DEVELOPMENT AUTOMATIC SWITCHING CONTROLLER FOR SHIFTING DRIVE MODE IN PROTOTYPE HYBRID VEHICLE

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STATEMENT BY THE AUTHOR

I hereby declare that this submission is my own work and to the best of my knowledge, it contains no material previously published or written by another person, nor material which to a substantial extent has been accepted for the award of any other degree or diploma at any educational institution, except where due acknowledgement is made in the thesis.

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ABSTRACT

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The Astra Manufacturing Polytechnic developed a manual transmission hybrid prototype vehicle in 2019, this vehicle is still conventional in power shifting, this research develops automation in the transfer of power transfer from an electric motor to an engine or vice versa by using an Arduino controller, inductive proximity sensor and a voltage sensor as input, the result of this research is the transfer of power from an electric motor to ICE or vice versa runs smoothly taking into account speed and changes the right gear lever. the transfer of power from the electric motor to the ICE running smoothly with a speed of > 15 km / h or a battery voltage of < 70 vdc then ICE is ON then the driver shifts to second gear lever, from ICE to an electric motor if the speed is <15km / h or the voltage is > 70 vdc then the driver shifts the gear to neutral.

Keywords: Hybrid Vehicle, Automatic Switching Control, ICE, Electric Motor, Power transfer.

DEDICATION

I fully dedicate this master's study to my beloved wife and two parents who gave strength and encouragement, to the Astra Manufacturing Polytechnic which has provided the opportunity to continue my master's studies, and to Almighty God who provides guidance, skills, and health.

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CHAPTER 1 - INTRODUCTION

1.1. Background

The development of the world in all fields in the 21st century is very fast, it is marked by many emerging industries and factories as well as an increasing number of motor vehicles for transportation, this has an impact on increasing fuel oil and gas and causing other problems, namely global warming as well climate change, according to data from the DKI Jakarta, environmental service 2019 from January to August the air pollution standard index (ISPU) is always increasing.

Figure 1 shows an increase in air pollution (ISPU) from January 59.4 to 88.9

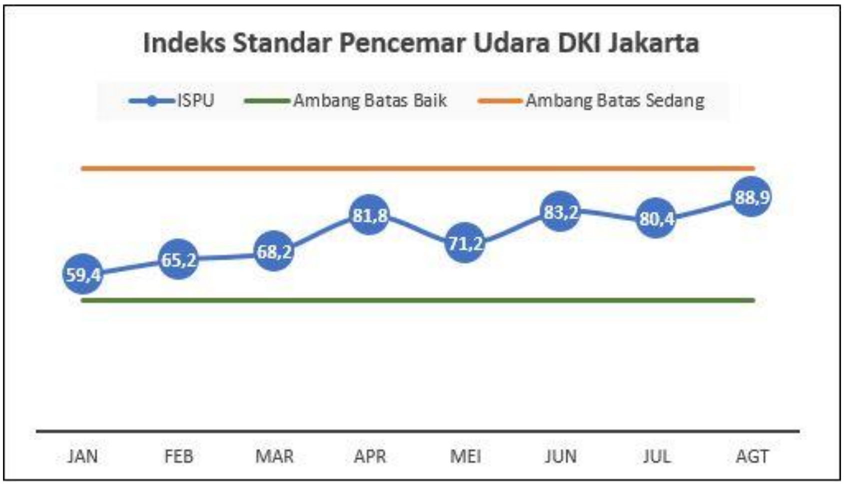

Figure 1. Air Pollution Standard Index DKI Jakarta 2019

(iku.menlhk.go.id/2020)

See air pollution that is increasing, the Automotive company is trying to reduce the exhaust gas content in motor vehicles by creating hybrid technology, hybrid vehicles are combining internal combustion engine technology with Electric Vehicle, to produce fuel efficiency that better and more environmentally friendly compared to conventional machines.

The way of hybrid vehicles is at the beginning of start to medium speed using an electric motor as a driving source, but if the speed increases, the ICE engine takes over as a source of propulsion and at the same time becomes a source of charging electric current towards the batteries needed for electric vehicles can be seen in the figure 2.

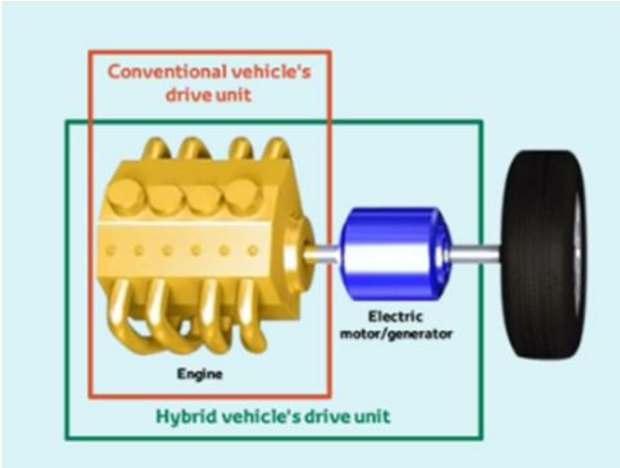

Figure 2. Hybrid Vehicle Drive

(toyota.astra.co.id/2020)

In 2001, the Astra Manufacturing Polytechnic Automotive Engineering Study Program received a practical unit vehicle contribution from Astra Daihatsu Motor in the form of a unit: "Daihatsu Midget 2" has a 3 cylinder with a capacity of 659 cc.
And in 2019 Polman Astra developed a hybrid vehicle based on the Daihatsu Midget 2 by making modifications to the driving part.

ENGINE TYPE	naturally aspirated petrol
ENGINE MANUFACTURER	Daihatsu
ENGINE CODE CYLINDERS	3 cylindel inline
CAPACITY	0.7 litre 659 cc
VALVE GEAR	single overhead camshaft (SOHC)
POWER OUTPUT	30.9 PS (30.5 bhp) (22.7 kW) at 4900 rpm
TORQUE	50 Nm (37 ft·lb) (5.1 kgm) at 3200 rpm
FUEL SYSTEM	Carburetor
DRIVE WHEEL	Rear Wheel drive

Figure 3. Daihatsu Mitged II

In this Daihatsu Midget 2-based hybrid vehicle using an internal combustion engine as the main propulsion source and a BLDC motor as additional propulsion, the drive system in this hybrid vehicle uses a belt drive that connects the pully differential with the propeller saft.

This hybrid vehicle unit is a plug-in hybrid type where the battery can be connected to electricity at home to charge the battery.

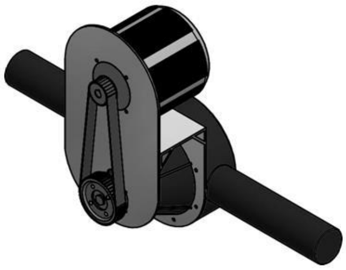

Figure 4. Belt Drive System

Figure 5. Battery and Control Motor

In the rear trunk of the Daihatsu Midget 2, the battery and BLDC motor control are placed, the battery serves to drive the BLDC and the battery has a capacity of 72 vdc. This hybrid vehicle unit is equipped with a manual control panel consisting of a control switch for the required type of drive, a reverse button, and an emergency button. And there are also indicators in the form of numbers and bars to determine the battery capacity of the electric motor.

Figure 6. Control Panel

Testing of this hybrid vehicle is carried out by the method:

1. Mode 1: Electric motor Drive

The test is done with a single charge until it is full, the battery used in this hybrid vehicle has a battery capacity of 40AH and a discharge current of 24.3 A and is driven at a speed of 20KM / H, the distance obtained is: 32 KM.

2. Mode 2: Engine Drive

The test was carried out by refuelling one litre of gasoline then driving the vehicle until the fuel runs out and the result is that it can travel 25 KM,

1.2. Research Problems

When the driver drives this hybrid vehicle, he finds several problems that arise:

1. Switching the drive mode on hybrid vehicles is not fast and precise.
2. Switching the drive mode is still manual.

1.3. Research Objective

In connection with the problems experienced, the purpose of this thesis is:

1. Determine the correlation between vehicle speed and switching drive mode in hybrid vehicles.
2. Determine the correlation of battery voltage with switching mode of drive-in hybrid vehicles.

3. Determine the precise and fast transfer switching mechanism in hybrid vehicles.
4. Developed automatic switching on prototype hybrid vehicles.

1.4. Significance of Study

This research has benefits, among others.

Design and develop controls to automatically shift the drive system of hybrid vehicles that are applied to manual transmission vehicles.

1.5. Research Question

1. How to Determine the correlation between vehicle speed and switching drive mode in hybrid vehicles
2. How to Determine the correlation of battery voltage with switching mode of drive-in hybrid vehicles
3. How to Determine the precise and fast transfer switching mechanism in hybrid vehicles
4. How to Develop automatic switching on prototype hybrid vehicle

1.6. Hypothesis

By using an automatic control switch, the driving power shifting in hybrid vehicles can be done quickly and precisely.

1.7. Scope Of study

The focus of this research is.

1. Making automation of power transfer control in manual transmission hybrid prototype vehicles
2. Power transfer analysis of manual transmission hybrid prototype vehicles

CHAPTER 2 - LITERATURE REVIEW

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2.1. History of HEVs

Hybrid vehicles have long been marketed that aim to reduce fuel consumption up to three times lower than conventional vehicles aimed at reducing exhaust emissions(Sumarsono, Utama and Kiswanto, 2012), Hybrid is a scientific term that refers to the combination of two separate species to create something completely new. The most common use of hybridization occurs with plants and animals, such as hybrid roses. When referring to vehicles, the result of a hybrid is a combination of two different sources of an engine that uses fuel oil and an electric motor to power the car. The resulting vehicle is fuel efficient and emits less carbon dioxide than standard internal combustion engines (conventional cars).

The concept of the hybrid electric vehicle is as old as the car itself, but the purpose for which it was created at the beginning of the concept was not for improve fuel efficiency but help the ICE Engine to increase its performance, because at the beginning of the ICE engine manufacture the engine engineering was less advanced(Ehsani Ehrdad, Gao Yimin, 2010). At the Paris Salon in 1899 a hybrid vehicle was first shown, the hybrid vehicle was made by the Pieper company in Liège, Belgium and by Vendovelli and Priestly Electric Carriage Company.

This first hybrid vehicle, called the Peiper, is a parallel type HEV using a gasoline-fuelled and air-cooled engine. It is also reported that this vehicle uses an electric motor with a lead-acid battery, the way the hybrid works is that the battery will be filled with the power source by the engine when the vehicle is moving or stopping, but when the vehicle needs more power, the electric motor gives additional power to the driving of the vehicle.

A few years later in 1901 a German engineer Ferdinand Porsche makes cars that are powered by a internal combustion engine and hub-mounted electric motor (Schiehlen, 2014), The first Lohner-Porsche Electro mobile with this innovation was presented at the Expo in Paris. The power produced by 2 x 2.5 PS reaches a top speed of 37 km / hour. Lohner's thinking why creating this Hybrid vehicle is to reduce air pollution.

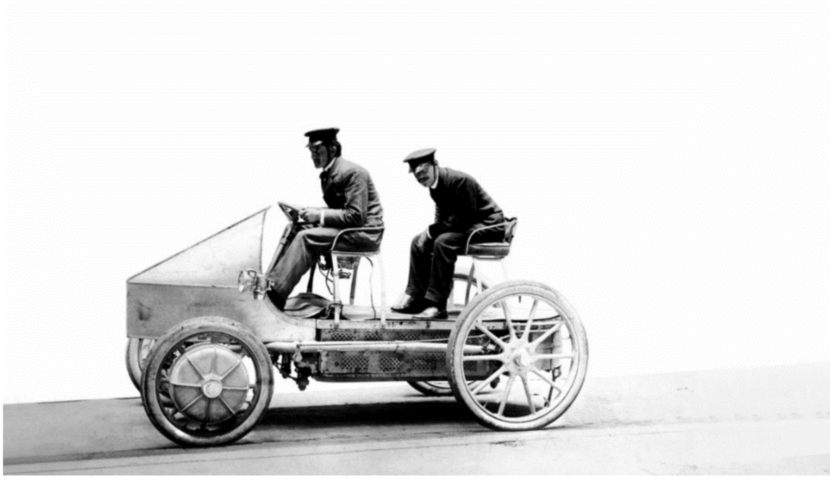

Figure 7. The first Porsche Electro mobile

(porsche.com/2020*)*

2.2. Classification of Hybrid Vehicles

There are several ways to classify a hybrid vehicle, one way is to see the components arranged in the vehicle, there are also ways of classifying them according to the relative contribution of the power source.

The two basic arrangements in parallel hybrid and series hybrid vehicles, in hybrid series vehicles are driven by one or more electric motors which are supplied by a battery or generator driven by an engine or from both, whereas in hybrid vehicles can be driven by ICE directly with connected to the transmission and then to the wheels or by an electric motor or at the same time an electric motor and ICE(Larminie and Lowry, 2012).

In general, hybrid vehicles have two sources of driving power, namely using an internal combustion engine and an electric motor, which are useful for increasing fuel efficiency and can take advantage of braking or regenerative brake into electrical energy. (Schouten, Salman and Kheir, 2002), There are three main types: micro hybrids, light hybrids and full hybrids,

2.2.1. The Micro Hybrid

Micro hybrids are not true hybrids because electric motors are not used to drive vehicles, micro hybrids use stop-start or idle-stop technology to increase fuel consumption and reduce CO2 emissions, especially when the vehicle is stopped, for example at a traffic light, the vehicle engine will be turned off.

How it works? if the vehicle is in a traffic jam or when it stops at a traffic light, the engine will automatically be turned off and if you want to start the engine again, the driver only needs to press the gas pedal without pressing the starter switch, and in the braking process the battery gets additional energy.

Micro HEV is a vehicle with an integrated alternator / starter that uses start / stop technology. Start / stop technology is when the vehicle turns off the engine during a complete stop and then starts again when the driver releases the brake pedal. During cruising, the vehicle is driven only by an internal combustion engine. The increase in fuel efficiency is usually around 10% compared to non-hybrids. Examples of micro hybrids currently on the road are the BMW 1 and 3 series, the Fiat 500, the SMART car, the Peugeot Citroen C3, the Ford Focus and Transit, and the Mercedes-Benz A-class.

2.2.2. The Mild Hybrid

Light HEV is very similar to micro HEV but the electrical components, especially the integrated alternator / starter, are upgraded so that they are stronger to help drive the vehicle. Compared with micro HEV, electric motor, alternator and larger battery, fuel efficiency can be increased by up to 20-25% compared to non-hybrid. Examples of light HEV on the market include the BMW 7 Series Active Hybrid, Buick Lacrosse with assist, Chevrolet Malibu w / assist, Honda Civic and Insight Hybrid, and Mercedes-Benz S400 Blue Hybrid.

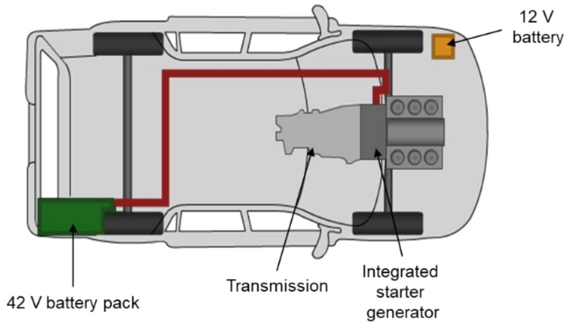

Figure 8. The Mild Hybrid Vehicle

(*https://www.ljcreatelms.com/Index.aspx*, 2020)

2.2.3. The Full Hybrid

Full Hybrid is similar to mild hybrid, seen by the use of electric components such as electric motors, alternators and battery packs, but with a larger size and capability, the difference between full hybrid and mild hybrid is that full hybrid uses a smaller engine, because the electric motor is the source. main power, the engine only works when high speed or heavy load, The Full HEV has a better control system and efficiency optimization capabilities than the previous type. The increase in fuel efficiency is usually around 40-45% compared to non-hybrids, Additionally, regenerative braking uses an electric motor as a generator to reclaim energy, charge batteries, and slow down the vehicle. Examples of full hybrids on the road today are the Chevrolet Tahoe Hybrid, Toyota Prius and Camry Hybrid, Ford C-Max, Honda CR-Z, and Kia Optima Hybrid.

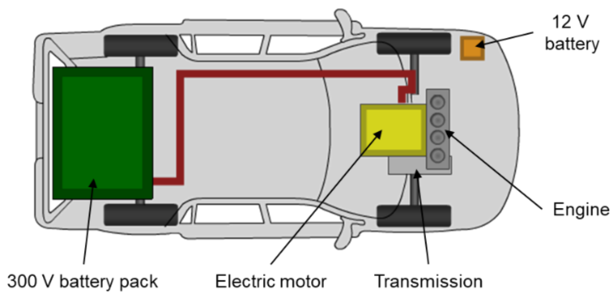

Figure 9. The Full Hybrid Vehicle

(*https://www.ljcreatelms.com/Index.aspx*, 2020)

2.3. The Basic Arrangements of Hybrid Vehicle

2.3.1. Series Hybrid Vehicle

This system consists of the internal combustion system of an engine running on gasoline, diesel, or gas. With all the components connected in series. The combustion in the engine room is connected to a generator to convert the power generated by the engine into electricity stored in a battery(Chan, 2007).

