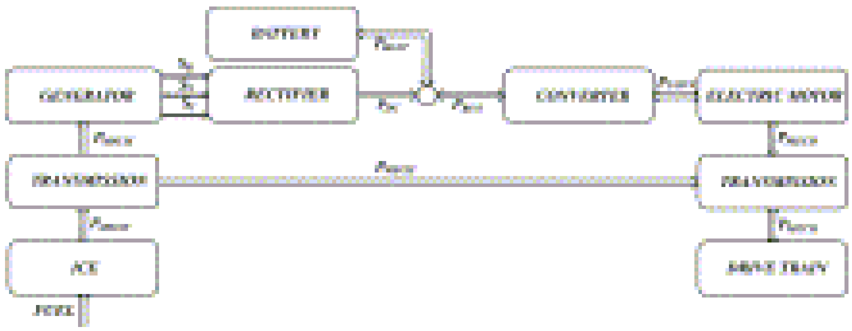

Figure 2.3: The combination of parallel and series hybrid configurations.

In the series-parallel hybrid, the configuration incorporates the features of both the series and parallel HEVs, but involves an additional mechanical link compared with the series hybrid and also an additional generator compared with the parallel hybrid. Although possessing the advantageous features of both the series and parallel HEVs, the series-parallel HEV is relatively more complicated and costly. Nevertheless, with the advances in control and manufacturing technologies, some modern HEVs prefer to adopt this system.

2.3.4 Complex hybrid system

As reflected by its name, this system involves a complex configuration which cannot be classified into the above three kinds. As shown in Fig. 1, the complex hybrid seems to be similar to the series-parallel hybrid, since the generator and electric motor are both electric machinery. However, the key difference is due to the bidirectional power flow of the electric motor in the complex hybrid and the unidirectional power flow of the generator in the series-parallel hybrid. This bidirectional power flow can allow for versatile operating modes, especially the three propulsion power (due to the engine and two electric motors) operating mode, which cannot be offered by the series-parallel hybrid. Similar to the series-parallel HEV, the complex hybrid suffers from higher complexity and costliness. Nevertheless, some newly introduced HEVs adopt this system for dual axle propulsion.

2.4 Series Hybrid Electric Vehicle (SHEV) studies.

This project will be more focusing on the series system and the study and research about series configuration hybrid vehicle is very important so that this project can proceed. However, the scope of this project will be smaller compare to other research that will only required a small scale of an in house energy management. Based on paper [3], series hybrids are more suited to large scale applications such as busses and military vehicles, since the traction motor is the only torque source in the vehicle and as such needs to be a considerable size in order to propel the vehicle at a reasonable speed [3]. The parallel configuration is better applied to smaller passenger vehicles since it utilities two torque sources in parallel (the ICE and electric motor) to the final drive simultaneously, meaning the motor can be sized smaller and such as the drivetrain itself will take up significantly less space [3]. The third configuration is the series-parallel architecture preferred by Toyota for its Hybrid Synergy Drive which combines the benefits of the series and parallel configurations through use of a planetary gear input that acts as a power splitting device. This technology will transfer engine power to the drive train and generator as necessary [8]. The downside of this method is the added cost and complexity resulting from the additional generator and planetary gearset [3].

In this project, energy management will be considered for a Series Hybrid Electric Vehicle. So, this paper [6] have discussed more about the energy management in the component have use. This paper said that, during the SHEV automobile working process, it often happens that energies from two or more sources superimpose. The main purpose of the correct matching of SHEV powertrain is determine the operating characteristics of the engine and its power distribution and energy balance with the energy storage device. By controlling the working status of various energy sources, the energy conversion efficiency can be improved, the loss due to energy transmission can be reduced, and ultimately the energy can be utilized in a maximum way for SHEVs. The general control strategy for SHEVs is developed normally based on the parameters such as battery, the driver's accelerator pedal position, the wheel speed and the average power of the driving wheel and then the engine and electric motor generate the corresponding torque to meet the requirements of the driving torque for the driving wheel. Commonly used control strategies include "thermostat" and "power follower" , where the power follower strategy are described as follows, when the battery SOC is greater than the upper limit of SOCmax, the engine stops working, but when the power demand of vehicle is too large, the engine needs to be restarted, when the battery SOC is less than the lower limit SOCmin, the engine needs to get to work, when the engine works, its power output should not only follow the changes of the power demand of the vehicle, but keep the battery SOC around the middle value of its working range, while he engine is working, its output power should not be too small or too large in order to ensure high efficiency.

2.5 Electric Motor

Based on this paper [3], the electric propulsion system consists of three main parts that are electric motor, a power electronic converter and its controller. At first, author said that DC motor drives have the proper characteristic for fraction application and was popularly used a couple decades ago. However, DC motor drives low efficiency, the need of maintenance and low reliability. Relate with my project, I will certainly use DC motor because this project prefers to develop an in house energy management of Hybrid Electric vehicle and it just a small scale component. With the coming era of power electronics and digital microprocessor control technology, other advanced motor drives are mature to replace the dc motor drive in traction applications. At present, permanent magnet brushless dc (BLDC) motors, induction motors (IM), and switched reluctance motors (SRM) are considered to be the most likely candidates for the vehicle propulsion application.

The different traction motor options available are also focus on number of papers [3], [4], [6]. Their author said that specifically there are three main choices, permanent magnet brushless DC motors, induction motors and witched reluctance motors. Generally no clear conclusions are given. In fact, the reader can make a choice depending on the application. The three traction motor have their advantages and disadvantages. Permanent magnet machines typically have a high power density and efficiency, low maintenance and easy to control but have a short constant power range impacting on the ability of the vehicle to use the motor cruise [1], [3]. Induction machines can be rated for high power levels and are relatively cheap and readily available. However they suffer from rotor copper losses which reduce efficiency over PM motors and will stall above a certain critical speed [3], [6]. Switched reluctance machines have a large extended power region, are different at high speeds, are fault tolerant and have a high power density, however they suffer from torque ripple and high acoustic noise, although this can be controlled and require a complicated controller [3], [4], [7]. The general consensus of the literature is that all three are appropriate for vehicle applications and have their respective advantages, although some comparisons could be made in ADVISOR.

2.6 Motors and generators

Generators make DC current, and batteries need DC for charging. Generators were used in automobiles until around 1970, when alternators became more practical (due to the availability of cheap, small diodes). Even old car generators must spin too fast to be practical for wind power, but there have been many good plans for modifying them. Generators are fairly complex compared to alternators. They must have brushes, and complex commutators. Brushes require maintenance, and commutators can wear out. For most purposes, alternators are more practical today, although generators do have certain advantages at times. Certain low rpm DC motors can be purchased as surplus and work very well as 12 volt low rpm generators.

Figure 2.6: DC motor [11]

2.7 Back EMF

DC motors as shown in Figure 4 and generators may be the same thing. For example, the motors of trains become generators when the train is slowing down, they convert kinetic energy into electrical energy and put power back into the grid. Recently, a few manufacturers have begun making motor cars rationally. In such cars, the electric motors used to drive the car are also used to charge the batteries when the car is stopped - it is called regenerative braking.

Every motor is a generator [29]. This is true, in a sense, even when it functions as a motor. The emf that a motor generates is called the back emf. The back emf increases with the speed, because of Faraday's law. So, if the motor has no load, it turns very quickly and speeds up until the back emf, plus the voltage drop due to losses, equal the supply voltage. The back emf can be thought of as a 'regulator': it stops the motor turning infinitely quickly (thereby saving physicists some embarrassment). When the motor is loaded, then the phase of the voltage becomes closer to that of the current (it starts to look resistive) and this apparent resistance gives a voltage. So the back emf required is smaller, and the motor turns more slowly.

2.8 Energy storage

Basically, in this project will required the energy management, and for sure the management will take part in many part such as in battery, the speed of the electric motor and lastly ICE (Internal Combustion Engine). Energy storage options are also the focus of a number of papers [3], [5], [9] focus on the analysis of various battery options. Lithium ion batteries seems to be the optimal choice give their high specific energy and efficiency as well as being significantly smaller than lead acid batteries [10]. Nickel metal hydride batteries also a reasonable choice and are adopted in the Lexus performance hybrids [9]. The major disadvantage with chemical storage methods is their comparatively low specific power, whereas ultracapcatiors have the opposite problem such as high specific power but low specific energy and difficult to use in HEVs due to high dependence of output voltage on the state of charge [5]. In order to combine the benefits of both options the energy storage can be hybridized and the solutions are presented in [3]. A third option is discussed in [11] that required two motors, one connected to the battery to provide "large energy capacity at lower power levels" and another one connected to the ultracapacitors to provide short bursts of torque as required, for example during overtaking a gradient. The use of two motors means that each can be sized to fit its energy storage system as required and any intuitively this would suggest that emissions will be reduced in comparison with a standard hybrid since some of the power boost is provided by the capacitor motor and not the ICE.

