Development of Automatic Switching Controller for Shifting Drive Mode in Prototype Hybrid Vehicle

[1,2] Yohanes P Agung Purwoko
[1] Astra Manufacturing Polytechnic
Jakarta , Indonesia
[2] Master of Mechanical Engineering
Swiss German University
Tangerang City, Indonesia
yohanes.agung07@gmail.com

Dena Hendriana
Master of Mechanical Engineering
Swiss German University
Tangerang City, Indonesia
dena.hendriana@sgu.ac.id

Ary Syahriar
Master of Mechanical Engineering
Swiss German University
Tangerang City, Indonesia
ary.syahriar@lecturer.sgu.ac.id

[1,2] Elroy FKP Tarigan
[1] Astra Manufacturing Polytechnic
Jakarta , Indonesia
[2] Master of Mechanical Engineering
Swiss German University
Tangerang City, Indonesia
elroy.fransiskus@gmail.com

Andreas Edi Widyartono
Departemen of Automotive
Engineering
Astra Manufacturing Polytechnic
Jakarta , Indonesia
edi.widyartono@polman.astra.ac.id

[1,2] Martinus Chorda
[1] Astra Manufacturing Polytechnic
Jakarta , Indonesia
[2] Master of Mechanical Engineering
Swiss German University
Tangerang City, Indonesia
oda.adi43@gmail.com

Abstract*—The Astra Manufacturing Polytechnic developed a manual transmission hybrid prototype vehicle in 2019, this vehicle is still conventional in power transfer. This research develops automation in power transfer from electric motors to ICE or from ICE to electric motors using inductive Arduino controllers. Proximity sensor and voltage sensor are used as the input; the result of this research is the transfer of power from the electric motor to the ICE or from the ICE to the electric motor that looks smooth and precise by paying attention to the speed and changes in the right gear lever. the transfer of power from the electric motor to the ICE seems to run smoothly with a speed of> 15 km / h or a battery voltage of <70 vdc, ICE is automatically ON then the driver switches to the second gear lever, from ICE to the electric motor if the speed is <15km / h or voltage> 70 vdc then the driver shifts to neutral.

***Keywords*—hybrid vehicle, automatic switching control, ICE, electric motor, power transfer**.

I. INTRODUCTION

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 the data of the DKI Jakarta environmental service from January to August 2019, the air pollution standard index (ISPU) is always increasing.

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

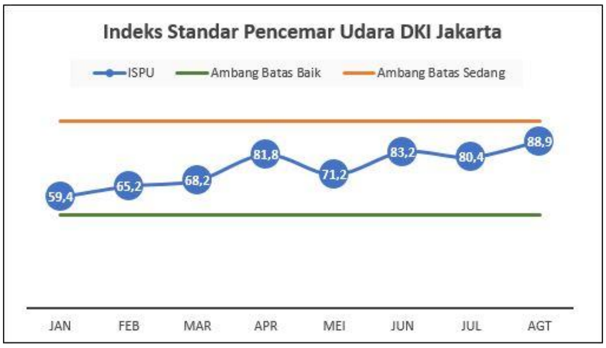

Fig. 1. Air pollution standard index DKI Jakarta 2019

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

This Daihatsu Midget 2-based hybrid vehicle uses an internal combustion engine as the main propulsion source and a BLDC motor as additional propulsion; the driving system in this hybrid vehicle uses a belt drive (Fig. 3) that connects the pully differential with the propeller saft.

Fig. 2. Daihatsu midget II

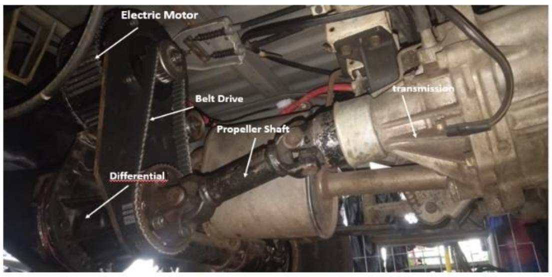

Fig. 3. Belt drive system

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 is showing in Fig. 4 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.

Fig. 4. Manual control panel

This research still has problems, The switching of the drive mode from ICE to an electric motor or from an electric motor to ICE in manual transmission hybrid vehicles still uses a manual controller and is less precise in making transfers.

So, to make a better transfer of power from an electric motor to an engine or from an engine to an electric motor, this study develop automation of switching the drive from ICE to electric motor or from the electric motor to ICE in manual transmission hybrid vehicles, so that it is precise in carrying out the transfer.