Generators in series type hybrid vehicles are connected to the engine so that they can generate electricity which will later be supplied to the electric motor via an inverter circuit. The disadvantage of this type is that the work efficiency of the electric motor will affect the power of the hybrid vehicle(Liu and Peng, 2008)

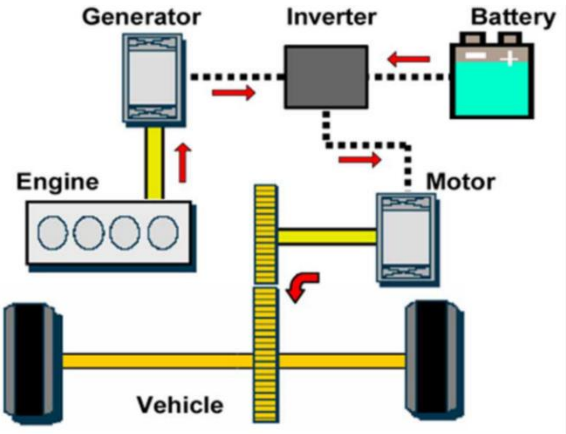

Figure 10. Series Configurations

(Liu and Peng, 2008)

2.3.2. Parallel Hybrid Vehicle

On a parallel system, the combustion system in the engine room is the main power producer, while the battery power is the supporting power.

Therefore, the efficiency of fuel is by limiting its consumption, this system uses an internal combustion engine and an electric motor to drive the vehicle, in this system, the electric motor is also a generator, so that when an electric motor is used, the battery cannot charge. The electric motor turns into a generator during charging and can only be done when the car does not use an electric motor to move, but uses the power generated from the combustion system. This system has limitations if it does not allow fuel.

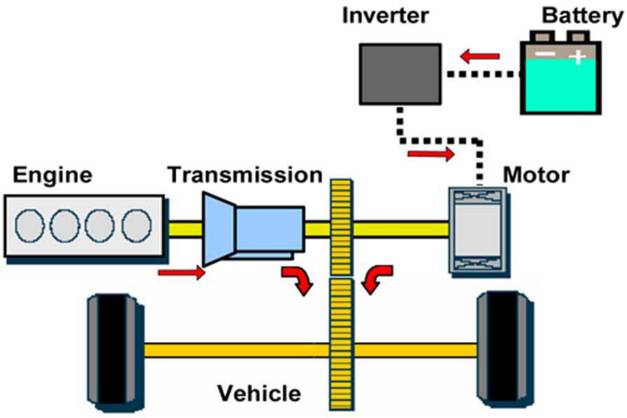

Figure 11. Parallel Configurations

(Liu and Peng, 2008)

2.3.3. Series- Parallel Hybrid Vehicle

The combination of the two previous systems is called the Series-Parallel Hybrid System. This system supports the most flexible and optimal power source, so as to achieve an impressive level of performance or reliability.

This hybrid technology has a special generator or power generator and a power divider capable of transmitting the power generated by the combustion system in the engine room to drive the wheels directly, or as power for the electric motor to make transfers, depending on driving conditions.

This supports the two power sources to work as efficiently as possible. At low to high speeds, the vehicle can also drive even if it only uses electric power. And this can lead to great efficiency. The generator can also be used to charge the battery via an inverter or converter. When accelerating or accelerating suddenly, it can also produce maximum performance, In the series-parallel type, the hybrid vehicle has a control strategy system that is more complicated than other hybrid types, but it can also be more efficient(Zhao and Burke, 2015)

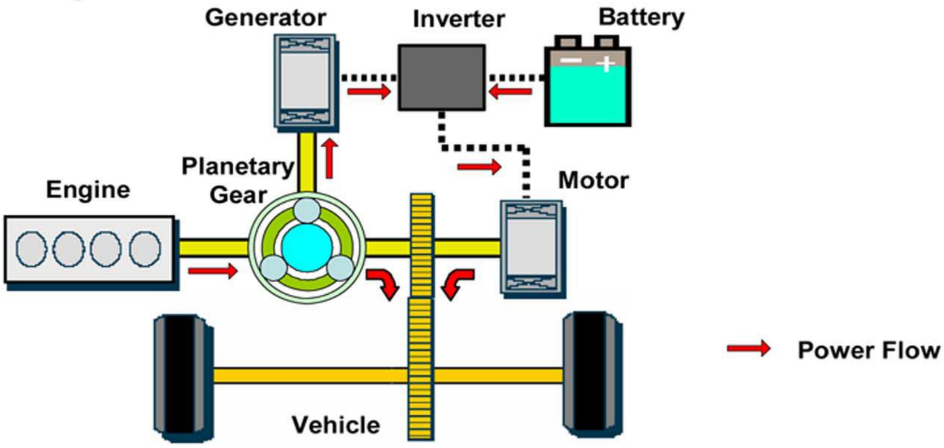

Figure 12. Series – Parallel Configurations

(Liu and Peng, 2008)

2.3.4. Plug-In Hybrid Vehicle

Plug-in hybrid vehicles (PHEV) are among the best vehicles to reduce the vehicle's contribution to petroleum dependence, air pollution and carbon dioxide emissions(Kalhammer *et al.*, 2014), cars with plug-in hybrid technology are more sophisticated than hybrids. In other words, a plug-in hybrid is a development of a hybrid.

Power from an electric motor can be channelled without the need to wait for the energy generated from the fuel engine rotation, such as in a hybrid car, the energy in a battery that has a greater capacity can be obtained by connecting to a power source for charging the battery.

In plug-in type hybrid vehicles, it uses two types of vehicle driving technology, namely using an electric motor and an internal combustion engine according to the needs of the driver. But the electric motor works when the car is traveling at a slow speed. Meanwhile, extended range electric vehicles (EREVs) rely on an electric motor to drive the car. While the combustion motor will be active and function when the battery needs charging energy.

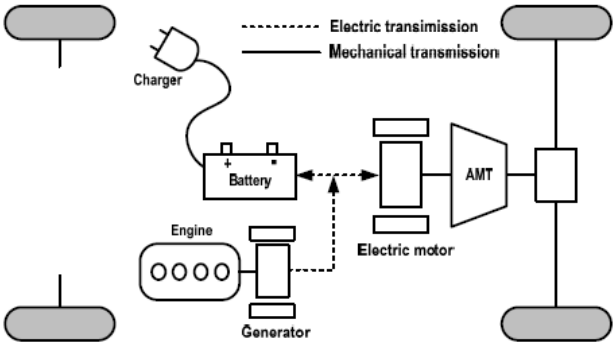

Figure 13. Plug – In Configurations

(Chen *et al.*, 2015)

A study conducted by the electric power institute with the US automaker, government agencies, the National Laboratory, and the University of California at Davis. in the study compared well-to-wheel energy use, carbon dioxide emissions and the cost of electric vehicles and internal combustion engines, full hybrid, and plug-in hybrid for simulating the driving cycle(Kalhammer *et al.*, 2014)

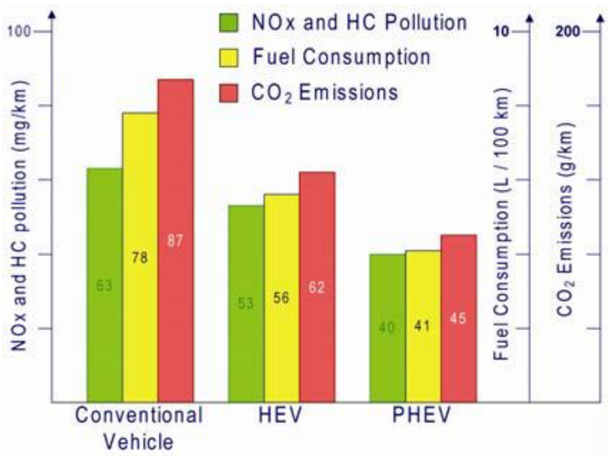

Figure 14. Comparation Conventional Vehicle,HEV,PHEV

(Kalhammer *et al.*, 2014)

2.4. Power Plant Characteristics

In each vehicle, the performance of the power generation is expected to have maximum power and torque available at any vehicle speed so that the vehicle's performance is very optimal, but in practice the vehicle torque is limited to low speed, so as not to exceed the maximum power which is limited by the adhesion between ground contact with the tire(Ehsani Ehrdad, Gao Yimin, 2010).

The character of this constant power will provide high traction at low speeds for acceleration purposes or to climb on high inclines.

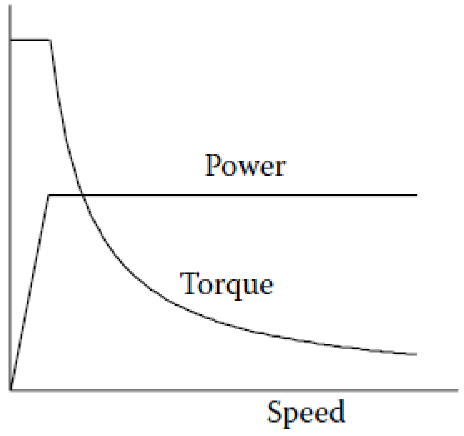

Figure 15. Ideal Performance Characteristics
(Ehsani Ehrdad, Gao Yimin, 2010)

On the Internal combustion engine in the figure 16 shows the representative characteristics of the engine test in a wide-open throttle, the torque-speed character is very far from the ideal performance characteristics required by traction.

Accurate and maximum combustion can be achieved at moderate engine speeds, but when engine speed increases, the torque will decrease due to increased losses in the air induction manifold due to a small amount of air entering the cylinder, besides that the power loss is also caused by mechanical friction of the components and hydraulic viscosity.

The output power will increase to the maximum at a certain higher speed, the engine power will decrease beyond that speed, in applications in vehicles the maximum allowable speed of the engine is usually set slightly above the maximum power output speed. ICE have a relatively flat torque-speed profile (compared to ideal power plants).

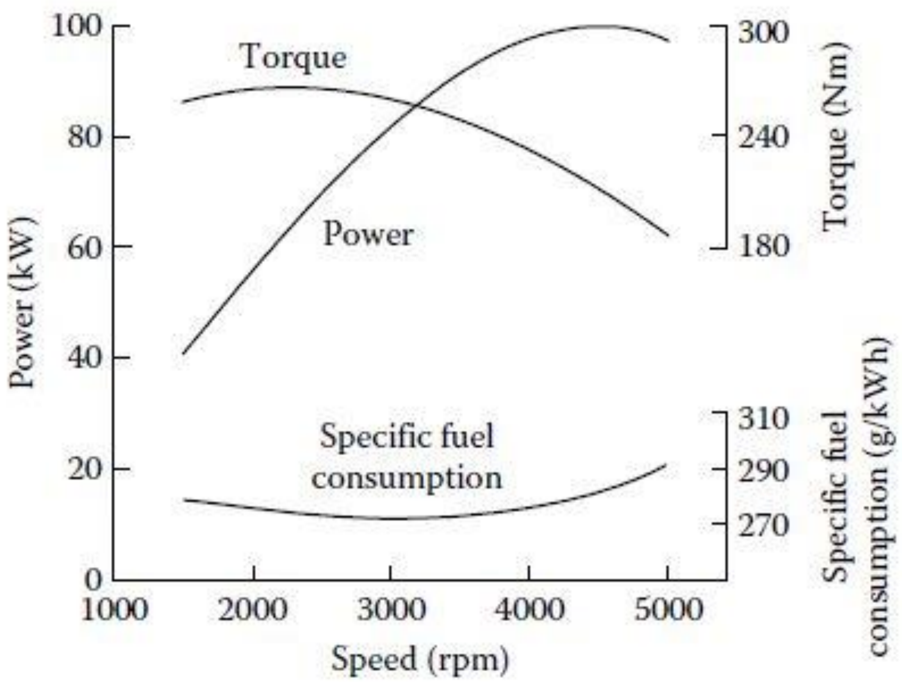

Figure 16. Performance Characteristics of Gasoline Engines

(Ehsani Ehrdad, Gao Yimin, 2010)

Electric motors are an alternative to generating power in vehicles which are currently becoming increasingly important with the rapid development of electric vehicles, hybrid electric vehicles and fuel cells, an electric motor with a good speed control has a speed - torque character similar to the ideal character shown in figure 17.

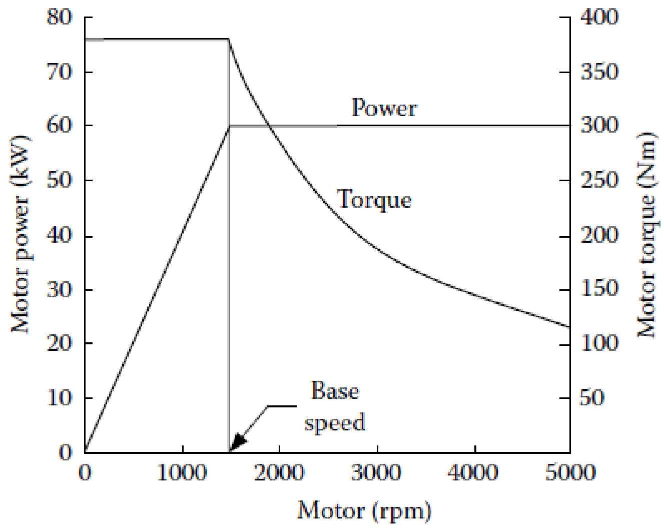

Figure 17. Performance Characteristics of Electric Motors for Traction

(Ehsani Ehrdad, Gao Yimin, 2010)

An electric motor produces constant torque from zero speed to the base speed, beyond the base speed, the voltage remains constant and the flux weakens.

This produces a constant output power while the torque drops hyperbolically at speed, because of the ideal speed - torque character of the electric motor, single or dual gear transmissions can be used to meet the performance of electric vehicles.

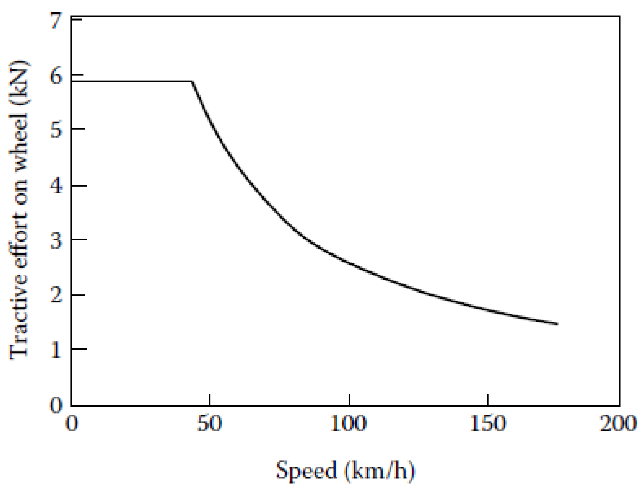

Figure 18. Tractive effort of a single-gear EV versus vehicle speed

(Ehsani Ehrdad, Gao Yimin, 2010)

2.5. Arduino

In 2005 the Arduino project was first developed designed in Italy by Massimo Banzi and David Cuartielles and this Arduino is an open-source microcontroller board. Because the design is open source, we can use and modify it according to what we will use (El-Abd, 2017).

The initial purpose of this Arduino microcontroller product is to help students carry out small research or the realization of a microcontroller device with a compact design and low price that can attract hobbyists, students and teachers. Digital and analog IO pins, USB connection, ICSP capability, serial communication on this Arduino board makes it easy to connect with other devices and components useful for data acquisition and control applications.

Arduino also provides support software that is open source as well, namely Arduino IDE and the language used for programming is C language, some examples of Arduino that use the AT Mega microcontroller are Arduino UNO, Arduino Nano, Arduino Leonardo, Arduino Nano Every etc.

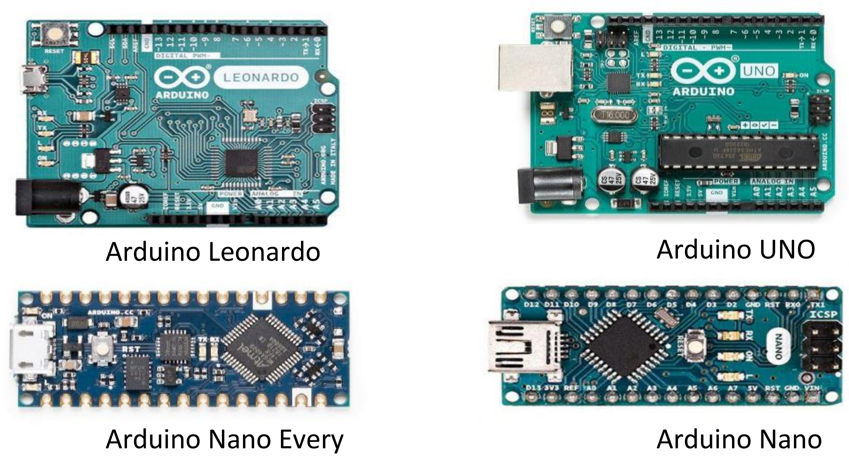

Figure 19. Arduino Board

(*https://www.arduino.cc/*, 2020)

Integrated Development Environment (IDE) is software that is built to carry out the functions of the programming language, the programming language on Arduino (sketch) is similar to the C language, the Arduino IDE is a development of the JAVA programming language besides that the Arduino IDE is equipped with C / C ++ libraries which aim to facilitate operation of input and output.