Some issues arise from the paper though that firstly the lack of any quantifiable performance information means that the benefits of adopting this configuration are no readily apparent since they cannot be compared with other vehicles. Secondly, the design rationale do not meaning and reasonable reason about the choices, for example the use of lead-acid batteries which could be down to issues of cost but there are better options available in terms of performance such as lithium ion batteries which have higher specific energy, peak power and efficiency only let down by the comparatively higher cost [3]. Finally, as stated in the paper, the efficiency of transferring power between the battery and the supercapacitors is low although this could possibly be compensated for in the control strategy and engine management in order to dynamically maintain battery and supercapacitor states of charge. However, in my project, the energy required less than other project. So, there are many type of battery that I can considered as long the battery can charge and the specification of the battery have know. Whilst the first paper could be considered out of date, a lot of information is still relevant and provides some useful comparisons for example whilst the values in the table of battery choices are not accurate [3] due to the advances in battery technology. However they both give an overview of the subject of HEVs and the technology behind them without going into too much depth, partly because of the large scope of the subject.

Another resource that really in scope of energy management is paper [5], the author said about the an on-board "energy manager," which contains an embedded computer, can track the energy content of the battery and optimize the load division between the battery and engine when given a travel time by the driver over a specified route. It can command the engine to deliver more power whenever the alternative is a life-shortening deep discharge of the battery. The vehicle designer needs to perform a system engineering analysis to optimize the ratings of the engine and battery. For this he needs to understand the power required to move the vehicle at desired speeds over hills on the expected routes, and through headwinds that vary from day to day.

In a hybrid electric car the fuel burning engine can run at a speed and output power which gives the highest efficiency. Transient power for start-ups and hill climbing can be supplied by a battery. Prototype hybrid vehicles have achieved fuel economies of over 100 miles per gallon.

Modeling is the key route to high efficiency in a hybrid electric vehicle. In aerospace engineering we have developed computational fluid dynamic models of airplanes. A scaled version of the modeled airplane is built and tested in the wind tunnel. The mathematical model is adjusted to make it reproduce the wind-tunnel results. The designer can then input small changes in the engine performance, aerodynamic form, and weight of his airplane. The model will predict the airplane's new performance in terms of fuel consumption and flight time for pertinent flight routes. The old DC-10 airplane delivered 30 passenger miles per gallon of jet fuel. The new 777 airplane, which was configured with computational fluid dynamics, delivers up to 90 passenger miles per gallon. The hybrid-vehicle variables that can be optimized by modeling are many. Components that can be optimized include engine rating, motor rating, and battery energy capacity. Variables to be considered in minimizing life-cycle cost include the size and type of battery. Deeply discharging most batteries reduces their lifetime as measured in charge/discharge cycles. Adopting a bigger battery reduces the depth of discharge and lengthens battery life, but at the cost of fuel for hauling the heavier battery over hills.

2.9 Servo Motor

A Servo is a small device that has an output shaft. This shaft can be positioned to specific angular positions by sending the servo a coded signal. As long as the coded signal exists on the input line, the servo will maintain the angular position of the shaft. As the coded signal changes, the angular position of the shaft changes. Servos are extremely useful in robotics. The motors are small, have built in control circuitry, and are extremely powerful for their size. Servo motors incorporate several components into one device package; a small DC motor; a gear reduction drive for torque increase and an electronic shaft position sensing and control circuit. The output shaft of a servo motor does not rotate freely, but rather is commanded to move to a particular angular position. The electronic sensing and control circuitry which is the servo feedback control loop will drive the motor to move the shaft to the commanded position. If the position is outside the range of movement of the shaft, or if the resisting torque on the shaft is too large, the motor will continue trying to attain the commanded position. The servo motor control is inherently consists of the three wires: power, ground, and control. The power and ground wires are simply connected to a power regulated first to 5 V before applying to the servo motor. The control signal consists of a series of pulses that indicate the desired position of the shaft. Each pulse represents one position command. The length of a pulse in time corresponds to the angular position. Typical pulse times range from 0.7 to 2.0 milliseconds for the full range of travel of a servo shaft. Most servo shafts 24 have a 180 degree range of rotation. The control pulse must repeat every 20 milliseconds. For this project, one servo motors activating at 6 V will be used for tracking the angle of the light radiation. The tracking system use FUTABA servo motor as it needs higher torque that carries the load.

3.0 Microcontroller

Since the project's focus is on embedded software control, the microcontroller is the heart of the system. The microcontroller selected for this project had to be able to convert the analog voltage into digital values to control speed of DC motor and servo motor rotation. This project required two type of microcontroller, PIC16F887 and PIC16F877. This microcontroller was selected as it satisfies these requirements in addition to already being provided with the class lab kit.

3.1.1 PIC16F887

- 10 bit multi-channel analog-to-digital converter
- 5 input/output ports
- 256 x 8 bytes of data EEPROM memory

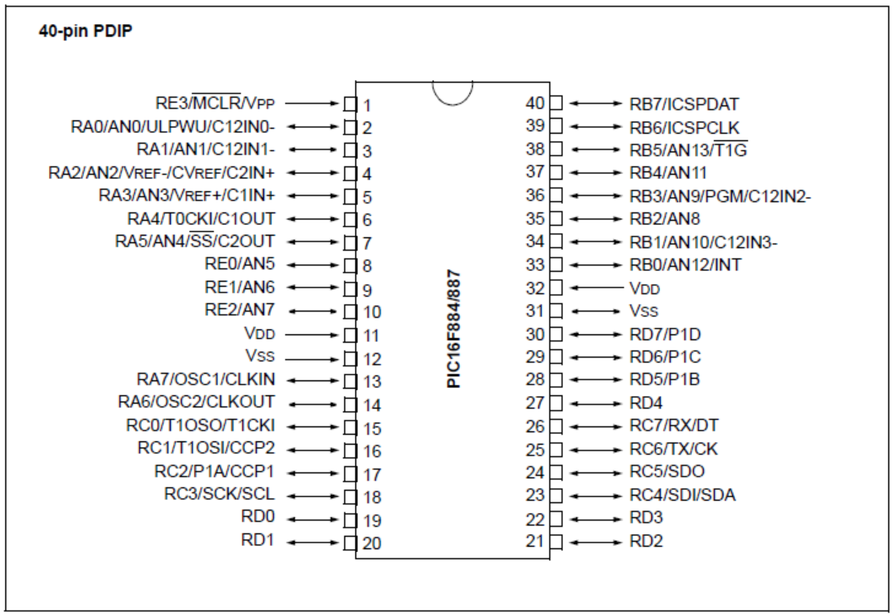

Figure 2.7: PIC16F887 Pin out [9].

2.7.2 PIC16F877

A 4 MHz crystal oscillator was also used in conjunction with the PIC16F877 to provide the necessary clock input. This speed is sufficient for the application. A pin diagram of the PIC16F877 is provided in Figure 2.8 from [15].

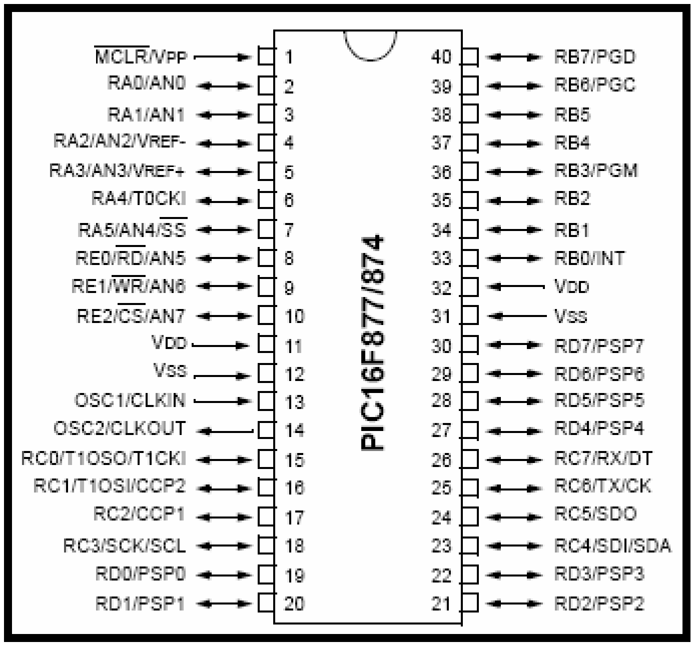

Figure 2.8: PIC16F877 Pin out [10].