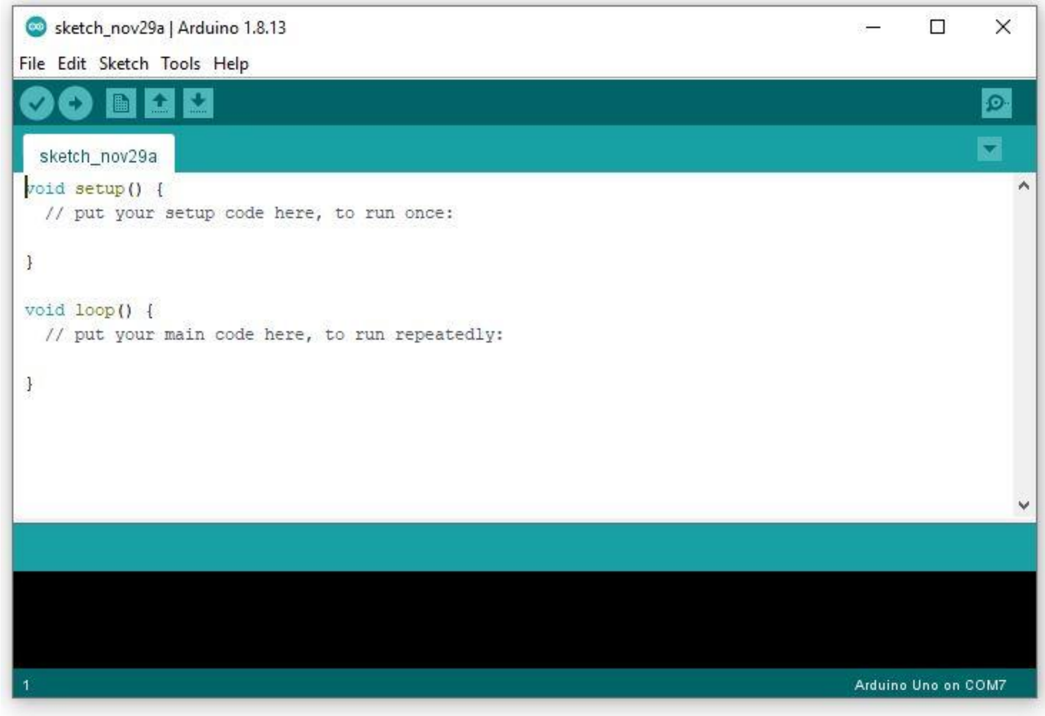

Figure 20. Arduino IDE

2.6. Inductive Proximity Sensor

An inductive proximity sensor is a non-contact sensing device used to detect an approach target(Mizuno *et al.*, 2009) , This non-contact proximity sensor detects iron targets, the ideal steel thickness for detection is more than one millimeter.

The main components of this inductive proximity sensor are a coil, a ferrite core, an insulator, a power amplifier and a Schmitt trigger, the working principle of proximity inductive is that so that there is a source voltage, the oscillator in the proximity will generate a high-frequency magnetic field. If a metal object is brought closer to the sensor surface, the magnetic field will change. Changes in this oscillator will be detected by the sensor as a signal of an object, when a ferrous target enters this magnetic field, small independent electrical currents called eddy currents are induced on the metal’s surface. This sensor has two configurations, namely normal open and normally closed configurations, if using normally open then the output signal is active when the target enters the sensing zone while with normally closed, its output is an off signal with the target present.

The output of the inductive proximity sensor is then read by external control devices such as (Arduino, PLC, Smart drive) and that converts the sensor on and off states into useable information. The on and off cycles of the sensor in per second are called frequencies whose speed ranges from 500Hz to 5khz in DC or 10 to 20Hz in AC, the inductance sensing sensor is relatively narrow, averaging a millimeter to 60mm fraction due to magnetic field limitations.

Although there is lack in the range, but this sensor can withstand other materials that accumulate in metals such as fluids, grease, and other non-metallic dust.

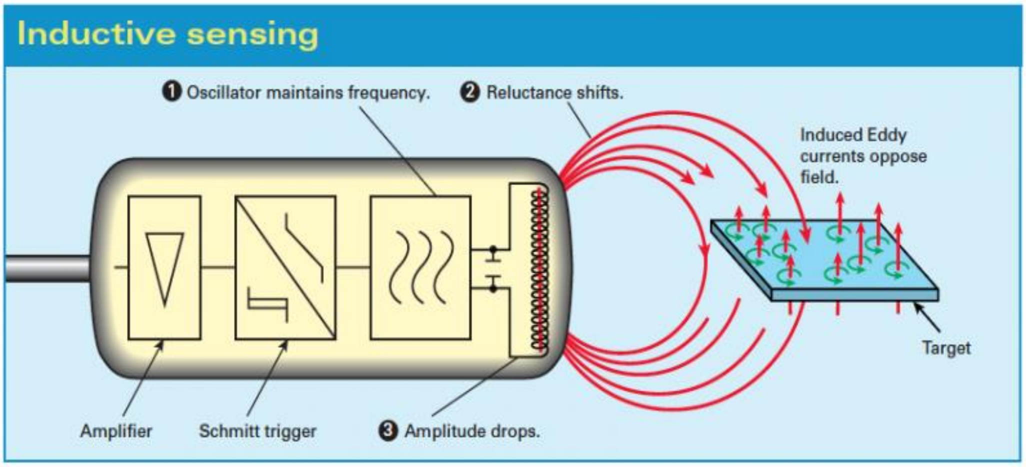

Figure 21. Inductive proximity sensor

(*https://www.machinedesign.com/*, 2020)

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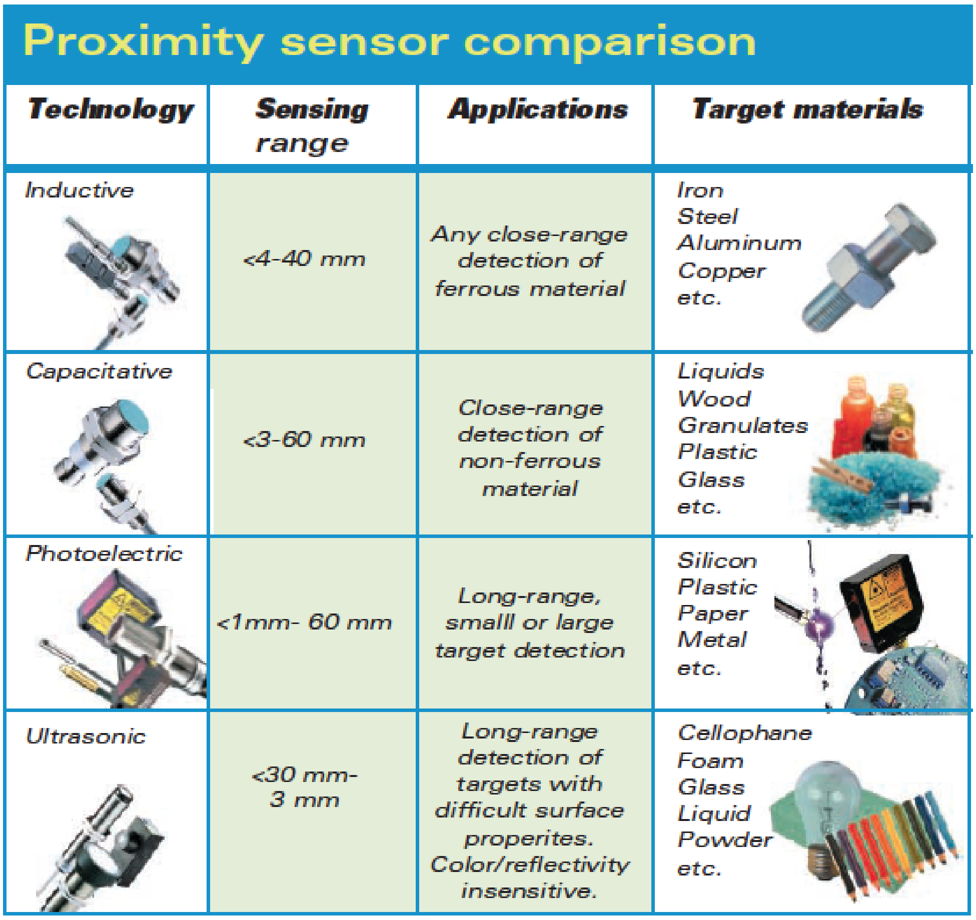

Proximity sensor comparison

Technology	Sensing range	Applications	Target materials
Inductive	<4-40 mm	Any close-range detection of ferrous material	Iron Steel Aluminum Copper etc.
Capacitative	<3-60 mm	Close-range detection of non-ferrous material	Liquids Wood Granulates Plastic Glass etc.
Photoelectric	<1mm- 60 mm	Long-range, smalll or large target detection	Silicon Plastic Paper Metal etc.
Ultrasonic	<30 mm- 3 mm	Long-range detection of targets with difficult surface properites. Color/reflectivity insensitive.	Cellophane Foam Glass Liquid Powder etc.

Figure 22. Inductive Proximity Sensor Comparison

(*https://www.machinedesign.com/*, 2020)

2.7. Voltage Sensor

Voltage sensor is useful as a provider of voltage information that will be used as input for Arduino, this voltage input will be processed by Arduino which will be used for various needs(Tung and Khoa, 2019), The voltage sensor used in this study uses a voltage divider because there is no voltage sensor on the market that supports the 72 volt that will be used in Hybrid vehicle batteries.

The voltage divider is a simple circuit of several resistors whose function is to convert a large voltage into a smaller voltage(Makan, Mingesz and Gingl, 2019) the result of this input will be given to the Arduino microcontroller.

Basically, the voltage divider circuit consists of two resistors arranged in series. Here is a simple circuit of a voltage divider or Voltage Divider. It is often used in analog circuits such as Op-Amp based circuits for example, where the voltage required can vary.

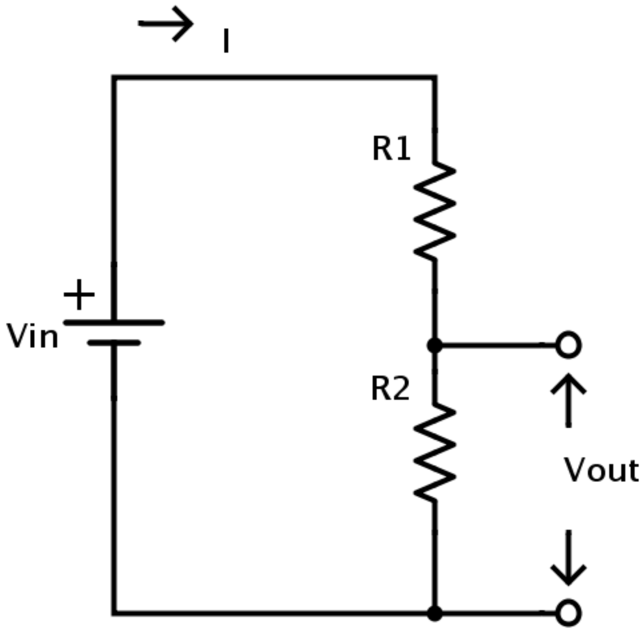

Figure 23. Voltage Divider Circuit

(electronicshub.org/2020)

The Voltage Divider rule is very simple, i.e., the Input Voltage is divided proportionally according to the resistance value of the two resistors connected in Series.

As we know that R = R1 + R2, the current flowing in the circuit is

$$I = \frac{Vin}{R} = \frac{Vin}{R1 + R2}$$

Since I is equivalent to I2, the formula for V out is as follows:

$$Vout = \frac{Vin}{R1 + R2} R2$$

By changing the above equation, the voltage divider formula is as follows:

$$Vout = Vin.\frac{R1}{R1 + R2}$$

In the application, only by adjusting the magnitude of R1 and R2, we can get the variation of the output voltage V out.

the output of the voltage divider will be an analog signal that will be read by the microcontroller before entering the microcontroller, this signal is converted to a digital signal by passing an ADC (analog-to-digital converter).

2.8. Previous Study

Based on previous research conducted by Danardono A. Sumarsono, Didi Widya Utama and Gandjar Kiswanto in 2011 with the title “Design and Development of Simple Control System for Small Hybrid Electric Vehicle”.

The scope of this research is to design and control the traction of a small hybrid vehicle by combining the power of a 6.54KW gasoline engine with a BLDC motor 2x 48V / 0.5KW, the control design using the ATMega-32 microcontroller which is easy in programming and implementation.

The microcontroller functions as the Master Control unit which regulates the switching of the drive mode on the small Hybrid, the sensor in the control uses a speed sensor that is mounted on the wheel, the second sensor is used to measure the rotation of the ICE engine crankshaft.

In addition, it is also equipped with a current module which functions to measure the current of the electric motor which is used as input data for the microcontroller. In addition, data on wheel rotational speed, engine rotational speed, and vehicle speed are the input.

The test was carried out at a speed of less than 35 km / H as far as 4 km by performing 3 test methods: Mode 1: vehicle runs with the internal combustion engine only, Mode 2: vehicle runs with electric motor only, Mode 3: vehicle runs with ICE and electric motor.

CHAPTER 3 – RESEARCH METHODS

3.1. Analytical Method

A typical problem-solving methodology will be implemented as a research methodology, the first stage is identification of the problem using the brainstorming method to supervisors in the company then selecting the problem as research material, the next step is determining targets and problem analysis, then. is to solve the problem by carrying out various methods such as determining sensors, controls and programs then applied to the Polman Astra hybrid vehicle, the next process is the maintenance and monitoring process.

This study also analyzes the relationship between changes in vehicle speed and battery voltage as a control input for the transfer of power from the electric motor to the ICE and vice versa.

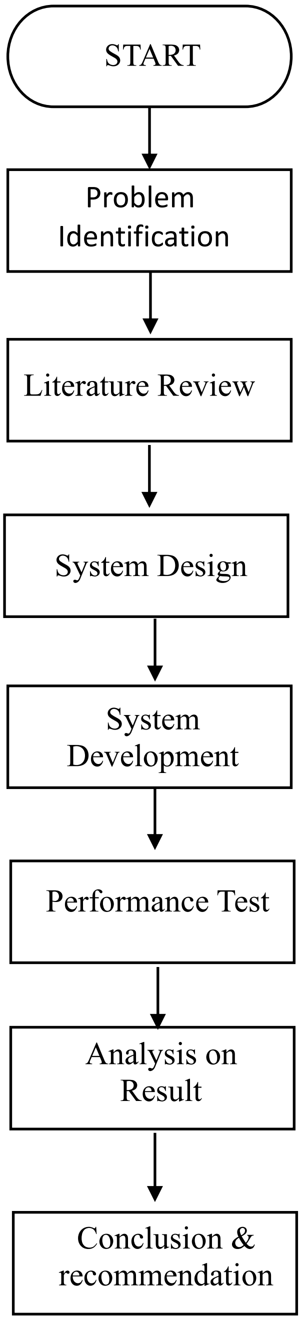

Figure 24. Research Workflow

3.2. Electric Motor Performance Testing

This electric motor performance test on hybrid vehicles is done to find out the characteristics of this electric motor, this test is done to get data from traction and power at speeds of 20 km / h , 30 km / h and 40 km / h.

This test is carried out using the MAHA Dynamometer, this test is a Chassis Dynamometer type where the vehicle testing is carried out on the wheels of the vehicle.

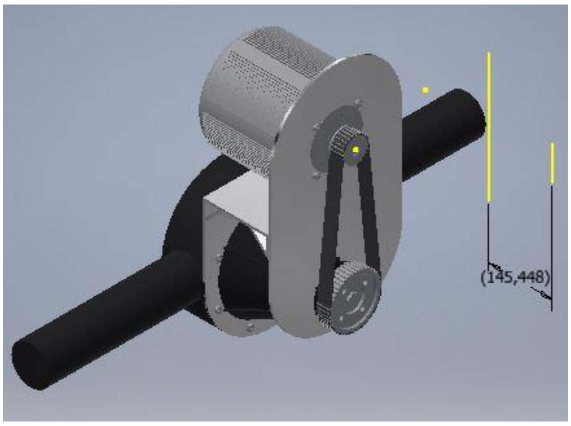

Figure 25. Placement of The Electric Motor

The electric motor is placed on a frame made of iron plate which is connected to the differential using a belt drive, besides the differential is also connected to the Propeller shaft, the output of the differential is the wheels of the vehicle which will be connected to the Dynamometer.

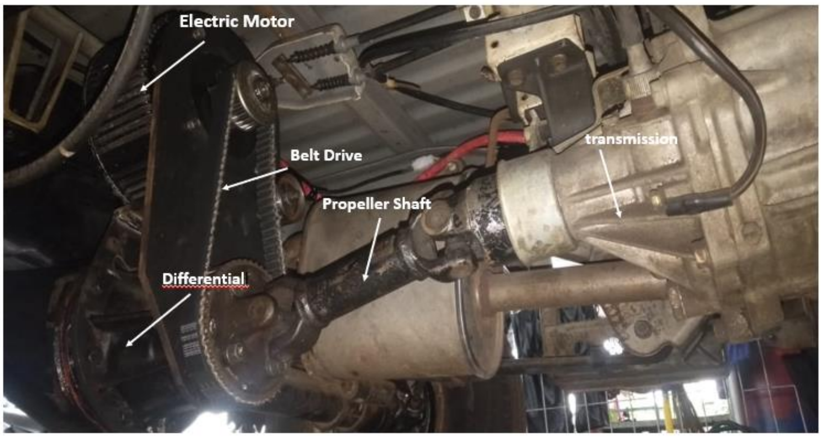

Figure 26. Parts Connected to The Electric Motor

Figure 27. Performance Test on Dynamometer (1)

Figure 28. Performance test on
Dynamometer (2)

The Figure 27 shows that the Daihatsu Midget 2 vehicle is currently testing the performance of the electric motor and ICE on the Maha Dynamometer, testing is carried out in stages.

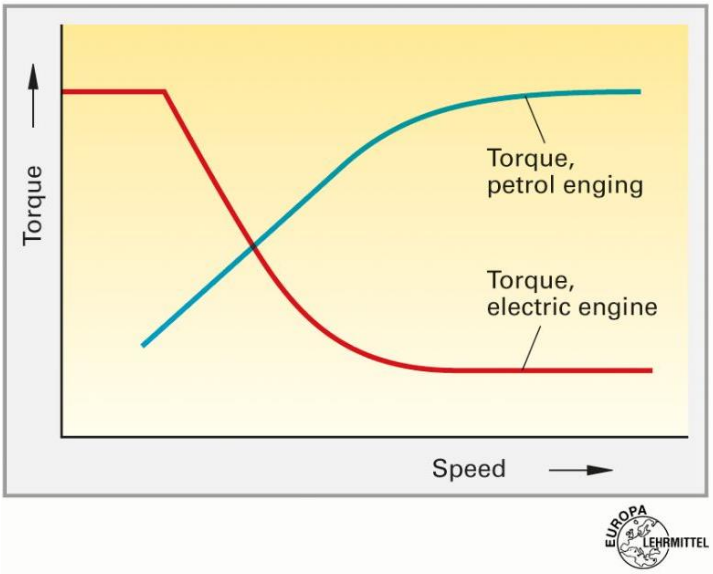

Figure 29. Electric Motor Torque and ICE Comparison

(Fischer and Gscheidle, 2014)

In the graphic image shows the comparison between the torque of the electric motor and the torque on the internal combustion engine, it can be seen that high motor torque at low speed and will decrease at high speed is inversely proportional to the torque in the engine.

The test was conducted to obtain traction and power data at motor speeds of 20 km / h, 30 km / h and 40 km / h.

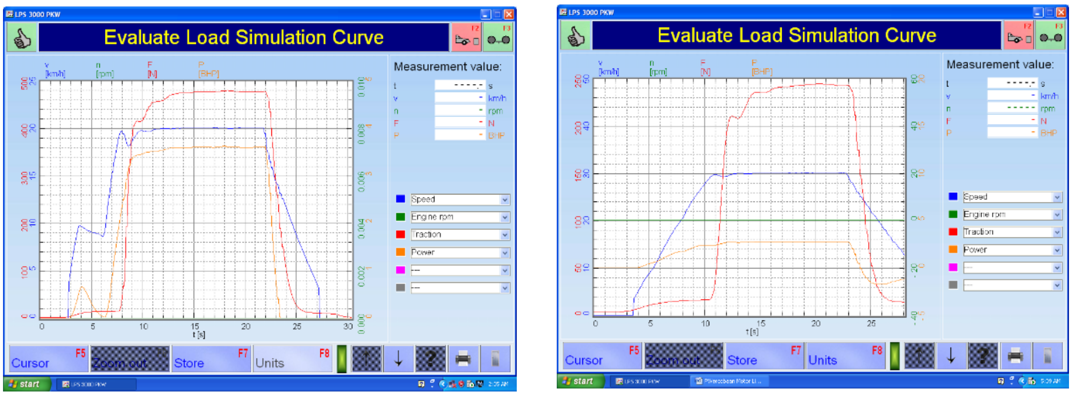

Figure 30. Testing Electric Motor at 20 km / h and 30 km / h

In the figure 30 is the result of measuring the performance of an electric motor using a dynamometer at a speed of 20 km / h and 30 km/h.

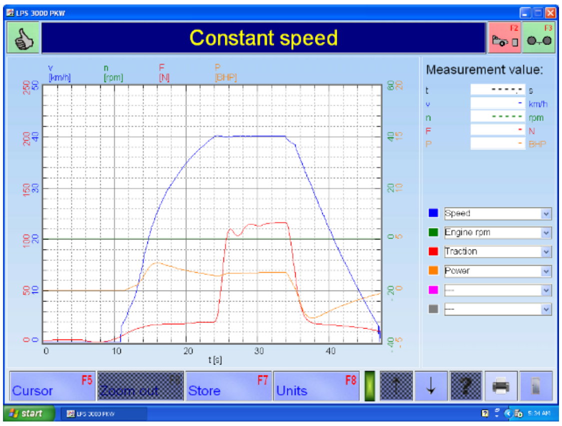

Figure 31. Testing Electric Motor at 40 km/h

In the figure 31 is the result of measuring the performance of an electric motor using a dynamometer at a speed of 40 km / h.

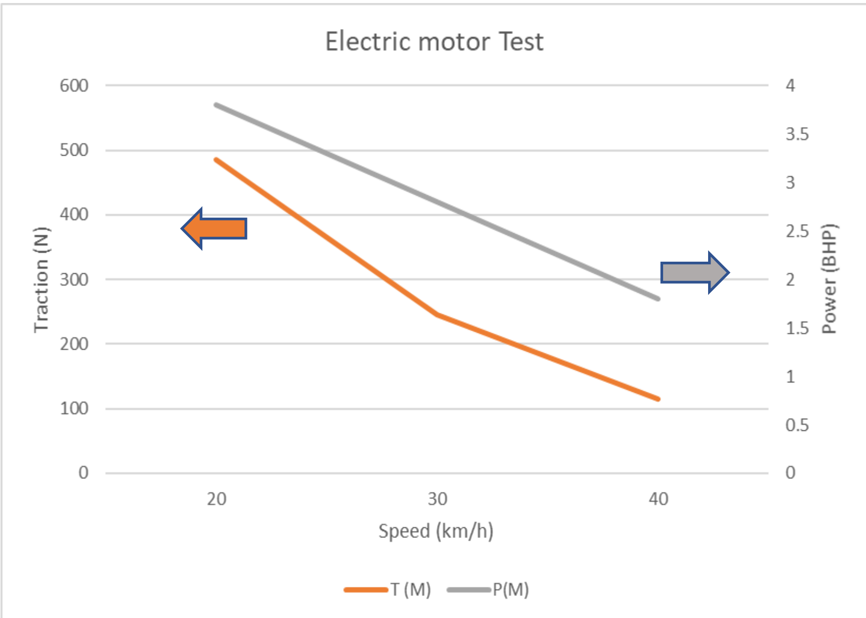

Figure 32. Electric Motor Test

The test results of the electric motor at a speed of 20 km / h, 485N traction and 3.8 BHP power meanwhile at a speed of 30 km / h, the traction of the electric motor is 245 N and a power of 2.8 BHP and at a speed 40kmh of traction that gets 115 N, power 1.8 BHP, there is a decrease in traction and power if there is an increase in speed.

3.3. Internal combustion Engine Performance test

After taking traction and power data at speeds of 20.30 and 40 km / h from an electric motor, data from the Internal Combustion Engine from Daihatsu Midget II is needed to determine the character of the engine by using a dynamometer as well.

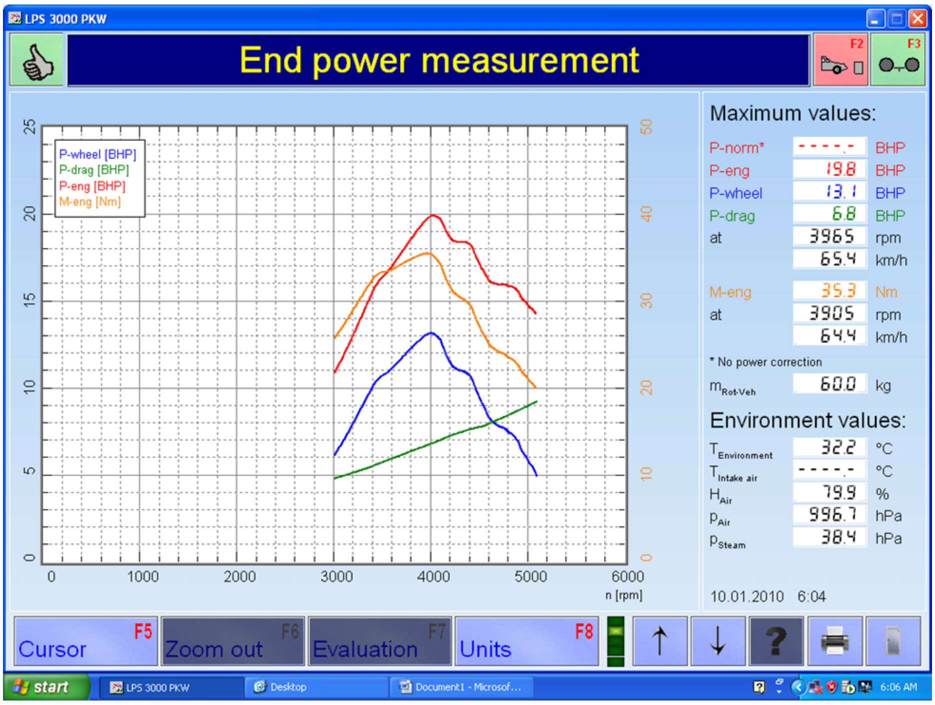

Figure 33. Testing Internal Combustion Engine

From the measurement results on the Daihatsu midget II using the dynamometer is 19.8 Bhp engine power, 13.1 Bhp power wheel, 6.8 BHP power drag at 3965 rpm and at a speed of 65.4 km / h while the torque is 35.3 Nm at 3905 rpm at a speed of 64.4 km /h.

In measurements using a chassis dynamometer, the first results obtained are the power wheel, which is the power output generated directly on the wheel because the wheel is directly attached to the dynamometer roller, then it is known that the power drag, this power drag is the power loss of the Daihatsu midget vehicle due to various factors, for example Decreasing the ability of engine and drivetrain components, ignition system and others, after the results of the power wheel and power drag are obtained, for engine power, it only remains to add the value of the power drag plus the value of the power wheel.

The next step is to measure traction and motor power at speeds of 20,30 and 40 km / h as in the measurement of electric motor performance so that it is expected to obtain comparative data from the two types of drives, measurements are only carried out on the 3rd gear and 4th gear, in gear 1 and 2 measurement cannot be made due to a slip on the wheel with the measuring instrument.

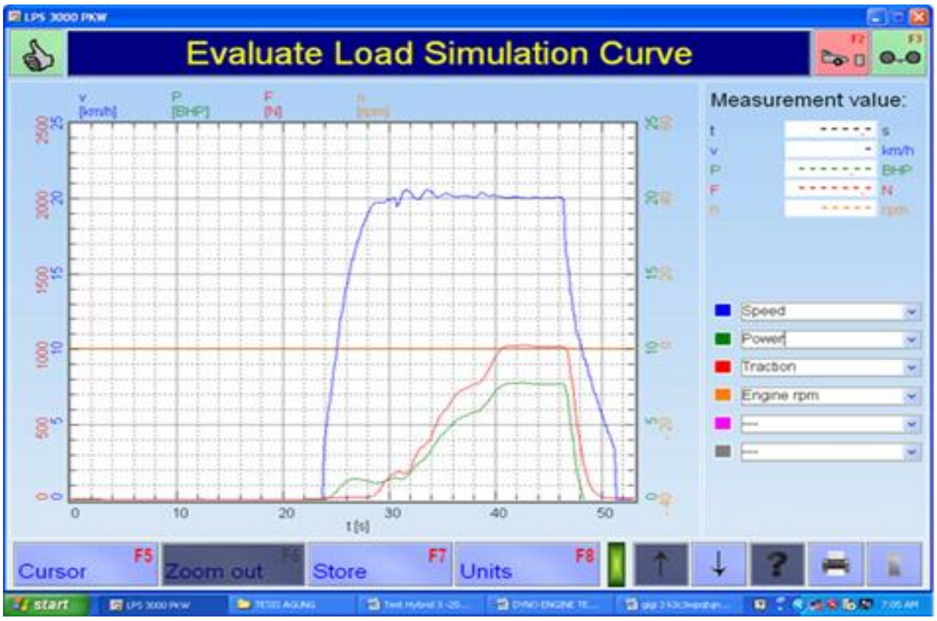

Figure 34. ICE measurements in 3rd gear at speeds of 20km/h

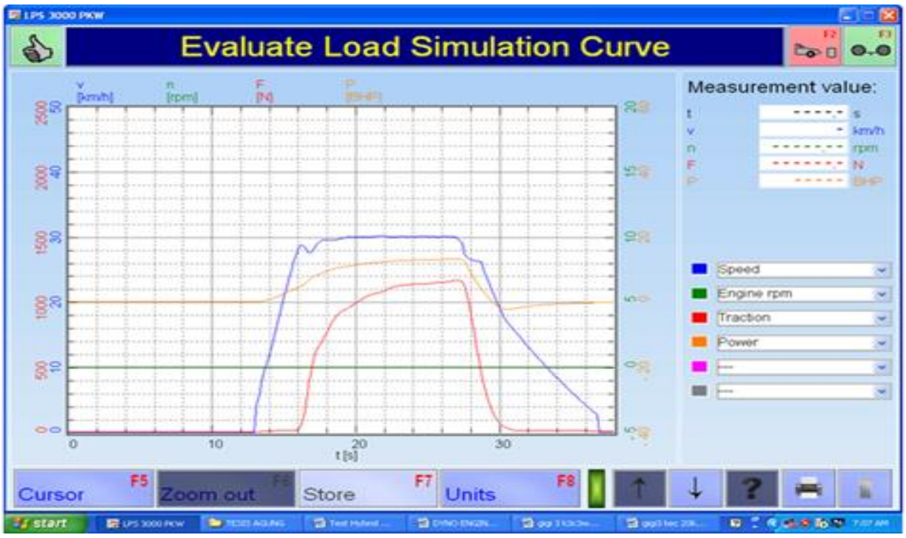

Figure 35. ICE measurements in 3rd gear at speeds of 30km/h

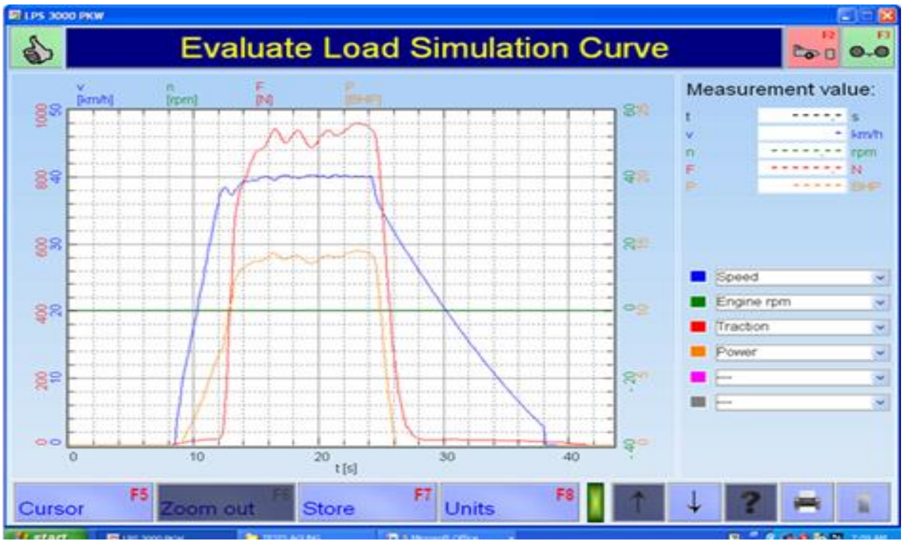

Figure 36. ICE measurements in 3rd gear at speeds of 40 km/h

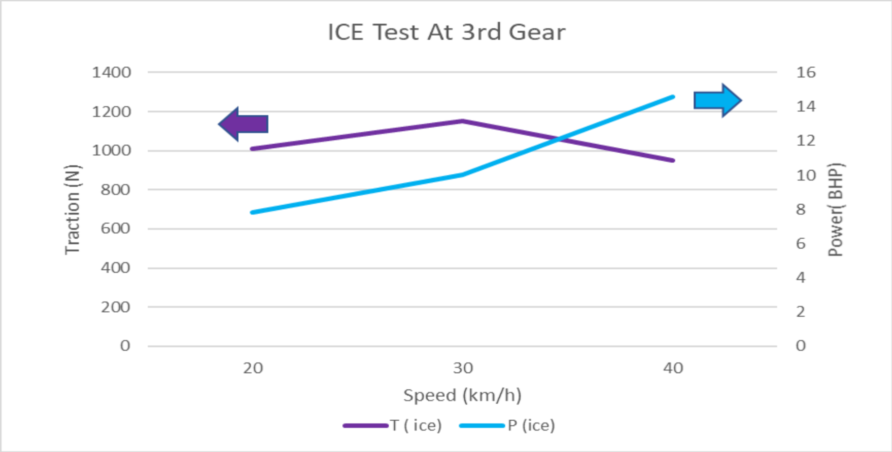

Figure 37. ICE Test At 3rd gear

In the graph above are the measurement results of the internal combustion engine in the 3rd gear at speeds of 20, 30 and 40 km / h to get traction and power, then the results are at a speed of 20 km / h traction 1010 N and Power 7.8 BHP, at a speed of 30 km / h traction 1150 N and Power 10 BHP and at a speed of 40 km / h traction 950 N and Power 14.6 BHP

The next step is to measure the internal performance of the engine combustion in 4th gear at speeds of 20.30 and 40 km / h to find out traction and power on the engine.