CHAPTER III

METHODOLOGY

3.1 Introduction

Based on the objectives, this project implements three phases to perform an energy management of Series Hybrid Electric Vehicle. In order to complete this objective, the method and technical strategies implied is the most important to focus on. So, this chapter discussed about the methods that are used for this project. It includes overview of the whole system on how the series configuration in Hybrid Electric Vehicle operate besides show the energy management after the software and hardware being integrate.

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`Phase I: Software Development - simulates the DC motor speed controller and servo motor rotation controller and use MPLAB software to program coding. After that burn it into microcontroller.

Phase II: Hardware Development - Develop a functional model to demonstrate a basic operation of series of HEVs system

Phase III: Integrate software and hardware and demonstrate an energy management of Series Hybrid Electric Vehicle.

3.2 Overview of Project

This project is about to create an energy management in series hybrid electric vehicle. So, to create an energy management, there will be integrate between the software and hardware. The software also will conducted into two stages that in stage 1, this project required microcontroller to control the speed of the DC motor and another stage is about to control the servo motor where its control the power generate by the ICE. The rpm or speed of the DC motor also will display to show that the DC motor in accelerating condition. In addition, there will two conditions that conducted, first condition accelerating mode and second condition is decelerating mode. In accelerating mode, DC motor will operate in high speed that required maximum voltage from the battery. At the same time, servo motor will operate that gives maximum degree where ICE provides maximum energy to charge the battery. After that, the ICE will provide minimum energy means servo motor will also move to minimum angle to show that this is decelerating mode, DC motor in low speed.

3.3 Software Development

In the software development, to perform an energy management on board of Series Hybrid Electric Vehicle, the DC motor performs as the load for the system. This DC motor call clutch in the real vehicle system which this clutch that will control the speed of the vehicle. Relate to this project, the DC motor will setup in two condition that covered accelerating and decelerating condition. Energy required or voltage during accelerating and decelerating was measured to observe and compare the values of the voltage during different condition. In this situation, speed of the DC motor was controlled by the programmable PIC16F887. Figure 3.3 shows the circuit of the PIC16F887.

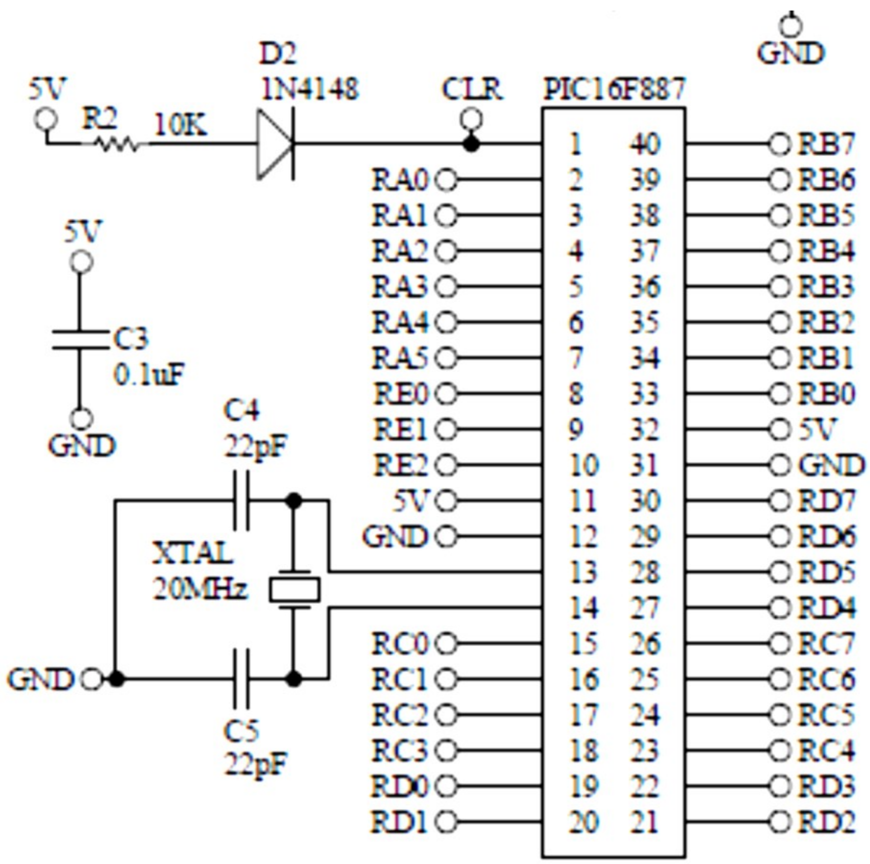

Fig 3.3.1: Circuit Diagram of PIC16F887 [39]

According to the Figure 3.3.1, each pin at PIC16F887 has their connection with the electronics component so that it can give suitable output voltage to control the speed of DC motor. For example, pins RA0, RA1 and RA2 were used in the part to control the speed of the DC motor. This pin only read the input in analog signal and produces the signal to digital output to other pins.

As mentioned in objectives, this project the software development countered in two parts, one is to control the speed of the dc motor and another one is control the rotation angle of servo motor. This project have to control dc motor to show the energy management created and show the series configuration of HEVs. Microcontroller have use to control the angle of servo motor is PIC16F676.

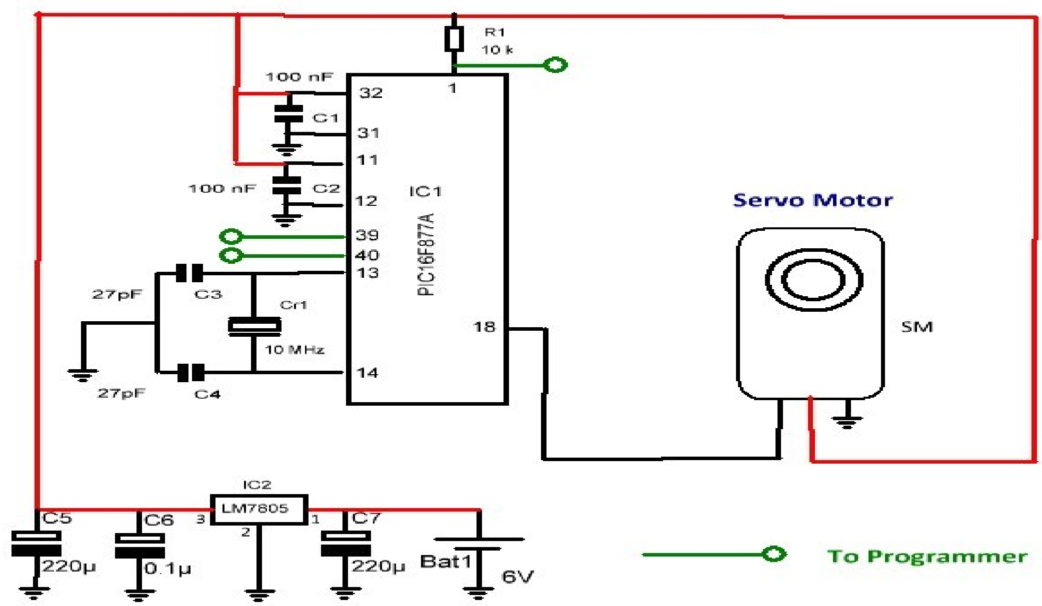

Fig 3.3.2: Circuit Diagram of PIC16F676 [40].

Figure 3.3.2 show the circuit of the PIC16F676 that able to control the rotation of servo motor. The same connection like PIC16F887, one pin at microcontroller connected to the variable resistor to control the rotation angle of servo motor. The programming inside the microcontroller gives a command whether the servo motor gives a maximum angle or minimum angle.