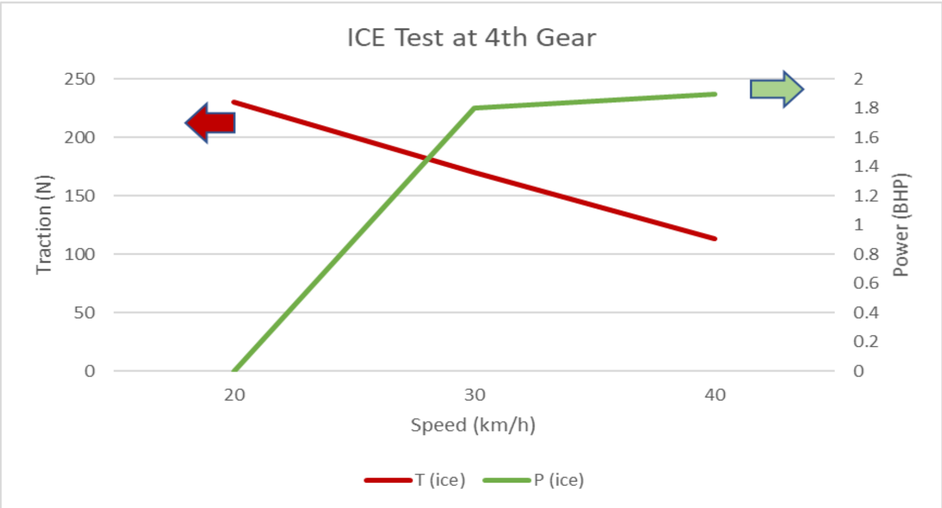

Figure 38. ICE Test At 4th gear

This graph shows traction and ICE power at speeds of 20, 30 and 40 km / h in 4th gear and the result is at a speed of 20 km / h traction ICE 230 N and Power ICE is 0 BHP, because the engine does not get power in 4th gear if engine speed is limited to 20 km / h, at a speed of 30 km / h traction ICE 170 N and Power ICE 1.8 BHP, and at a speed of 4 0 km / h traction ICE 113N and Power ICE 1.9 BHP, there is a decrease in ICE traction in 4th gear compared to 3rd gear when increasing speed this is due to changes in the gear ratio on the vehicle

3.4. Electric motor comparison with ICE

After getting data from the power and traction of the electric motor and ICE at speeds of 20.30 and 40 km / h, we compare the traction and power of the two driving modes to get the right potential when switching from electric motor to engine or from the engine to the electric motor in this hybrid prototype vehicle.

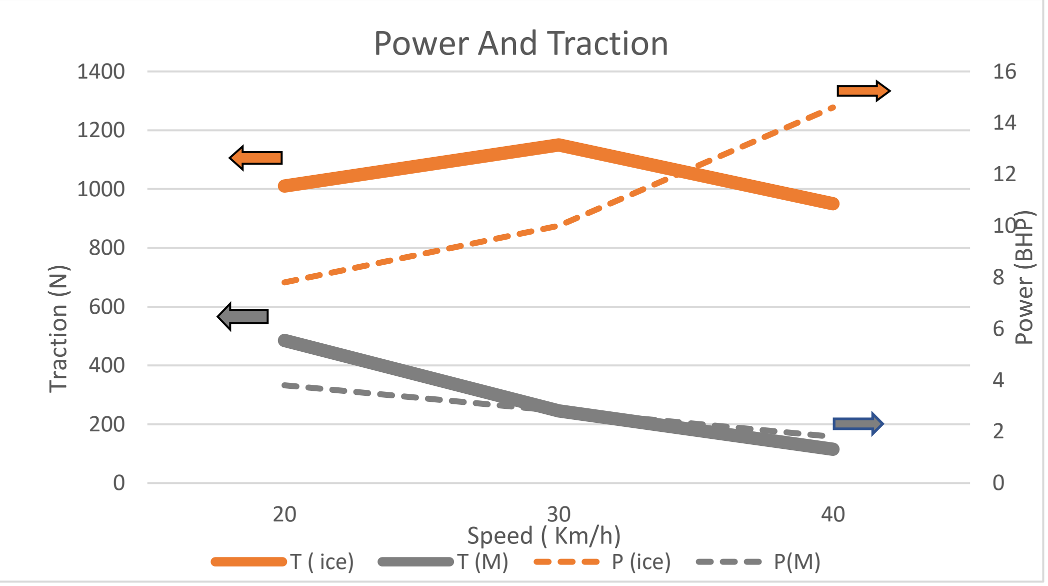

Figure 39. Comparison of electric motor power and traction with ICE in 3rd gear

In the graph, it can be seen that the ICE traction and power are greater than the power and traction of the electric motor at various speeds, the traction on the motor appears to be decreasing at high speed while the ICE traction increases at 30 km / h and decreases at 40 km / h, Motor power decreases as speed increases, while ICE power increases to a speed of 40 km / h.

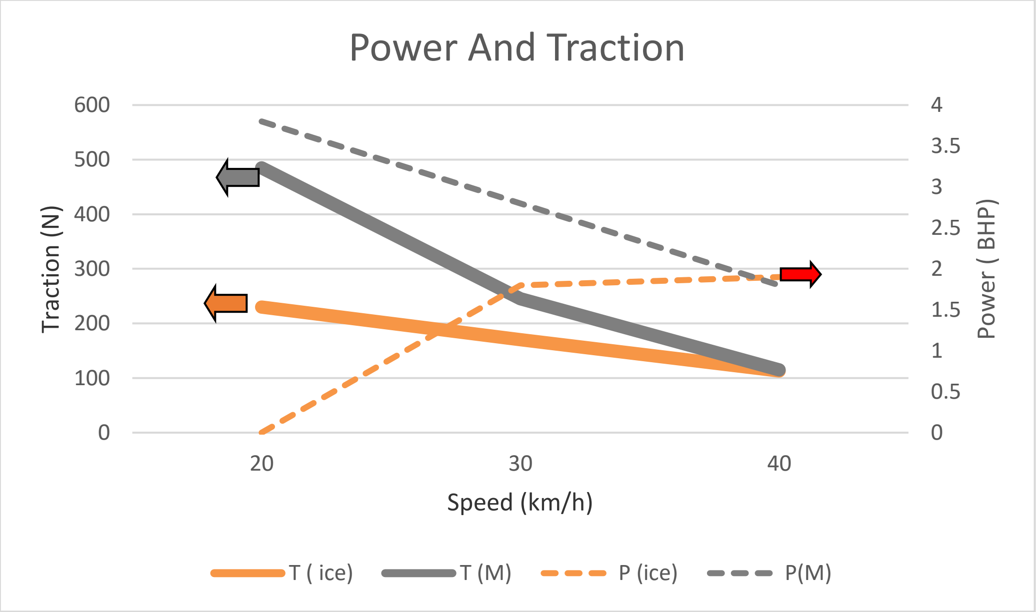

Figure 40. Comparison of electric motor power and traction with ICE in 4th gear

This graph shows that the ICE traction in 4th gear continues to decrease even the traction of the electric motor is higher when the speed is 20 km / h and 30 km / h compared to ICE traction. At a speed of 40 km / h the traction of the electric motor and ICE looks almost the same as 113 N, as well as the electric motor power with Ice power at 40 km / h, the electric motor power is 1.8 BHP, and the ICE power is 1.9 BHP.

By looking at the results of these measurements, to transfer power from the electric motor to the ICE or vice versa is done with the same power and traction so that there are no surprises, and it is expected to be connected smoothly.

3.5. Tools and Material

3.5.1. Daihatsu Midget II

In this study using the Daihatsu Midget 2 vehicle as the object of research for hybrid vehicles, here is information about the Daihatsu vehicle.

Early manufacturing the Daihatsu Midget had the concept of a mini and compact and three-wheeled vehicle, which was made in 1957 with a two-stroke gasoline engine with a 250-cc engine capacity and air-cooled, this vehicle had 10 horsepower and a maximum speed of 65 km / h. This first midget was distributed to Indonesia under the name BEMO which is useful for public transportation vehicles.

In 1996 the Daihatsu manufacturer released a second product from the Daihatsu midget generation called Midget II, this vehicle is different from the previous generation because it uses a four-stroke engine that is more environmentally friendly and has more power.

Figure 41. Daihatsu Midget II

(carfolio.com/2020)

Table 1.Technical Specification of Daihatsu Midget II

Parameter	Performance
Production	Apr-96
Country of origin	Japan
Make	Daihatsu
Model	Midget II Pick
EEC Segmentation	A (mini cars)
Class	Pick -Up
Body style	Pick -Up truck
Doors	2
Traction	RWD 9 (rear-wheel drive)
engine type	Spark-Ignition 4- Stroke
Fuel Type	Gasoline (petrol)
Cylinder alignment	Line 3
Displacement	659 cc
Horsepower	23kW/31 PS/31 Hp at 4900 rpm
Torque	50 nm /3200 rpm
Transmission type	Manual
Number of gears	4

3.5.2. Brushless DC Motor

Brushless DC Motor Type does not use Brush to send electricity to the commutator to reduce spark and electrical resistance which can reduce motor output power, in this type has the advantage that the torque produced by the motor is greater than the Brushed DC Motor type and has high durability but the price more expensive.

In this study using an electric motor type BLDC manufactured from golden motor with a specification of 5 Kw.

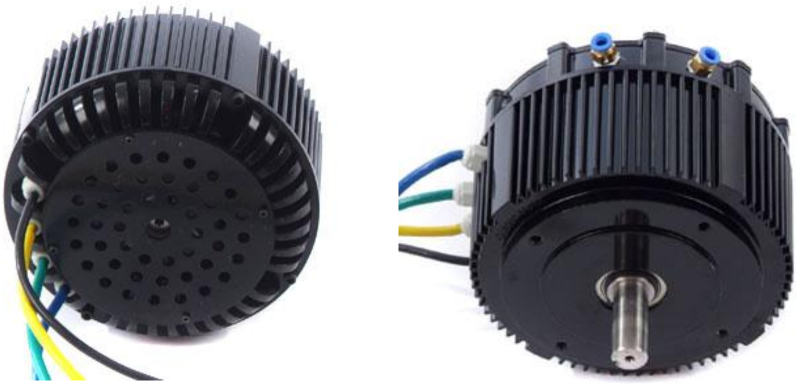

Figure 42. BLDC Motor

(goldenmotor.com/2020)

Table 2. Technical Specification BLDC Motor

Parameter	Performance
Model	HPM 5000B
Voltage	48V/72V/96V/120V
Rate Power	3KW-7.5KW
Efficiency	91%
Phase Resistance (Milliohm)	6.2/48v ;12.0/72V ;36.0/120V
Phase Induction(100KHZ)	68uH/48V ;154uH/72V; 504uH/120 v
Speed	2000-6000 rpm (customizable)
Weight	11 kg
Casing	Aluminum
Length (Height)	126 mm
Diameter	206 mm
Keyway size	5 mm(W) x 43 mm(L) x 19 mm (D: 22.3mm)
features	Compact design, Water Resistant, Stainless steel Shaft, self-Cooling fan
Applications	Electric car, electric motor cycle, electric bike, golf car, fork lift, electric boat,etc.

3.5.3. Inductive Proximity Sensor (LJ 12A3-4-Z/BX-5V)

Inductive proximity sensors are used in this study to detect the rotation of the engine as input to Arduino which then controls the switching of the engine or electric motor drive mode based on the speed of the vehicle.

Inductive Proximity Sensor is used to detect the presence of both ferrous and non-ferrous metals. This sensor can be used for presence detection (presence or absence of metal objects), counting metal objects and positioning applications. Inductive sensors are often used instead of mechanical switches because of their ability to operate at higher speeds than ordinary mechanical switches. This Inductive Proximity Sensor is also more reliable and more powerful.

Figure 43. Inductive Proximity Sensor

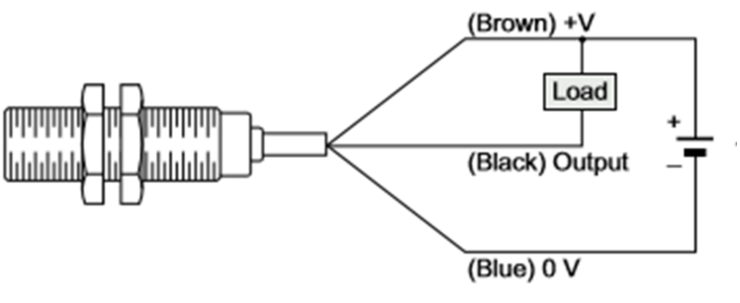

Figure 44. Inductive Proximity Sensor wiring diagram

Table 3. Technical Specification Inductive Proximity Sensor

Parameter	Performance
Brand	HUCHDQ
Part Number	LJ12A3-4-Z/BX-5V
3 Wire Polarity	NPN Detection
Voltage	DC 5 V (Support Arduino)
Detection Distance	4 mm
Output status	Normally Open
Output Current	300 mA
Detection Objects	Conductor
Screw length	61 mm

3.5.4. Voltage Sensor

In this study using a voltage sensor to measure the input voltage which is useful for determining the switching mode of the drive, voltage measurement is done by making a voltage divider resistor because the input voltage to be read is 72 V dc while the Arduino can only read 5v dc analog input, so a resistor divider is needed. This voltage divider resistor is connected to the hybrid vehicle prototype battery as a voltage sensor which functions to provide voltage input to the hybrid vehicle battery, if the voltage is less than 70 Vdc, the electric motor drive mode will be switched to engine drive mode.

The resistors used in this voltage divider are R1 = 8500 ohms and R2 = 4700 ohms, R1 is connected to the input voltage coming from the hybrid vehicle battery, R2 is connected to the negative battery and the output goes to the Arduino analog input, with the input voltage of 72 V and after passing the voltage divider circuit, the voltage read by the Arduino microprocessor is 3.773 V

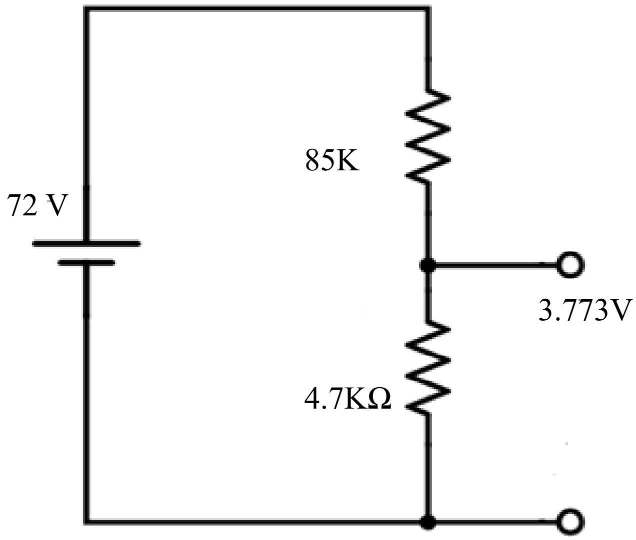

Figure 45.Voltage sensor

3.5.5. Arduino Uno

In this study, Arduino Uno is used as a medium to control the input and control board, a microcontroller board based on the ATmega328P 8-bit microcontroller. and there is a crystal oscillator, serial communication, voltage regulator, etc. to support the microcontroller. The Arduino Uno has 14 digital input / output pins (6 of which can be used as PWM outputs), 6 analog input pins, a USB connection, a power barrel jack, an ICSP header and a reset button.

Figure 46. Arduino UNO
(*https://www.arduino.cc/*, 2020)

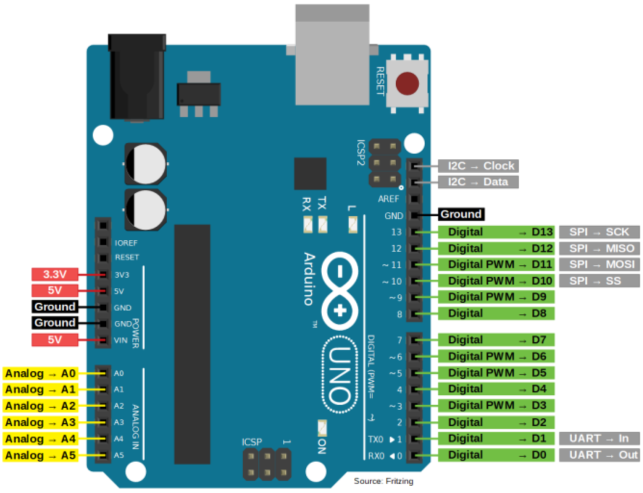

Figure 47. Arduino UNO pin out

(diyi0t.com)

Table 4. Technical Specification Arduino Uno

Microcontroller	**Atmega328P**
Operating Voltage	5 V
Input Voltage (recommended)	7-12V
Input Voltage (limit)	6-20V
Digital I/O pins	14 (of which 6 provide PWM output)
PWM Digital I/O Pins	6
Analog Input Pins	6
DC Current per I/O Pin	20 mA
DC Current for 3.3 V Pin	50 mA
Flash Memory	32 KB (ATmega328P) of which 0.5 KB used by bootloader
SRAM	2KB (ATmega328P)
EEPROM	1 KB (ATmega328P)
Clock Speed	16 MHz
LED_BUILTIN	13
Length	68.6 mm
Width	53.4 mm
Weight	25 g

3.5.6. LCD Display (LCD CHARACTER 16X2 1602 5V)

In this research using an LCD display (16X2 1602A) to display battery voltage, rpm and power transfer in hybrid vehicles.

Figure 48. LCD 16X2 1602 5V
(*https://www.arduino.cc/*, 2020)

Table 5. LCD Display Specification

Parameter	Performance
Module dimension	80mm x 35mm x 11mm
Visual Area	64.5mm x 16 mm
Character	2 lines x 16 characters
Input Voltage	5 Vdc
BackLight	LCD
LCD controller	Built-in HD44780 equivalent LCD controller

3.5.7. I2C Serial Interface for LCD 1602

To connect Arduino with LCD, this IIC / I2C serial interface is needed because it only uses 2 ports to control the LCD so that it saves port usage on Arduino, for example on Arduino UNO, just connect it with A4 / SDA and A5 / SCL pins in addition to the + 5V pin. and GND for power

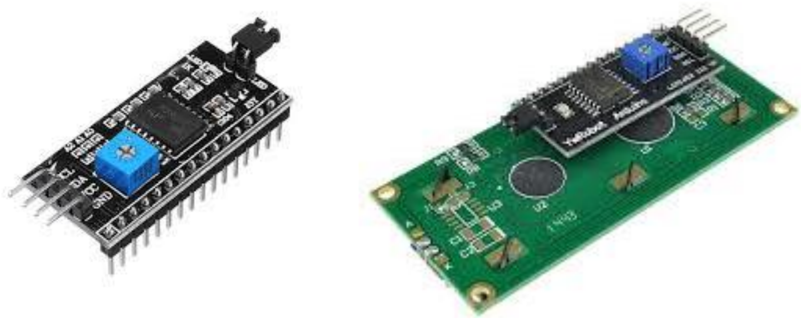

Figure 49. I2C Module for LCD 1602
(*https://www.arduino.cc/*, 2020)

Table 6. Specification I2C Module

Parameter	Performance
Module dimension	41.5mm x 19mm x 15.3mm
Control pins	SDA, SCL, VCC dan GND
Input Voltage	5 Vdc
Screen control	Equipped with a light control trimpot and screen contrast
Device Address	0 x 20

3.5.8. Relay

In this research, using a relay to connect the microcontroller to the actuator, there are two types of relays used, namely a relay with a 5vdc input voltage that supports Arduino and a 12vdc relay which supports the battery voltage on the vehicle.