3.3.1 Rotary encoder

Besides that, in software development, the speed of the DC motor also was measured in this project to show differences value during the accelerating mode and decelerating mode. The speed of the DC motor is measured by the rotary encoder. Motor speed is measured in revolutions per minute together with infrared sensor encoders. Encoder is a plate that has a blade which is placed to rotate with the motor shaft. Infrared will read these blades to produce a pulse. It depends on the number of blades on the encoder. For example, using encoder with 8 blades of the motor will produce 8 pulses. In addition, there is a step to convert the unit rpm. In the PIC program, set the time frame for pulse counting. For example, within 0.5 seconds, when the motor is rotating will produce multiply with the number of pulse.

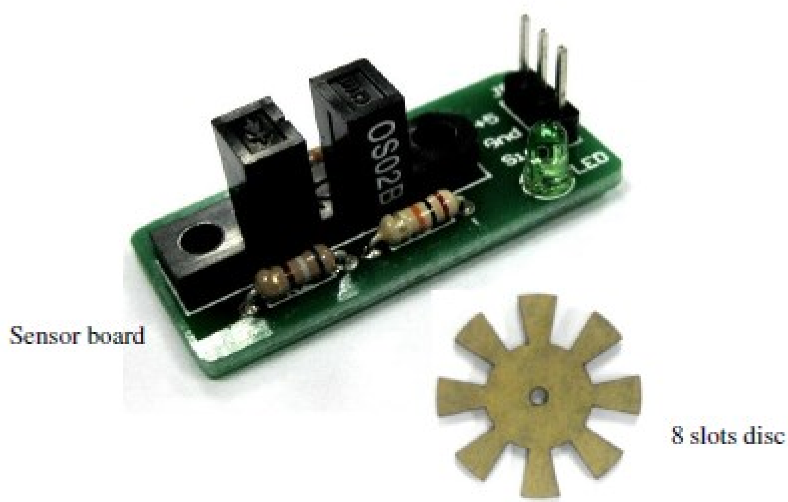

Fig 3.3.3: Picture of rotary encoder [30].

After installation, the rotary encoder as shown in Figure 3.3.3 is ready to count the rotation of output shaft. This information can further be calculation to obtain speed of output shaft or the velocity of motor. This kit is very simple and compact. User can connect it to any microcontroller using the 3- pin header. The onboard infrared beam detects missing slots in a slotted encoder disk, and generates a pulse train. The generated pulses are a 0 to 5V output. It provide a +4.6V output when the optical beam is blocked, and a 0.97V output when the beam is unblocked. The microcontroller can simply read the 0-5-0V pulse train to determine the distance of robot if the shaft is mounted to wheel and the wheel diameter is known, of course it can further be used for velocity. Simply follow the installation guide and configure microcontroller to count the pulses generated when the shaft rotates.

Figure 3.3.4 above show how the DC motor connect with the circuit that consist Infrared sensor that count the RPM of the DC motor.

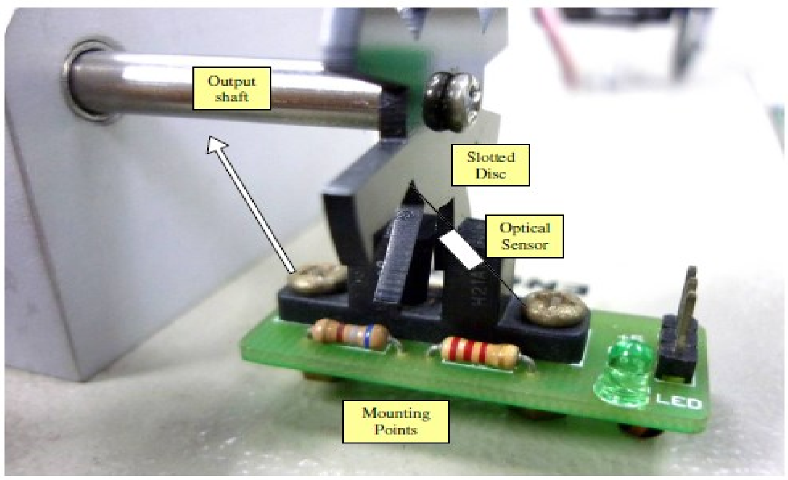

Fig 3.3.4: The port of DC motor between the infrared sensors [30].

3.3.2 Dual-Full Bridge Driver (L298)

DC motors are electric motors that use direct current. DC motor also has two terminals only. Motor will turn when the two terminal voltages is given in accordance with requirements such as 12V. Direction of cycles depends on the polarity of supply. To control DC motor, microcontroller H bridge driver is used.

H Bridge driver L293 or L298 as shown in Fig 3.3.5 for example is for higher motor current. With this driver, there are two inputs that allow control of direction of the motor either clockwise or anti-clockwise. This driver also enabled input that allow controlling the motor speed by provide PWM pin.

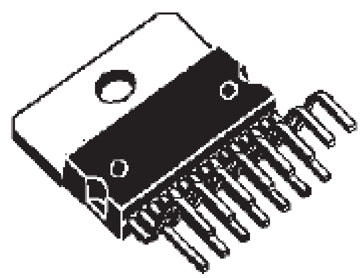

Figure 3.3.5: Picture of L298 [31]

This motor driver connected with the microcontroller, PIC16887 to control the speed of DC motor by inject different voltage in different condition. Figure 3.3.6 shows the connection diagram of the motor driver with microcontroller and DC motor. From the motor driver, pins no. 15, 14, 13, 12, 11, 10, 9, 8, 4 and 1 were used in this project in order to control the speed of DC motor.

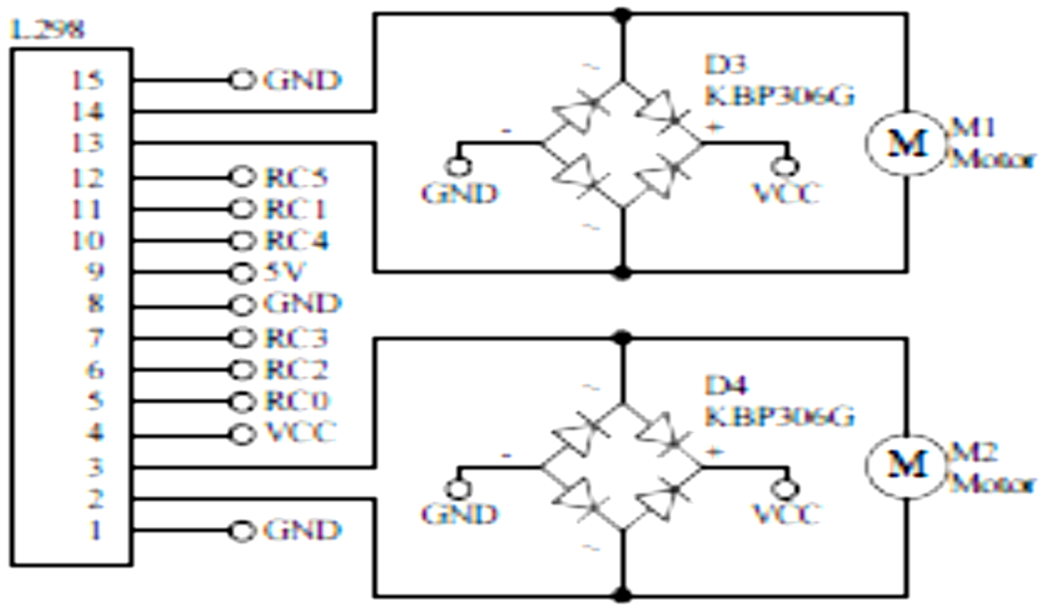

Fig 3.3.6: Circuit Diagram for Motor Driver L298

The L298 is an integrated monolithic circuit in a 15-lead Multiwatt and PowerSO20 packages. It is a high voltage, high current dual full-bridge driver designed to accept standard TT Logic levels and drive inductive loads such as relays, solenoids, DC and stepping motors. Two enable inputs are provided to enable or disable the device independently of the input signals. The emitters of the lower transistors of each bridge are connected together and the corresponding external terminal can be used for the connection of an external sensing resistor. In additional supply input is provided so that the logic works at a lower voltage.