1) Modul Relay 2 Channel 5 V

Figure 50. Modul Relay 2 Channel 5 V

(*https://www.arduino.cc/*, 2020)

Table 7. Specification Modul Relay 2 Channel 5 V

Parameter	**Performance**
Input Voltage	5 Vdc and each one needs 15-20mA Driver Current
Trigger	Active Low (Low Triggered)
Out Put relay	AC250V 10A ; DC30V 10A
Relay Output Status	LED
Support Microcontroller	Arduino, 8051, AVR, PIC, DSP, ARM, ARM, MSP430, TTL logic

2) Relay 12Vdc

Relay12vdc is needed as a connection to electricity and components on a Daihatsu Midget 2 Hybrid vehicle that uses 12 Vdc input voltage.

Figure 51. Relay 12 Vdc

(enginemaster.com.au/2020)

3.6. Blok diagram

Below is a block diagram of power transfer control on the Daihatsu Midget II hybrid Prototype vehicle.

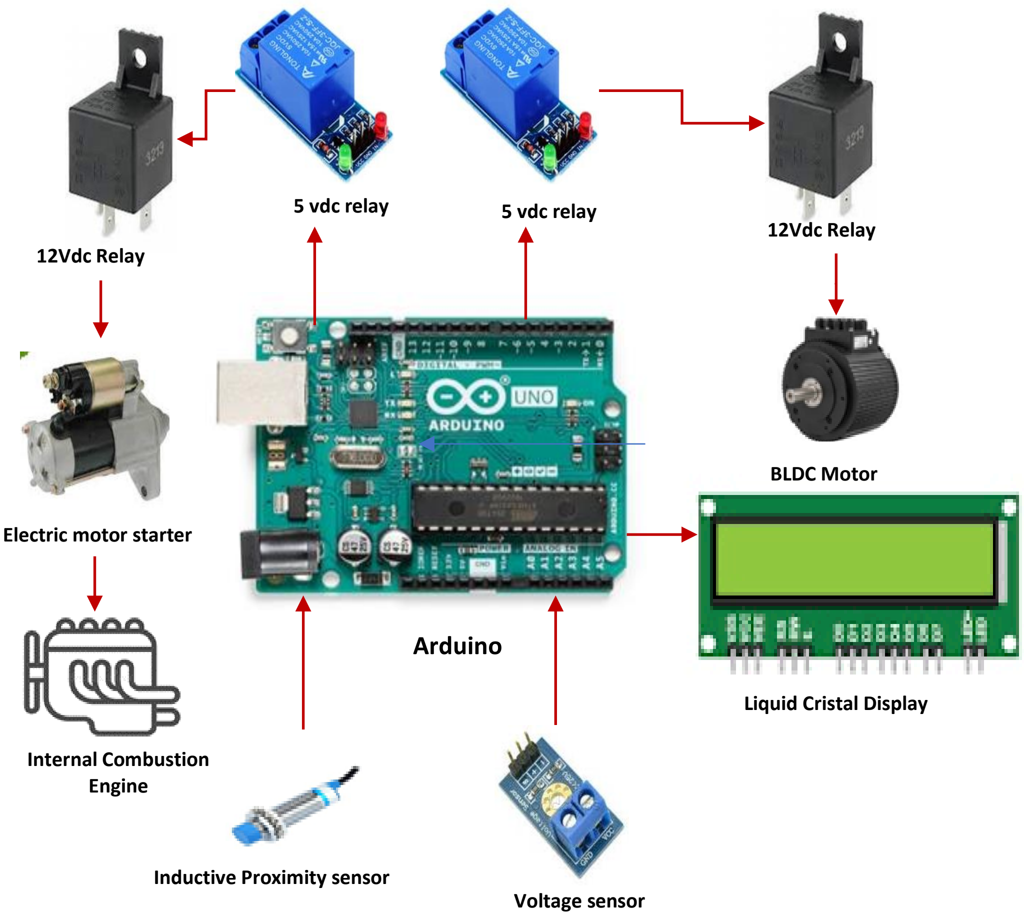

Figure 52. Block diagram

3.7. Circuit Diagram

Below is a circuit diagram of a hybrid vehicle power transfer arrangement

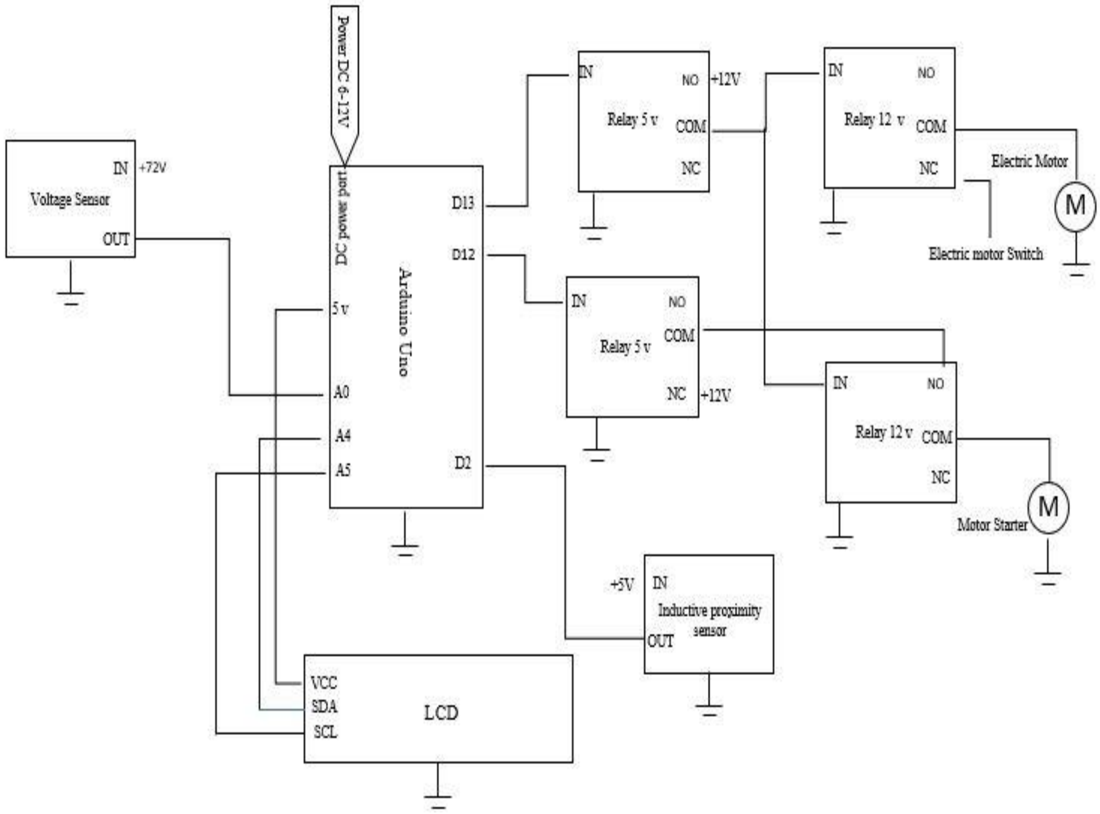

Figure 53. Circuit Diagram

3.8. Flow Diagram

Below is a Flow diagram of power transfer control on the Daihatsu Midget II hybrid Prototype vehicle.

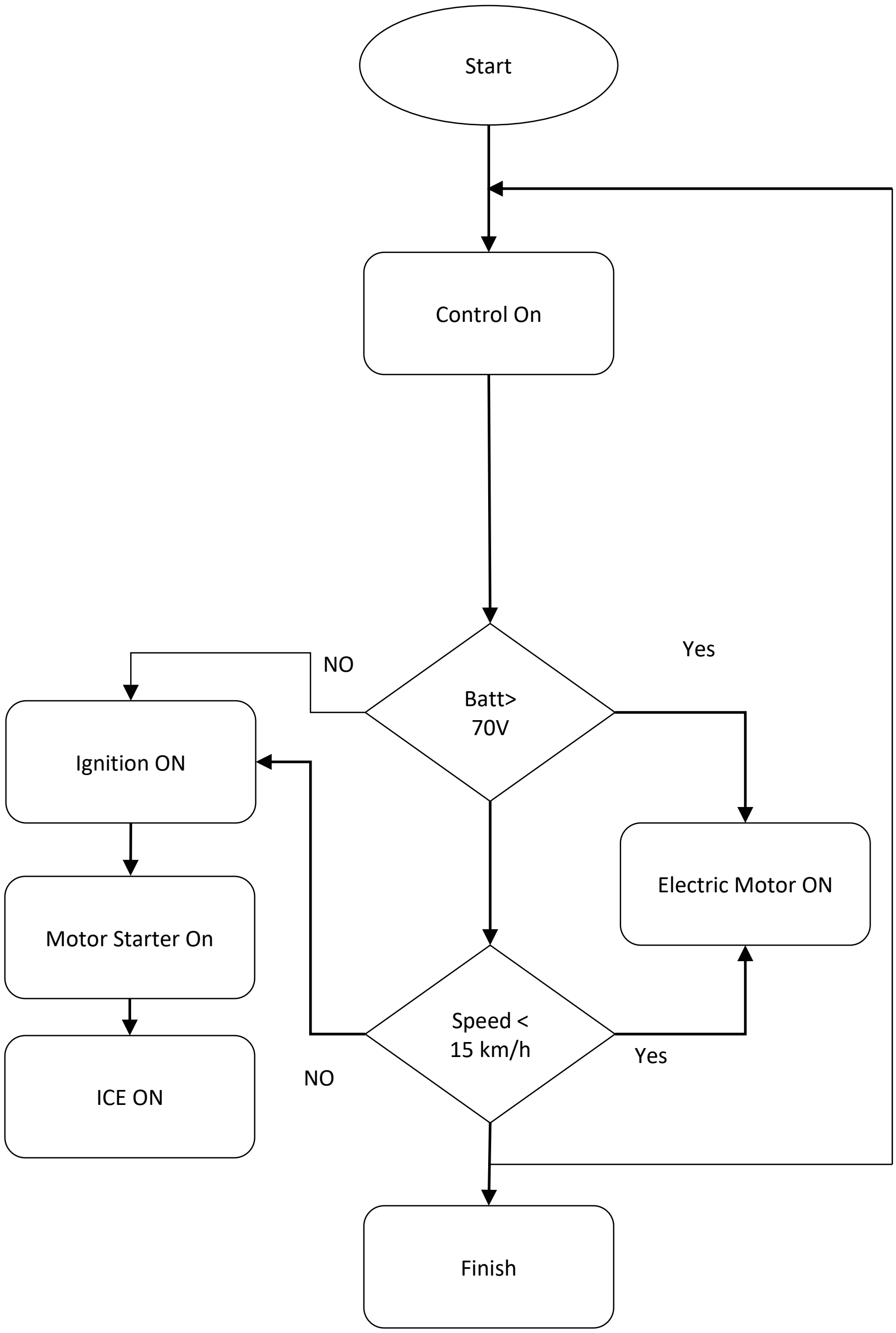

Figure 54. Flow Diagram

3.9. Power Transfer Controller Design

In the design of the power transfer controller consisting of an Arduino controller and a drive relay, this system controls the transfer of power from the electric motor to the ICE and from the ICE to the electric motor based on vehicle speed and battery voltage.

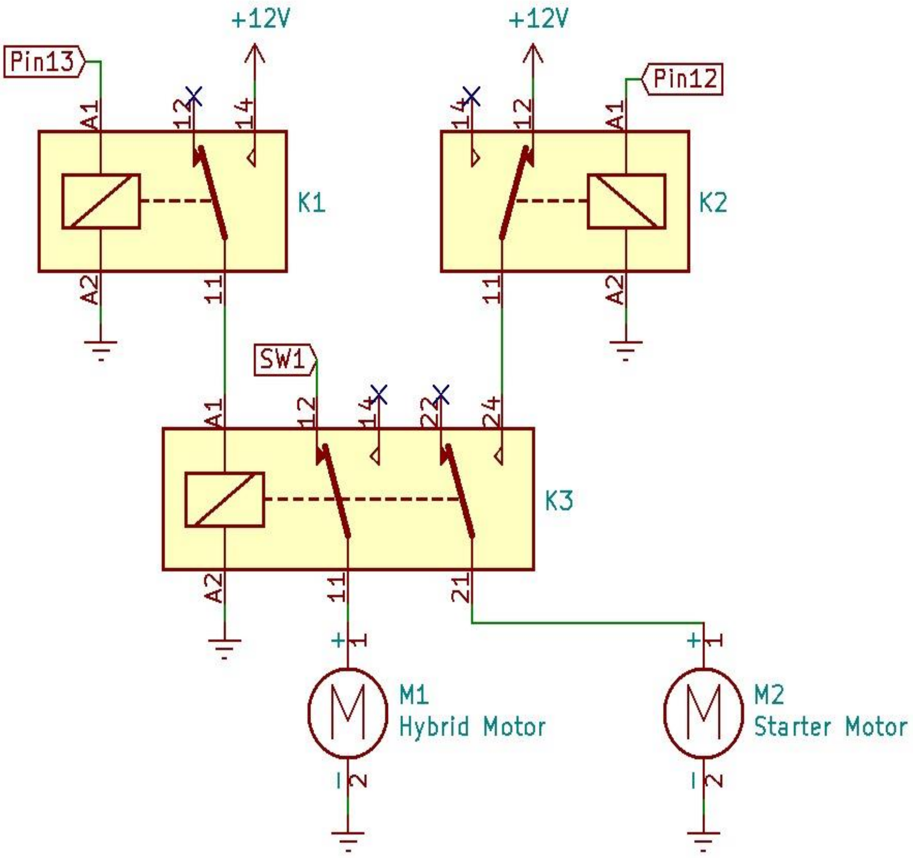

Figure 55. Power Transfer Controller Design

3.10. Testing of Components

Component testing in this study is carried out with the aim of ensuring that all components tested are fit for use in research.

3.9.1. Testing Of Inductive proximity Sensor (LJ 12A3-4-Z/BX-5V)

Inductive proximity sensor testing is done to get accuracy in providing rpm data input to Arduino, testing is done by comparing the results of inductive proximity sensor input with the Sanfix DT-2234L measuring instrument.

Figure 56. Digital tachometer Sanfix

The way to do speed testing is a measurement using a tachometer compared to the Arduino program, first the Inductive proximity sensor is installed near the rotating iron object then the iron object is measured using a tachometer with different speed variations then the measurement results are compared with the reading results from Arduino then tables and graphs are made.

Figure 57. Validation With Tachometer

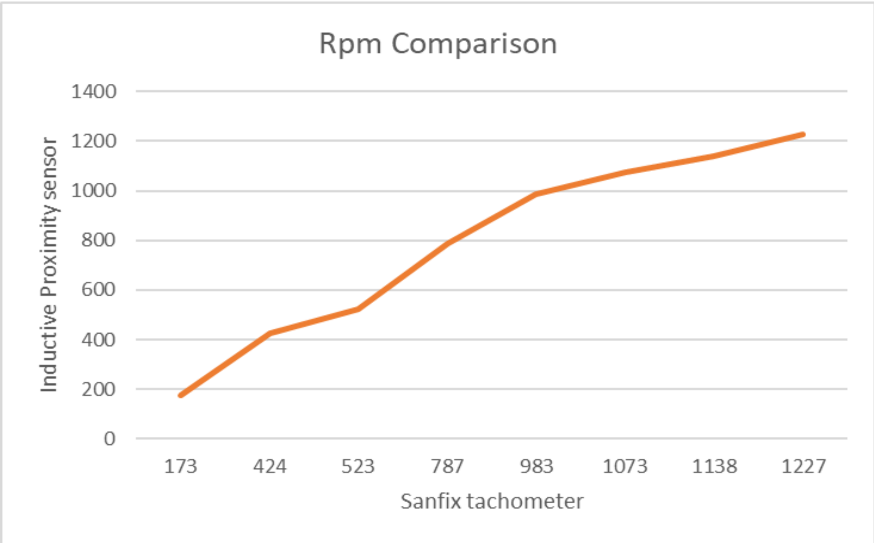

Figure 58. Rpm comparison

From the measurement results graph there is a slight difference between the rpm measurement using a tachometer and the reading from Arduino, the higher the accuracy of the measurement results, the graph will form a 45-degree line.

3.10.1. Testing of Voltage Sensor

Voltage sensor testing is done by comparing the measurement of the output voltage from the voltage sensor using a digital measuring instrument for the Sanwa CD800a Voltmeter with the measurement results using Arduino then it is expected that the results of the comparison of these measurements are the same.