3.3.3 Servo Motors

A motor, is a commonly used component in many gadgets that involve movement, it is used for linear motion, rotation (full/partial) or to and fro motions. There are different types of motors that are used in gadgets or robots to achieve these types of motions. Servo motor is used for controlled forward and backward motion or clockwise and anticlockwise rotation, particularly so when the torque (load) requirement is high. There are different types of servo motors available in the market; In this project we are only talking about simple servo motors that are used in hobby projects and experiments. Typically these motors can rotate -45 degree to +45 degree or -90 to + 90 degree or make full rotation clockwise or anticlockwise at controlled speeds. These are generally not precision motors, but can be easily programmed to position sensors, move objects forward or backward without depending heavily on feedback mechanism, once it is tuned.

Servo motors, typically comes with three wires. Two wires are designated for power supply and the third wire is for control. A Pulse Width Modulated (PWM) signal controls the position and direction of rotation of the motor spindle. You apply a few pulses of a certain pulse width through the control wire to position the spindle. The actual width of the pulse required is in the range of 1.0 to 2.0 milliseconds (this could vary depending on the brand and make of the motor)

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Partial rotation Servos are controlled by sending them a sequence of pulses of different widths. Figure 3.3.7 shows the graph according to the angle wanted and typically the pulse would repeat every 10-20 milliseconds (ms) and when the pulse width (duty cycle) is around 1.5 ms servo motor will return to the neutral position. The angle is determined by the duration of a pulse (pulse width) that is applied to the control wire. The servo expects to see a pulse every 10-20 ms. The length of the pulse will determine how far the motor turns. For example, a 1.5 ms pulse will make the motor turn to the 0 degree position (neutral position). 1 ms pulse width would move the motor to anti-clockwise direction by 90 degrees. Anything between 1 and 1.5 ms will rotate the motor anticlockwise direction proportionately. 2 ms pulse rotates the motor clockwise by 90 degrees.

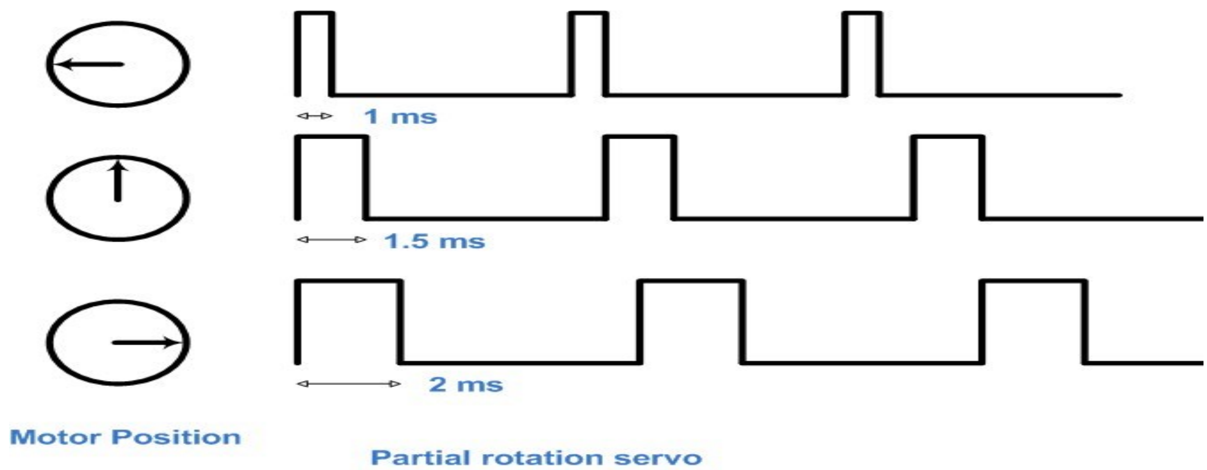

Fig 3.3.7: Partial rotation servo [19]

When these servos are commanded to move they will move to the position and hold that position. If an external force pushes against the servo while the servo is holding a position, the servo will resist from moving out of that position. The maximum amount of force the servo can exert is the torque rating of the servo. Servos will not hold their position forever though; the position pulse must be repeated to instruct the servo to stay in position.

3.4 Hardware Development

This paper required to develop an in house for a Series Hybrid Electric Vehicle, means that required hardware to operate it. Figure 3.4 shows the series configuration that will be develop. Each hradware will explain below:

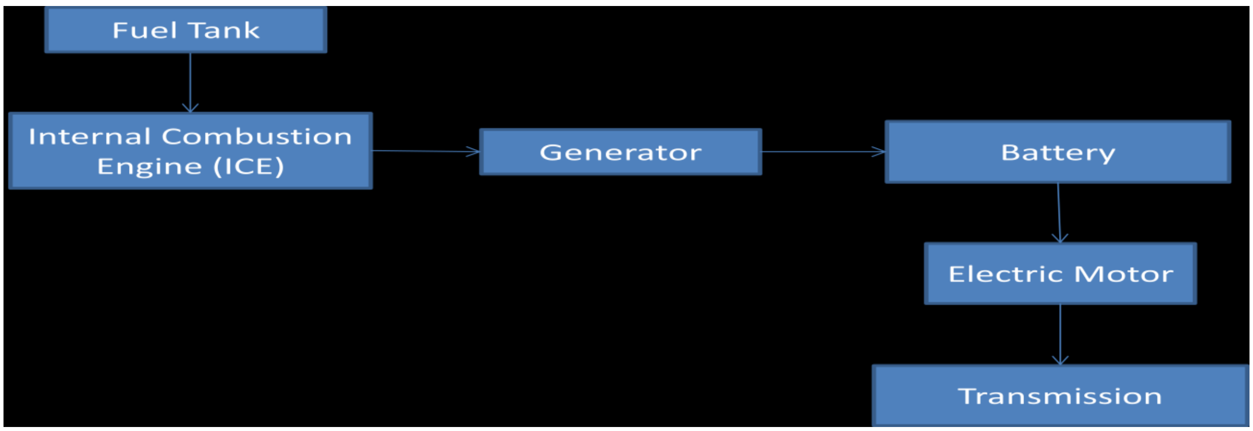

Fig 3.4: Congfiguration of Hardware Energy Management

3.4.1 Electric motor

An electric motor converts electrical energy into mechanical energy [19]. Most electric motors operate through the interaction of magnetic fields and current-carrying conductors to generate force. The reverse process, producing electrical energy from mechanical energy, is done by generators such as an alternator or a dynamo; some electric motors can also be used as generators, for example, a traction motor on a vehicle may perform both tasks. Electric motors and generators are commonly referred to as electric machines.

DC motor is designed to run on DC electric power. Two examples of pure DC designs are Michael Faraday's homopolar motor, and the ball bearing motor, which is a novelty. By far the most common DC motor types are the brushed and brushless types, which use internal and external commutation respectively to reverse the current in the windings in synchronism with rotation

In this project, DC motor have used to produce mechanical energy from electrical energy. Brushless Permanent Magnet DC motor have decided to use. The sepecification of the the DC motor are in the Table 3.4.1 below.

Table 3.4.1: Electric Motor Specifications

Name	**RX-RS380SMP-3270 (DC motor)**
Nominal voltage	12 V
Speed	15200 r/min
Current	0.34 A

From the table, the DC motor that used in this project required a nominal voltage 12 volt and its suitable for the circuit and show the acelerating and decelerating mode in order to manage the energy management of the series hybrid electric vehicle.

3.4.2 Battery

A battery, which is actually an electric cell, is a device that produces electricity from a chemical reaction. Strictly speaking, a battery consists of two or more cells connected in series or parallel, but the term is generally used for a single cell. A cell consists of a negative electrode; an electrolyte, which conducts ions; a separator, also an ion conductor; and a positive electrode.

Storage batteries are the traditional solution but there are advances in chemistries that make them realistic competitors to even the newest energy generation and storage devices [13]. Involving battery chemistries have demonstrated greater storage potential and are becoming more readily available for such endeavors. Consider the advancements in rolled Lead Acid, NiMH (Nickel Metal Hydride and Li-Ion (Lithium Ion) Batteries. Each type exhibits pros and cons for usage as a hybrid electric battery pack. Lead acid Batteries are readily available and relatively inexpensive. NiMH batteries provide and improvement in energy density and power density but with a higher cost and more risk because of the relative newness of this chemistry in larger batteries. The Li-On batteries promise even further advancement in energy and power density for the battery packs but holds the highest risk demands the largest monetary investment and will require a period maturation to define and establish a production base

A rechargeable battery as shown in Figure 3.4.2 or storage battery is a group of one or more electrochemical cells. They are known as secondary cells because their electrochemical reactions are electrically reversible. Rechargeable batteries come in many different shapes and sizes, ranging anything from a button cell to megawatt systems connected to stabilize an electrical distribution.

Fig 3.4.2: Sealed Lead-Acid Battery [13]

Specifications:

1) Nominal voltage: 12V
2) Nominal capacity: 7.2Ah

After all, a few properties have been determined where a battery should:

a. Provide enough voltage at full charge roughly around 12 V to 12.8 V
b. High discharge down rate as much as least 60% and above at time after time.
c. Not easily damaged by excessive rate of overcharge, discharge or even negative charge within to tolerable range.
d. Safe in operation when exposed to harsh ambient environment
e. Low in cost since more than one cell is required

Thus, on the whole that deep cycle lead acid batteries perform the overall characteristic to be used in the project. A deep cycle lead acid battery is designed to be regularly discharged to most of its capacity. Besides that, it is sufficient to powered output to load more than 12 V [19]. Certainly, the low cost of deep cycle lead acid battery is an attractive point beside less dangerous compare to volatile lithium-ion cell. Therefore, deep-cycle lead acid batteries are more suitable to be installed in stand-alone solar system in rural area in this project

3.4.3 Internal Combustion Engine (ICE)

The internal combustion engine (ICE) is a heat engine that converts chemical energy in a fuel into mechanical energy, usually made available on a rotating output shaft. Chemical energy of the fuel is first converted to thermal energy by means of combustion or oxidation with air inside the engine. This thermal energy raises the temperature and pressure of the gasses within the engine and the high pressure gas then expands against the mechanical mechanisms of the engine. There are two type of engine cycle, one fours stroke cycle and one is two stroke cycle. For this project, the two stroke cycle engine has chosen. A two stroke cycle has two piston movements over one revolution for each cycle.

Two fairly typical RC model car nitro engines are shown in Figure 3.4.3 (a) a pull start one (left) and non-pull start (right):

Fig 3.4.3 (a): Internal combustion engine [21]

The cylinder head sits on top of the crankcase and has extended or additional cooling fins to greatly increase the surface area of the head, to catch more air for cooling. This is because, unlike a glow plug engine in a radio control plane, an RC car engine doesn't get a huge amount of airflow over it so the surface area of the head needs to be increased to compensate. Inside the cylinder head is the piston which is the drum-shaped component that moves up and down many times a minute (hundreds or thousands) as the fuel/air mixture is ignited in the combustion chamber, which is the area inside the cylinder head above the piston. The piston is connected to the crankshaft by a connecting rod, or 'con rod'; this crankshaft runs perpendicular to the con rod through the crankcase and is connected to the clutch of the car. Sitting at the front of the engine on top of the crankcase is the carburetor, which is the part of the engine that introduces the fuel and air into the crankcase. The fuel / air mixture inside the combustion chamber is ignited by a glow plug, screwed into the top of the cylinder head.

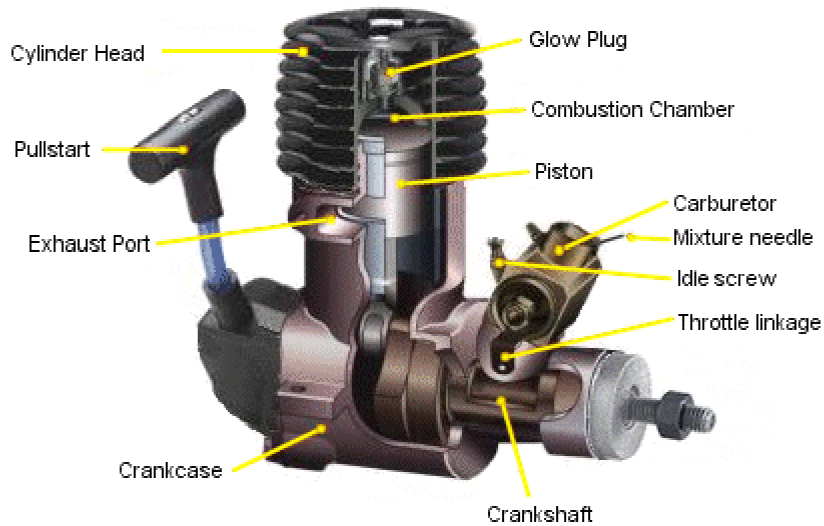

Fig 3.4.3 (b): Parts and features of RC engine [21].

RC nitro car engines are mainly 2 strokes whereas engines for RC planes can be two or four stroke. Two stroke means that the piston just needs to complete one up-stroke and one down-stroke to complete the whole internal combustion process of drawing the fuel/air mixture in and up to the combustion chamber, compressing the mixture just before it ignites and then expelling the exhaust gases after the explosion. A 4 stroke engine needs two complete revolutions to do the same job.

Now that fuel is in the crankcase and has mixed with air, the glow plug in the top of the cylinder head needs to be heated up and the piston needs to start moving up and down for the whole internal combustion process to get going. So to start, the nitro engine needs to be turned over manually which is either done with the pull cord if it has one, or by an electrical engine starter temporarily attached to the clutch. At the same time, the plug is made to glow red hot by connecting a glow plug igniter to it for a few seconds; the filament of the plug heats up immediately. With the fuel/air mixture sitting in the crankcase, it needs to be moved up to the combustion chamber and ignited in order for the engine to start running under its own power.

CHAPTER IV

RESULT AND DISCUSSION

4.1 Introduction

This chapter discusses on the result, analysis and problems that are encountered throughout the completion an Energy Management of Series Hybrid Electric Vehicle using Microcontroller and integrated with the small scale hardware. After the development and completion software and hardware, the integration system was observed and energy management of series hybrid vehicle conducted.

4.2 Hardware Configuration

Based on the Figure 4.2.1, its show the complete hardware setup that is series configuration. Hardware components used for this project more to the RC nitro compartment in order to perform the series configuration of HEVs in small scale and demonstrate it. From the right of the figure, a fuel tank was placed and followed by exhaust, RC nitro engine (Internal Combustion Engine), gearing system and generator. According to the literature review, these hardware setups obey the series configuration system.