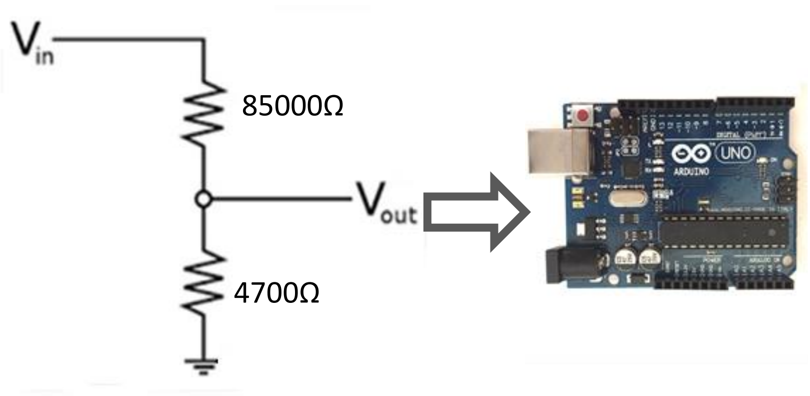

Figure 59. Measurements with the Arduino Program

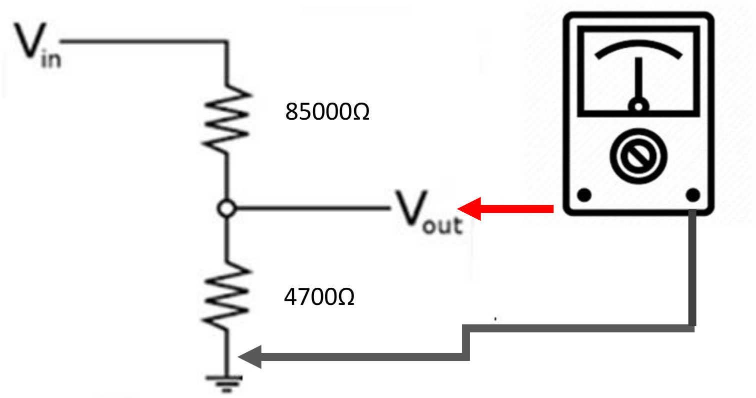

Figure 60. Validation with the Voltmeter

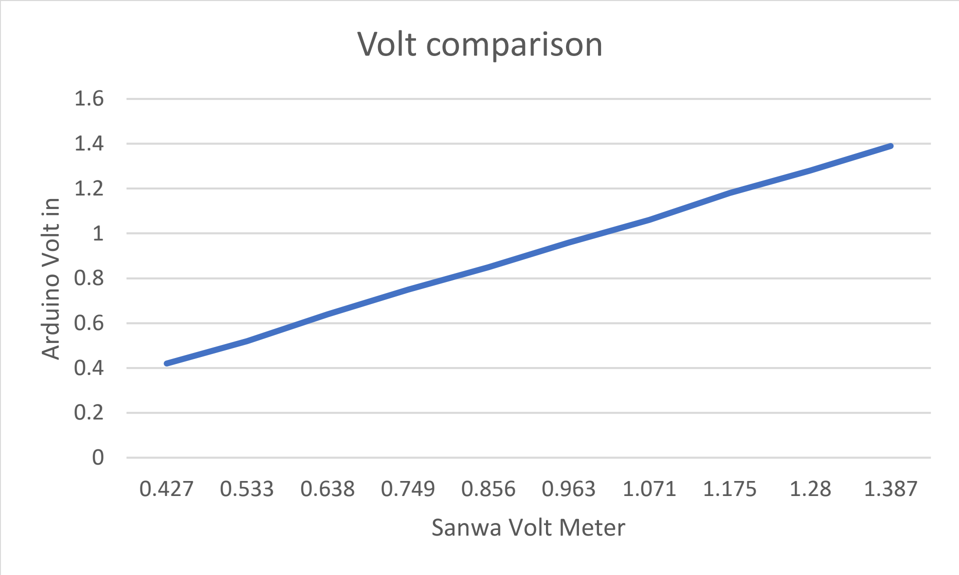

Figure 61. Volt comparison

Comparison of the two measurements using a voltmeter and using the program from Arduino looks to form a 45-degree angle so that the validation of these measurements is good.

3.11. Power Transfer Scenario

Before developing a power transfer control, a scenario is created to make it easier to operate the hybrid vehicle and adapt it to road conditions and the ability of the components of the hybrid vehicle.

3.11.1. Electric motor RUN Mode

- Battery voltage >70Vdc
- Speed 0-15km / H

When the vehicle is driving using an electric motor, the first is that the battery voltage must be at least 70 Vdc because if the voltage decreases, the ability of the electric motor to provide torque to the wheels also decreases. And the driving speed is not more than 15 km / h because the electric motor of this hybrid vehicle only has 5kW of power so there is not enough capability to drive faster.

3.11.2. ICE RUN Mode and Vehicle going Faster

- Battery voltage <70Vdc
- Speed >15km/H

The Internal Combustion Engine will run if the battery voltage is less than 70 Vdc, then the power from the electric motor will automatically be transferred to ICE, and if the speed in driving using an electric motor is more than 15km / h, the power from the electric motor will also transfer to ICE.

When a hybrid vehicle is stationary or not yet running, the electric motor mode will be active, such as when at a traffic light or when there is a traffic jam and need to stop and go, an electric motor that functions before the speed increases to 15 km / hour.

However, if there is a problem, for example the engine is damaged or the vehicle runs out of fuel, then the position of the gear lever must be neutral and the driver drives the vehicle at a low speed or less than 15 km / h in electric motor mode, until he gets fuel at the nearest gas station.

3.11.3. Charging System

A good hybrid vehicle must be equipped with a generator that functions to charge the battery if the battery is low voltage, Polman Astra hybrid vehicles are included in the Plug-In Hybrid category with external charging or the charging process is carried out outside the vehicle system.

Polman Astra hybrid vehicle has two different batteries, the first battery function is to drive the starter motor and vehicle electricity with a working voltage of 12V, while the second battery functions to drive an electric motor with a working voltage of 72 V.

On the Daihatsu Midget II engine, it is equipped with an alternator that supplies voltage to 12V batteries for the charging process, the alternator is connected to the engine using a van belt, to turn the 12 V alternator into a generator with an output voltage of more than 72 v to supply the hybrid vehicle battery, DC required to DC Step -Up Power Supply.

Figure 62. Alternator
(parts.longotoyota.com. /2020)

Figure 63. DC Step-Up Power Supply 0-80Vdc

(amazon.com/2020)

The output of the alternator is connected to the Step-up Power supply so that the voltage from the 14 V alternator will be increased to above 72V for charging the hybrid vehicle battery.

CHAPTER 4 – RESULTS AND DISCUSSIONS

4.1. Circuit Implementation

4.1.1. Sensor Characteristic

In this research, inductive proximity sensors and voltage sensors are important keys to regulating the transfer of power from the engine to the electric motor or from the electric motor to the engine, Inductive proximity sensor and voltage sensor will send data to Arduino control, Arduino will calculate the data then send the data to the LCD monitor and will control the electric motor and engine in accordance with the command.

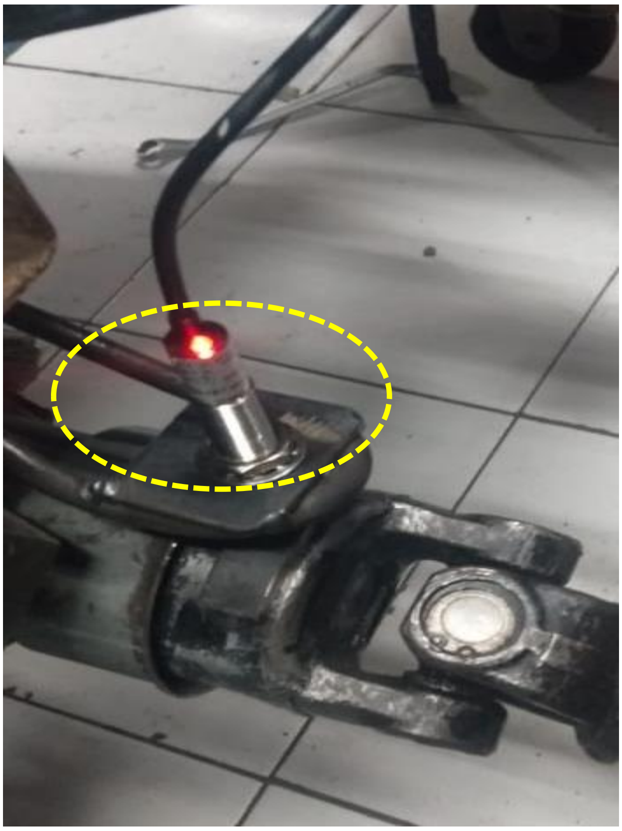

Figure 64. Inductive Proximity Sensor on top of the Propeller Shaft

Inductive proximity sensor is mounted on top of the propeller shaft which aims to read the rpm from the engine or from the electric motor, the placement is done on the propeller shaft for easy installation and adjustment of the sensor.

Figure 65. Iron blade to trigger Signal

To the propeller shaft two pieces of iron with a thickness of 5 mm are added which function as a trigger signal which will be generated by the output of the inductive proximity sensor in the form of the RPM value, the difference from the height of the iron added will be read by the inductive proximity sensor as a change in distance which is then be the sensor input.

Apart from the difference in the distance read by the inductive proximity sensor, the rotational speed of the propeller shaft is also input from the sensor, this sensor is equipped with an LED which will turn ON if the trigger signal iron is close to the sensor and will turn OFF an if the trigger signal iron stays away from the sensor.

The voltage sensor uses two resistors as a voltage divider, R1 85K ohm and R2 4.7 k ohm which is attached to a PCB, and as input for this voltage sensor is a 72 Vdc battery which functions as a voltage supply to drive an electric motor.

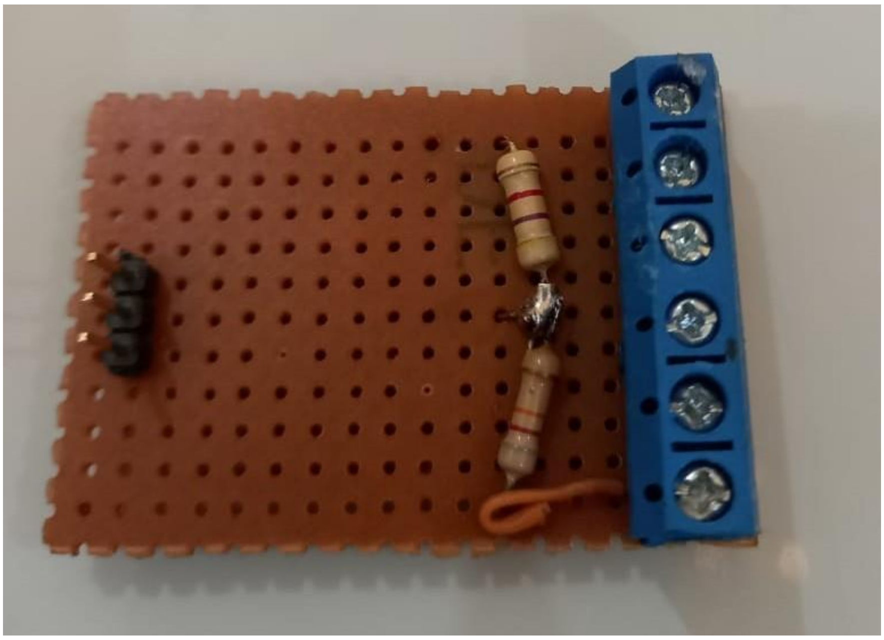

Figure 66. The Voltage sensor is installed on the PCB

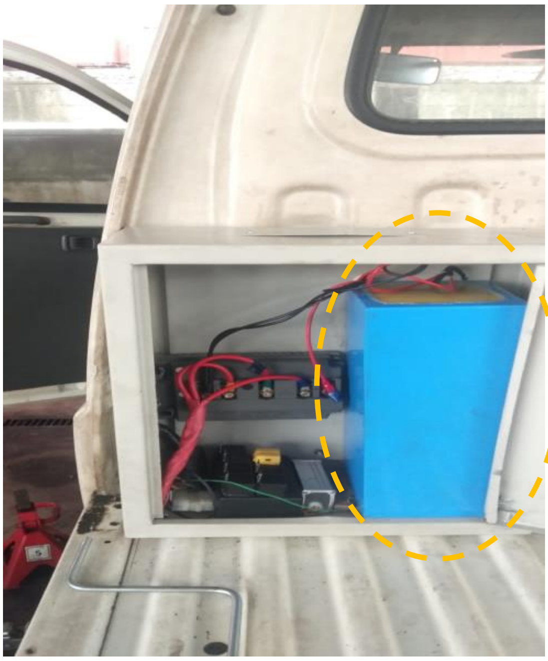

Figure 67. Battery input for the voltage sensor

Figure 67 shows the battery that is used as input to the voltage sensor, the battery is an electric motor drive.

The output from the voltage sensor will be processed by the Arduino controller and will be displayed on the LCD by showing the input and output voltage into Arduino, then it will be forwarded to a relay which will activate engine mode or electric motor mode.

4.1.2. Control Device Arrangement

Placement of the Arduino control, voltage sensor and 5v relay on the monitoring box Show in figure 68, to keep the components inside safe and tidy, the LCD monitor is placed on the cover box by making a hole in the cover box, the display on the LCD screen shows information to the driver, in the form of input and output voltages from the driving battery electric motor, then displays the power transfer mode on the vehicle.

Figure 68.Monitoring Box

For example, if the battery voltage is less than 70vdc, the LCD displays in 70.00, Out: 3.67, ICE is ON or if the voltage is 73 Vdc the LCD displays In 73.00, Out: 3.8, EM is ON. and if the speed is less than 15 km / h then EM ON, if the speed is more than 15km / h then ICE is ON.

ICE ON is the engine in RUN mode and EM ON is the electric motor in RUN mode.

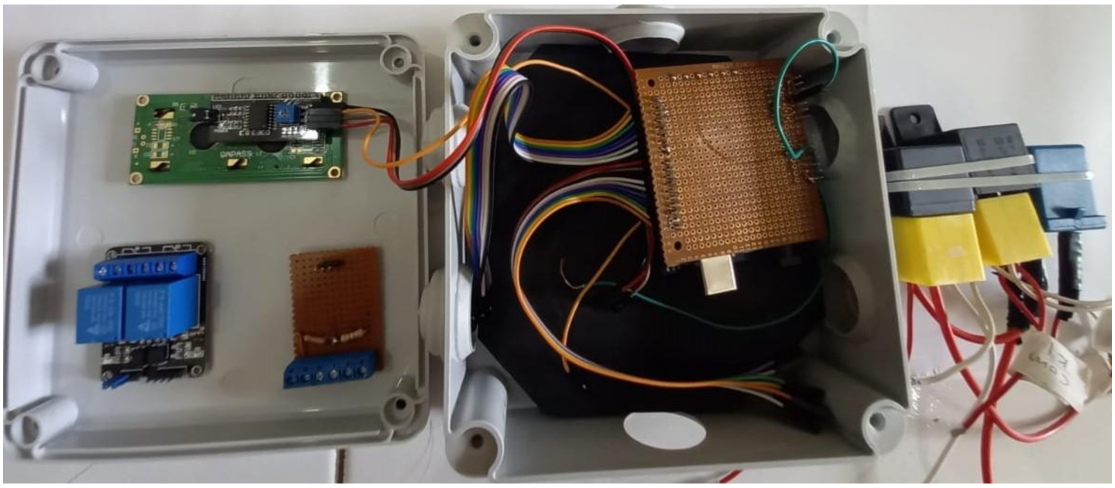

Figure 69.Placement of the controlling components

Figure 69 shows the placement of Arduino control, 5v relay and voltage sensor in the monitoring box, but the 12v relay, the 5v relay function is a bridge to activate the 12v relay because the 5v relay gets input from Arduino while the 12 v relay is used to drive an electric motor switch and, another 12v relay drives the starter motor on the engine, the 12v relay placement is outside the monitoring box.

4.2. Gear ratio 4 speed manual transmission

The vehicle used is the Daihatsu Midget II which uses a 4-speed manual transmission, to determine the character of the gear shift ratio in the transmission, a certain speed is tested for each gearshift.