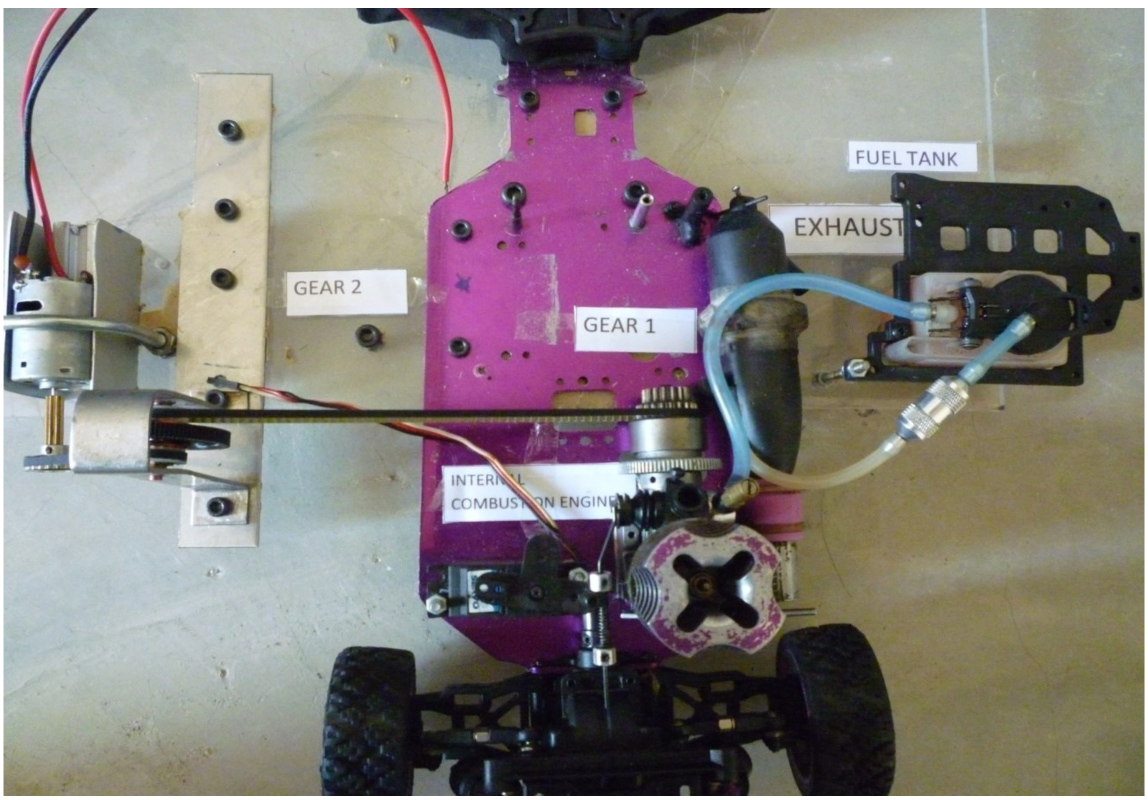

Figure 4.2.1 : Top view of the hardware

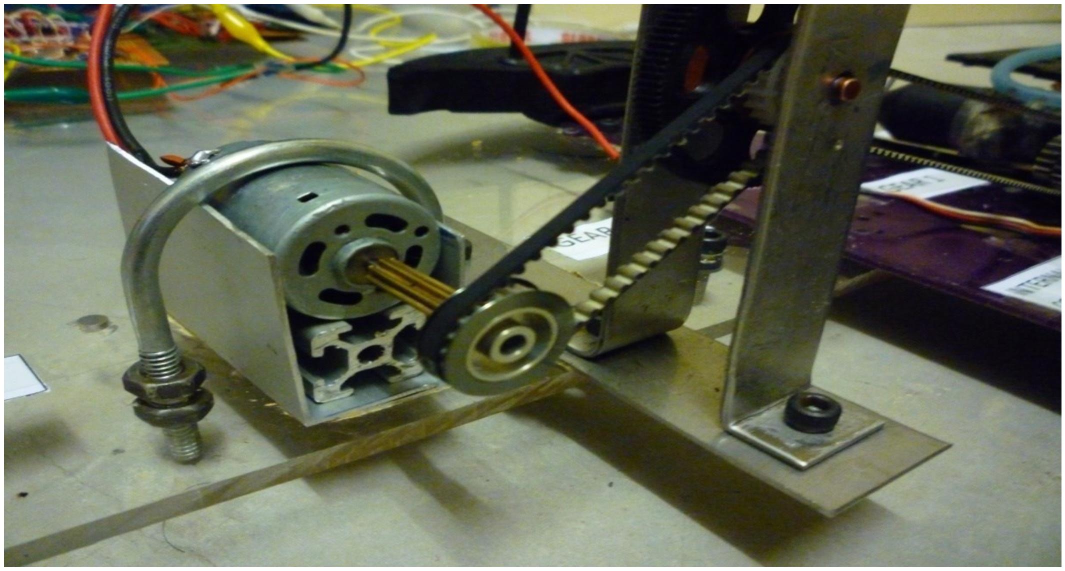

Figure 4.2.2: Gearing system of the generator

Based on the Figure 4.2.2, the picture focused on the gearing system where the shaft of the RC nitro engine connected with the gear placed at the generator using belt. According to this paper [38], the gearing range indicates the difference between bottom gear and top gear, and provides some measure of the range of conditions with which the gears can cope the strength, experience, and fitness level of the cyclist are also significant. A range of 300% or 3:1 means that for the same pedaling speed a cyclist could travel 3 times as fast in top gear as in bottom gear. Conversely, for the same pedaling effort, a cyclist could climb a much steeper hill in bottom gear than in top gear.

The approximate gear ranges which follow are merely indicative of typical gearing setups, and will vary somewhat from bicycle to bicycle.

- 180% 3-speed hub gears
- 250% 5-speed hub gears
- 300% 7-speed hub gears
- 350% 8-speed hub gears; derailleur with 2 chain rings; continuously variable transmission

So, in this project, 3 speed hub gears were used to give a high kinetic energy for the generator to produce high electricity.

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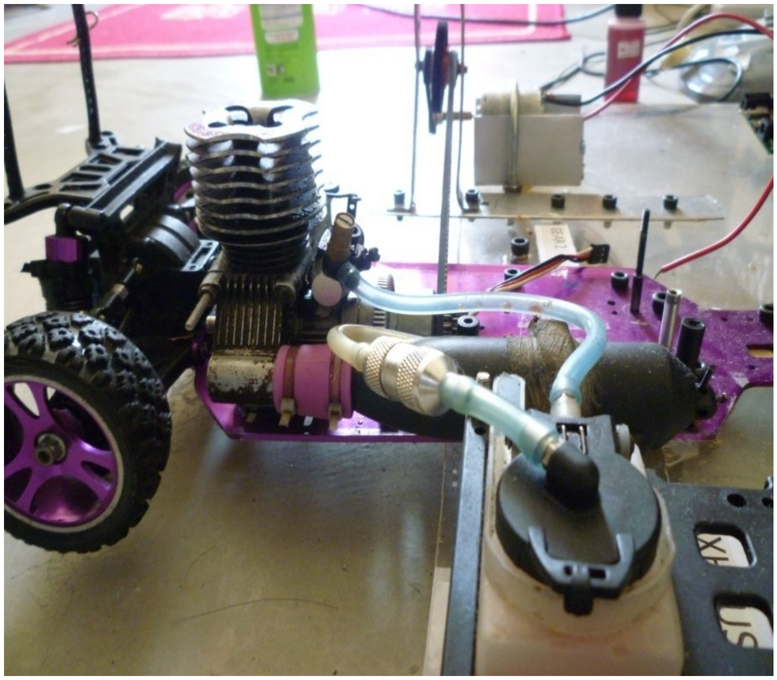

Fig 4.2.3: ICE system

From the figure 4.2.3, this figure focused on the RC nitro engine used in this project. So, the engine used is HPI 18 SS that can operated about 29,500 rpm. This is the LRP Z .28R Spec 3 Nitro Engine with pull starter. However, this RC nitro engine was modified which the engine can start by the starter box. This rear exhaust engine features a slide valve carburetor with an 8.5mm venture. ABC piston and sleeve construction, aluminum piston with a Brass sleeve that is Chrome plated. An SG (pilot) type crankshaft that is 13.0mm from tip to threaded area of the crankshaft. Fork shaped aluminum connecting rod with double bushings and a black anodized crankcase with blue anodized 10-fin cooling head.

Features

- Slide valve carburetor
- 8.5mm venture with ball link on throttle
- ABC piston and sleeve construction, (Aluminum piston with a Brass sleeve that is Chrome plated)
- SG (pilot) type crankshaft 13.0mm from tip to threaded area
- Fork shaped aluminum connecting rod with double bushings
- Black anodized crankcase with blue anodized 10-fin cooling head
- Rear exhaust

Specifications:

Engine Size	: 28 cu in (4.58cc)
Bore	: 0.73" (18.5mm)
Stroke	: 0.63" (17.0mm)
Max RPM	: 38,500
RPM Range	: 2,000-33,0000
Power Output	: 3.81 PS
Exhaust	: Rear Exhaust
Carburetor	: Slide
Crank Shaft	: SG
Piston & Sleeve	: ABC
Number of Ports	: 8+1 (8 intake, 1 exhaust)
Weight	: 15.9 oz (450g)2,250 rpm 32,500 rpm w/ kit $170

4.3 Electrical and Electronic in control speed of the DC motor

From this circuit in Figure 4.3.1, its mean that the voltage output that will produce is 5V that require by all circuit to conduct for example microcontroller. In this project, the input voltage is 6 V that from battery and then this circuit will drop it to 5V. In addition, input voltage about 12 V also can be drop to 5 V by this circuit.

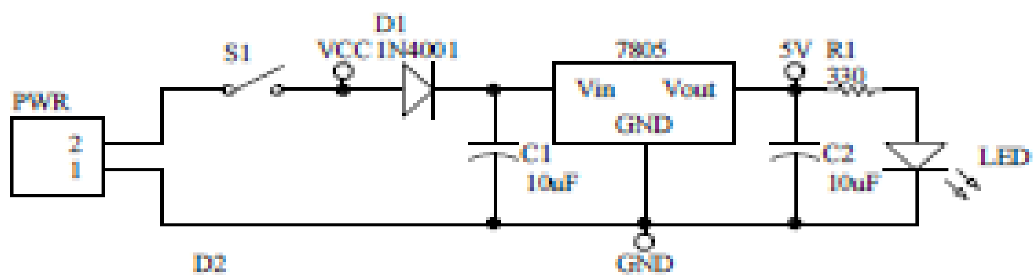

Fig 4.3.1: Voltage supply circuit

From this circuit, its mean that the voltage output that will produce is 5V that require by all circuit to conduct for example microcontroller. In this project, the input voltage is 6 V that from battery and then this circuit will drop it to 5V. In addition, input voltage about 12 V also can be drop to 5 V by this circuit.

Based on the Figure 4.3.2 below, it is show the electronic system in order to control the speed of DC motor. Relate to project objectives, this project will perform energy management of series hybrid electric vehicle and DC motor used in the electronic system act as a load where the DC motor accelerated and decelerated.

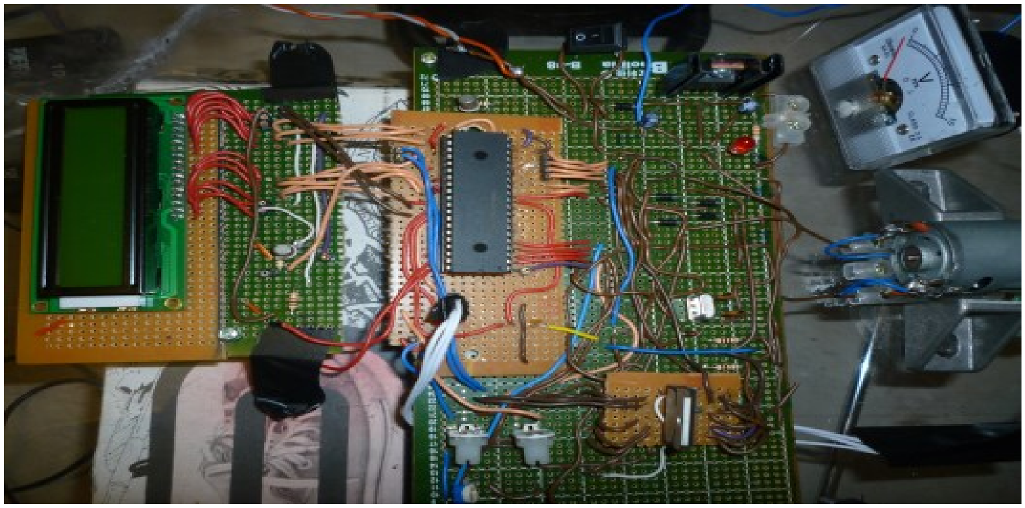

Fig 4.3.2: The electronic system control DC motor

4.4 Electrical and Electronic in control the angle of servo motor

Based on the Figure 4.3.3, it is show the complete circuit in order to control the angle servo motor. In addition, integration of the system show when the hardware and software integrate and the electronic system between the control DC motor and Servo motor control. When the DC motor (Load) accelerate, the servo motor rotate in high angle and when DC motor (Load) in decelerate mode, the angle rotate in low angle.

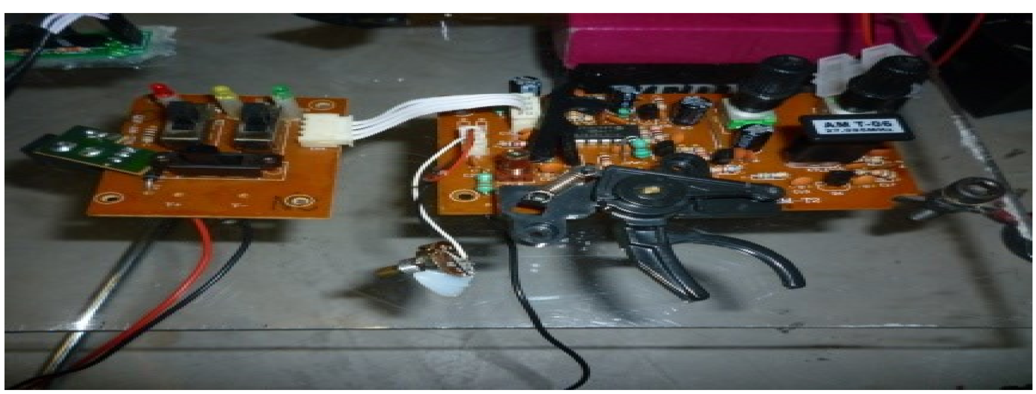

Fig 4.3.3: The electronic system control the angle of servo motor

4.5 Result Integration of Hardware and Software

In this part, it will show the result of this project and will be focusing on the energy management of the series hybrid electric vehicle. Firstly, in series hybrid electric vehicle, the generator that turn by internal combustion engine will generate electricity and charge the battery. So, the energy that comes from the internal combustion and battery manage.

At the beginning, in this project, there is DC motor that can controlled the speed of the rotation and two condition of DC motor were stated. First condition, the DC motor is in accelerating and the second condition DC motor is in decelerating mode. In each condition, the voltage that drawn from the battery was measured, Table 4.5.1 shows the value of voltage measured.

Table 4.5.1: Result of the condition

Condition of DC motor	Voltage measured	Current Measured	RPM
Accelerating	4.06 V	8.9 A	3845
Decelerating	1.42 V	8.9 A	1280

In this project, the function of the servo motor is to control the speed of the internal combustion engine which is angle of the servo motor will affect the speed of the internal combustion engine. So, the angle of the servo motor was set depends on the condition of the DC motor. Table 4.5.2 show the value of the angle based on the condition of DC motor.

Table 4.5.2: The angle of servo motor

Condition of DC motor	Servo motor angle	Voltage Measured at Generator	RPM
Accelerating	30 degrees	2.83 V	3845
Decelerating	45 degrees	0.33 V	1280

The value of the angle will control the speed of the internal combustion engine. After that, the based on speed of the internal combustion engine, the generator turn and charge the battery. The generator produced electricity means voltage and current to charge the battery, so the third column of the Table 4.5.2 show the voltage measured when the RC nitro engine move.

CHAPTER V

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

An Energy Management for Series Hybrid Electric Vehicle is a system that manages the energy from the source. The development of the hybrid electric vehicle is different between the conventional vehicles. This is because, the word hybrid describe that there will be dual energy supply from, battery and also internal combustion engine while the conventional vehicle only use supply from the internal combustion engine. This project will show the energy management of the series hybrid electric vehicle which is the internal combustion engine turns the generator and generator will produce electricity to charge the battery. As conclusion, this project shows the configuration of series hybrid electric vehicle system and the energy management was also conducted. Previous studies is more focusing on the system and configuration but in this project, its more focusing on the energy management of the series hybrid electric vehicle. Hybrid electric vehicle famous that can reduce the emission of carbon dioxide while in this project, the energy supply form the sources also can be manage in certain condition.

5.2 Problem Encounters

Throughout the project development, quite a number of problems are faced and appropriate steps are taken to solve it. Among the main problems together with the suitable solutions are:

1) Problems to ensure that the components in a good condition and functioning.
   This problem was main problem while make a controller circuit and charge controller circuit. It will happen when there are short circuits or circuit modifications had made depends on situation. From this project, have taken two modifications that result in the PIC microcontroller burn. Furthermore, the transistor also burned if excessive voltage or current happen. Relay also will not work if the transistor is damaged.

5.3 Project Cost

This project demand high cost in every aspect either for the hardware development and also the software development:

i) Hardware development

- RC Nitro Engine = RM 350
- Fuel Tank = RM 30
- Fuel (Nitro) = RM 50/liter
- Exhaust = RM 60
- Belting = RM 150
- DC motor/Generator = RM 100

Total = RM 800

ii) Software development

- Components = RM 200

iii) Total Project Cost = RM 1000

5.4 Project Commercialization

For commercialization, this project is suitable for students to study and know how the series configuration of HEVs operate and can know advance information that energy management can be manage by the integration between hardware and software. Apart from that, this project can be show at any university or school so that students can know advance about the new technology HEVs.

5.5 Recommendation

This project will be more focusing on the accelerating and decelerating of the dc motor. As recommendation, this project can be renovated by add the braking and reverse system to the series hybrid electric vehicle configuration and the energy management will different.

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