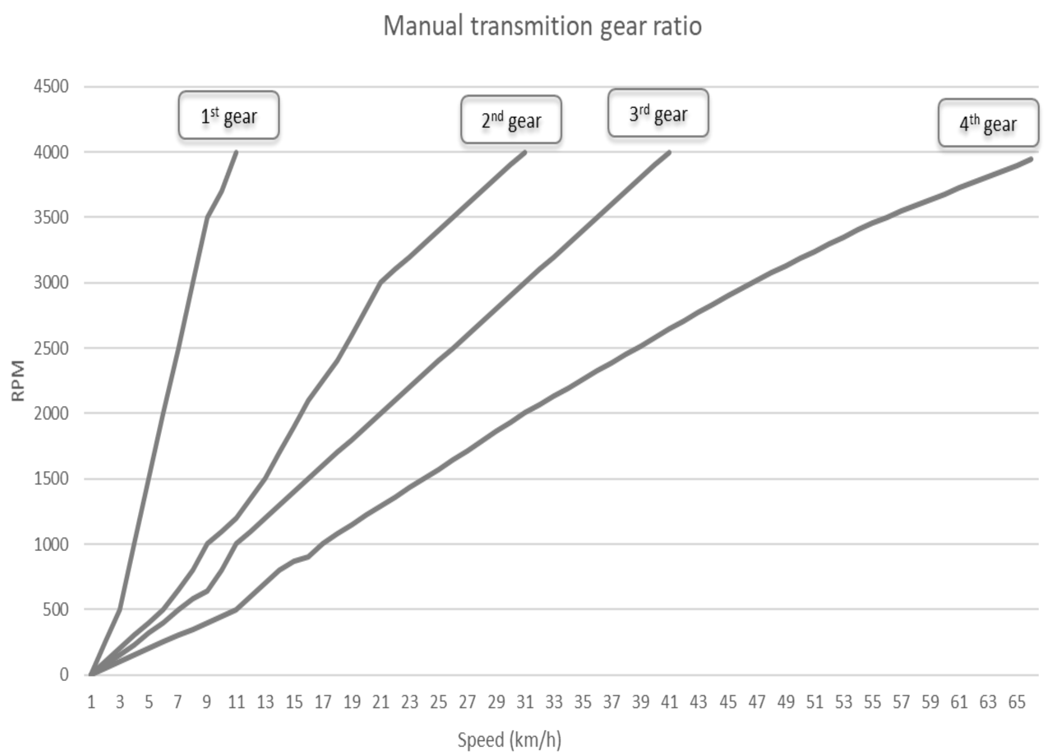

Figure 70. Gear Ratio 4 Speed Manual Transmission

The gear ratio data collection in hybrid vehicles is carried out at each gear shift by considering the RPM and vehicle speed, with this data retrieval can see changes in speed and RPM at each gear change.

4.3. Electric Motor Ratio

In addition to using the internal combustion engine, this Hybrid vehicle also uses an electric motor which helps when the initial vehicle moves.

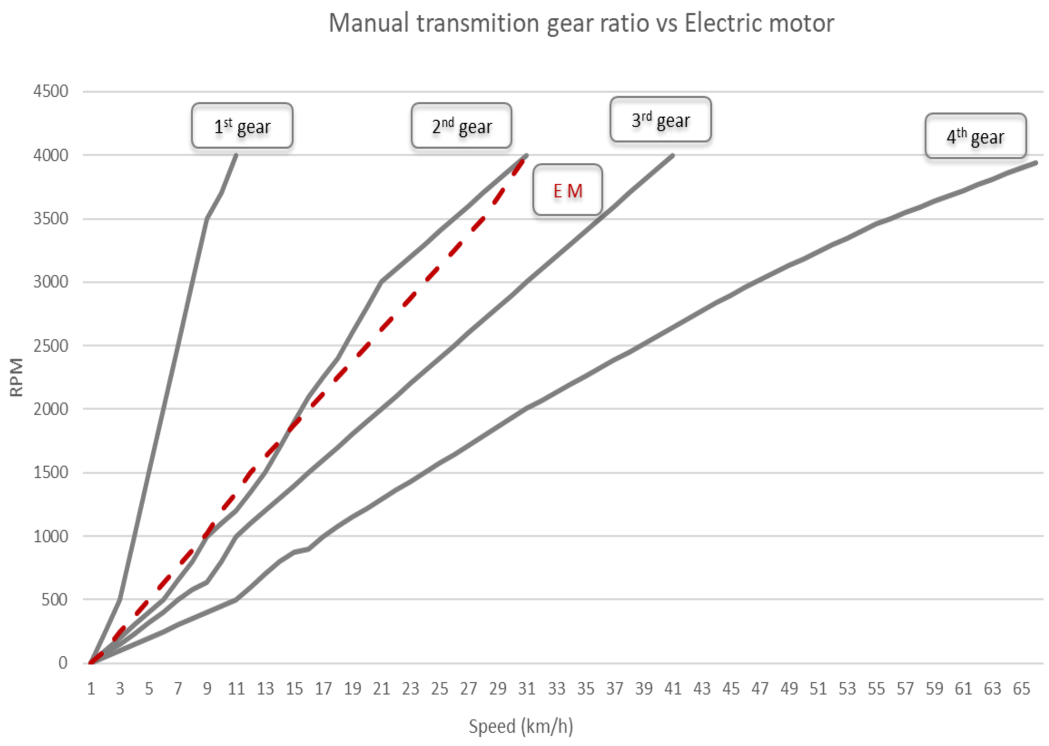

Figure 71. Electric Motor Ratio

In addition to data collection on vehicle gearshift, data is also taken for changes in rpm and speed at electric motor rotation, the electric motor ratio on the graph is red and the electric motor ratio data is compared to the gearshift ratio on the Hybrid vehicle.

4.4. Power Switching Strategy

By knowing the ratio of the gear shift and the ratio of the electric motor, we can determine the power transfer according to our needs by considering speed and RPM.

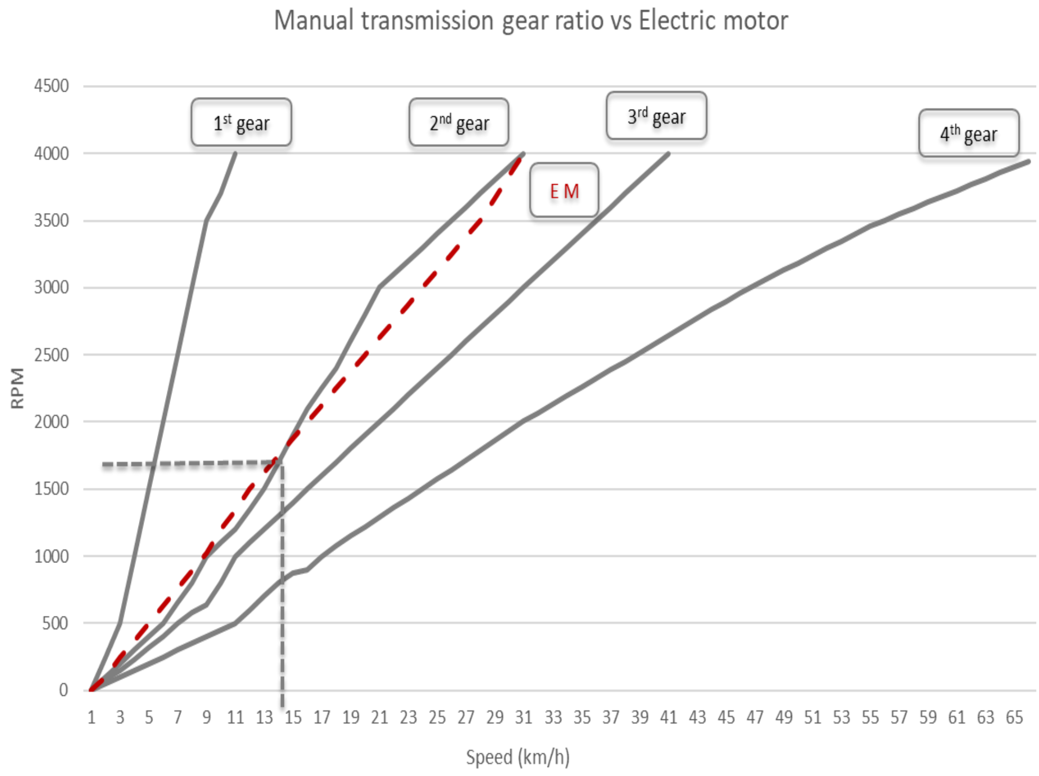

Figure 72. Power Switching Strategy

The strategy of transferring power from the electric motor to the engine or from the engine to the electric motor smoothly depends on the accuracy in the gear shift which is done according to the ratio of the electric motor which is the same as the gear ratio of the gear shift.

In the Figure 70 shows the ratio between the electric motor and the ratio in the second gear shift is at one point, namely at a speed of 14 km / h with 1700 RPM so it is hoped that when the power transfer from the electric motor to the engine can be carried out smoothly.

Several parameters are needed in regulating the power transfer that will be carried out on this hybrid vehicle by looking at the parameters and conditions needed so that precise control can be made using Arduino.

Table 8. Electric Motor ON Mode

Parameter	**Condition**
Battery Voltage	> 70Vdc
Ignition Engine	OFF
Vehicle speed	< 15km/h
Gear shift Lever	Neutral
Clutch pedal position	Not Engaged
Starter Motor	OFF

When the electric motor is ON, the control is done by reading the battery voltage (> 70Vdc) and the vehicle speed (<15km / h), if in this condition the Arduino control will turn off the ignition engine and motor starter, then the driver must shift the transmission lever. must be in neutral so there is no jerk when driving and the clutch is not connected to the engine.

Table 9. ICE ON Mode

Parameter	Condition
Battery Voltage	< 70Vdc
Ignition Engine	ON
Vehicle speed	>15km/h
gear shift Lever	2nd gear
Clutch pedal position	Engaged
Starter Motor	ON (3 second)

When the Internal Combustion Engine is ON mode, the control is done by reading the battery voltage (<70Vdc) and the vehicle speed (> 15km / h), if in that condition, the control Arduino will turn ON the Ignition Engine and Starter motor (3 seconds) so that the engine can turns on in Idle, all the driver has to do is step on the clutch pedal so that the clutch is depressed and connect the engine to the transmission, then move the transmission lever to 2nd gear, then if the speed increases then the driver can change to 3rd and 4th gear.

If when driving fast using ICE mode and the driver slows down the vehicle or stops then Arduino control will automatically switch to Electric motor mode by turning off the ignition engine, the driver must move the gear lever to the Neutral position.

4.5. Comparison of the Mileage with Electrical Load

This hybrid vehicle is a Plug-in Hybrid type that charges the battery using external charging or there is no generator that helps in charging while driving, so the efficiency of battery use depends on the distance traveled by using an electric motor.

Tested the mileage of hybrid vehicles with a constant speed of 20km /h in a single charge, the vehicle load is only the electrical load from the electric motor (the vehicle is not driven on the road).

Figure 73. Discharging Measurement

Table 10. Mileage with Electrical Load

Parameter	Condition
Battery capacity	40 A H
Discharging current	24.3 A
Speed	20 Km/h
Mileage	40 A H:24.3Ax 20km/h
	32 km

Measuring the discharging current using an Ampere meter, with a battery capacity of 40 AH, the discharging current is 24.3 A, the distance that can be obtained with a single battery charge is 32 km.

The faster we drive this hybrid vehicle, the distance traveled by using an electric motor will decrease and the increasing load of the vehicle will also reduce the mileage.

4.6. Experimental

Some final tests cannot be carried out such as testing the shift to an electric motor to an engine with gear shifting settings due to problems in the electric motor controller, and also experimental making a step-up generator to supply voltage to a hybrid vehicle battery also cannot be done due to time constraints and COVID-19.

This is because the project can only be done at work while activities at work are canceled due to a pandemic.

CHAPTER 5 – CONCLUSIONS AND RECCOMENDATIONS

5.1. Conclusions

1 The result of this research is the manufacture of power transfer switching control by testing using a dynamometer so that it can see the potential power and traction from the electric motor and ICE so that it can develop proper control in this hybrid vehicle.

2 The result of this research is to be able to do automatic switching of electric motors to ICE or from ICE to electric motors using Arduino control by taking data from inductive proximity sensors and voltage sensors, this data will then be displayed on the LCD so that it can be read by the driver.

3 The result of this research is that it can transfer power from the electric motor to the ICE quickly and smoothly, considering the speed and proper gearshift, when ICE is in RUN mode, the electric motor will turn off when the speed is 15 km / h and the driver must shift the manual transmission gear in 2nd gear, When the vehicle slows down and the ICE is off, the electric motor will be in RUN mode, so the driver must move the transmission lever to a neutral position

.

5.2. Recommendations

There are some aspects that do need to be changed and further learned from the research that has been done to obtain more detailed data and test equipment that has optimal functions, in compliance with current conditions in the field. To optimize this study, the following are some suggestions that can be done.

1 This research uses a manual transmission vehicle that makes it difficult for the driver when automatic switching works, because the driver must determine the right gear, so that the power transfer from the electric motor to the ICE can be smooth, for further research it is highly recommended to use an automatic transmission so that the prototype of this hybrid vehicle can work. with maximum

and the transfer of power from the electric motor to the ICE becomes smooth and fast.

2 The placement of the inductive proximity sensor must be better because this sensor is sensitive if there is high vibration, if the placement is not correct then the inductive proximity sensor will be error so that Arduino cannot read properly and the control cannot work, it is also advisable to use a highly capable sensor to overcome vibration.

APPENDIX

Arduino program for automatic switching control on hybrid vehicles

```
#include <Wire.h>
#include <LiquidCrystal_I2C.h>

LiquidCrystal_I2C lcd(0x27, 20, 4);


unsigned long rpmtime;
float rpmfloat;
unsigned int rpm;
bool tooslow = 1;
int proximity = 2, relay1 = 13, relay2 = 12 ;

const int voltageSensor = A0;
float vOUT = 0.0;
float vIN = 0.0;
float R1 = 82000.0;
float R2 = 4700.0;
int value = 0;

void setup() {


lcd.init();
lcd.init();
lcd.backlight();

  Serial.begin(115200);
  TCCR1A = 0;
  TCCR1B = 0;
  TCCR1B |= (1 << CS12); //Prescaler 256
  TIMSK1 |= (1 << TOIE1); //enable timer overflow
  pinMode(proximity, INPUT);
  pinMode(relay1, OUTPUT);
   pinMode(relay2, OUTPUT);
  attachInterrupt(0, RPM, FALLING); //RISING
}

ISR(TIMER1_OVF_vect) {
  tooslow = 1;
}
void loop() {
 delay(1000);

 value = analogRead(voltageSensor);
 vOUT = (value * 5.0) / 1024.0;
```

```
 vIN = vOUT / (R2 / (R1 + R2));

 if (vIN <= 3.60) {
   digitalWrite(relay1, HIGH);
  } else {
    digitalWrite(relay1, LOW);
  }

  lcd.setCursor(0, 0);
  lcd.print("In: ");
  lcd.setCursor(4, 0);
  lcd.print(vIN);

  lcd.setCursor(0, 1);
  lcd.print("Out: ");
  lcd.setCursor(5, 1);
  lcd.print(vOUT);

  Serial.print("Input: ");
  Serial.print(vIN);
  Serial.println(" volt");

  Serial.print("Output: ");
  Serial.print(vOUT);
  Serial.println(" volt");


  if (tooslow == 1) {
    Serial.println("TOO SLOW!");
  }
  else {
    rpmfloat = 120 / (rpmtime / 31250.00);
    rpm = round(rpmfloat);
    Serial.print(rpm);
    Serial.println(" rpm");
    if (rpm >= 1400 && rpm <= 1500 ) {
      digitalWrite(relay1, HIGH);
      //Lcd ice on
      lcd.clear();
       lcd.setCursor(0, 0);
  lcd.print("In: ");
  lcd.setCursor(4, 0);
  lcd.print(vIN);

  lcd.setCursor(0, 1);
  lcd.print("Out: ");
  lcd.setCursor(5, 1);
  lcd.print(vOUT);
lcd.setCursor(10, 1);
```

```
      lcd.print("ICE ON");
      //
      delay(3000);
      digitalWrite(relay2, HIGH);



    } else {
      digitalWrite(relay2, LOW);
      digitalWrite(relay1, LOW);
      //Lcd ice on
      lcd.clear();
       lcd.setCursor(0, 0);
  lcd.print("In: ");
  lcd.setCursor(4, 0);
  lcd.print(vIN);

  lcd.setCursor(0, 1);
  lcd.print("Out: ");
  lcd.setCursor(5, 1);
  lcd.print(vOUT);
lcd.setCursor(11, 0);
      lcd.print("EM ON");
      //
    }
  }
}

void RPM () {
  rpmtime = TCNT1;
  TCNT1 = 0;
  tooslow = 0;
}
```

GLOSSARY

Alternator is an electric generator that transforms mechanical energy into electric power in the form of alternating current. Most alternators use a rotating magnetic field with a stationary armature for reasons of cost and simplicity. A linear alternator or a revolving armature with a stationary magnetic field is occasionally used. Any AC electrical generator can, in theory, be called an alternator.

Arduino is an open-source business, project and user community for hardware and software that designs and produces single-board microcontrollers and microcontroller kits for digital computer construction.

Arduino Uno is an open-source microcontroller board created by Arduino.cc based on the Microchip ATmega328P microcontroller. The board is fitted with digital and analog input/output pin sets that can be attached to different expansion boards and other circuits**.**

BLDC motor Brushless DC Motor Type does not use Brush to send electricity to the commutator to reduce spark and electrical resistance which can reduce motor output power, in this type has the advantage that the torque produced by the motor is greater than the Brushed DC.

Differential is a mechanism that splits the torque of the engine in two ways, enabling each output to spin at a different speed.

Dynamometer or short 'dyno' is a system for calculating the torque and rotational speed of a generator, engine or other rotating prime mover simultaneously so that its instantaneous power can be measured and typically shown as kW or bhp by the dynamometer itself.

Electric Motor is an electric machine that transforms mechanical energy into electrical energy. Many electric motors work to produce force in the form of torque applied to the shaft of the motor through the interaction between the magnetic field of the motor and electrical current in a wire winding.

Gear shift lever in an automotive transmission, a gear stick, gear lever, gearshift or shifter is a metal lever connected to the shift assembly. The term gear stick often refers to the manual transmission shift lever, while a similar lever is known as a gear selector in an automatic transmission.

Generator is a device that converts motive power (mechanical energy) into electrical power for use in an external circuit.

Hybrid vehicle is a combination of an internal combustion engine system with an electric propulsion system to achieve better fuel economy and performance.

ICE Stands for internal combustion engine usually used in vehicle engines.

Proppeler Shaft a device that connects the transmission to a differential on a vehicle.

RPM The number of turns in one minute is revolutions per minute. It is a rotational speed unit or the rotation frequency around a fixed axis.

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CURRICULUM VITAE

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