Hybrid vehicles have long been marketed to reduce fuel consumption up to three times lower than conventional vehicles aimed at reducing exhaust emissions [1].

The Basic Arrangement of the Hybrid Vehicle consists of:

- Series Hybrid Vehicle
- Parallel Hybrid Vehicle
- Series-Parallel Hybrid Vehicle
- Plug-in hybrid Vehicle

In the 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 [2].

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

The Series-Parallel Hybrid System 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 transfers depending on the driving conditions [3].

Plug-in hybrid vehicles (PHEV) are among the best vehicles to reduce the vehicle's contribution to the dependence of petroleum, air pollution and carbon dioxide emissions [4], Plug-in type hybrid vehicles 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 function and be active when the battery needs the charging energy [5].

II. METHODE

A. *Performance Testing*

The character of the electric motor produces constant torque from zero speed to the base speed, beyond the base speed, the voltage will remain constant and then the flux weakens [6].

Electric motor measurements are carried out to see the power potential and traction of an electric motor so that it can measure the ability of an electric motor when moving a vehicle; measurements are made using a dynamometer chassis as shown in Fig. 5.

Measurements were made at speeds of 20 km/h, 30 km/h and 40 km/h to see the traction potential and power at the output of the electric motor.

Fig. 5. Performance test on dynamometer

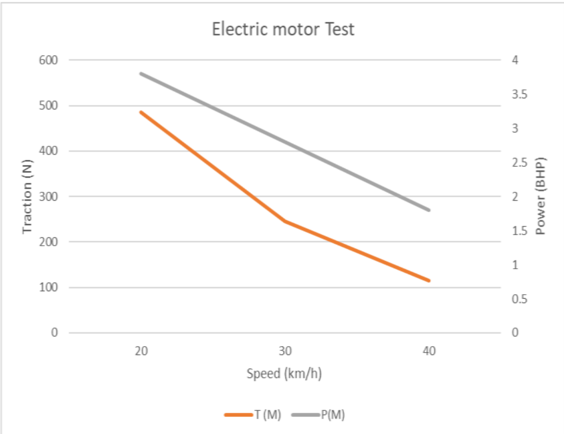

Fig. 6. Electric motor test

Referring to Fig. 6, the test results of the electric motor are 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 of 40 km/h, the traction gets 115 N, and a power of 1.8 BHP, there is a decrease in traction and power if there is an increase in speed.

Besides measuring the electric motor, the measurement of traction power and torque from the internal combustion engine is also carried out to see the potential of the manual transmission hybrid vehicle engine.

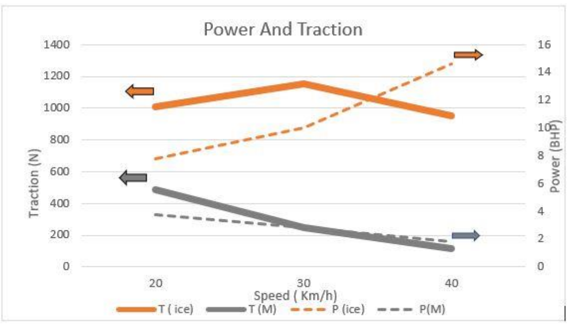

Fig. 7. Comparison of electric motor with ICE in 3rd gear

In the Fig. 7, 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.

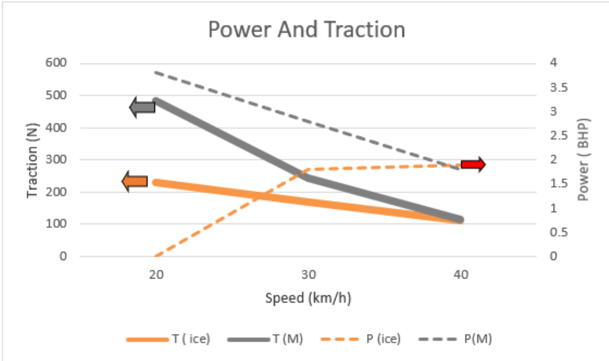

Fig. 8. Comparison of electric motor with ICE in 4th gear

Fig 8 is showing that the ICE traction in the 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, and 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, the transfer power from the electric motor to the ICE or vice versa is done with the same power and traction so that there is no shock, and it is expected to be connected smoothly.

B. Block Diagram

Fig. 9 shows a block diagram of controlling the transfer of power from an electric motor to an ICE or from an ICE to an electric motor using Arduino as a microcontroller, there is an LCD for monitoring system.

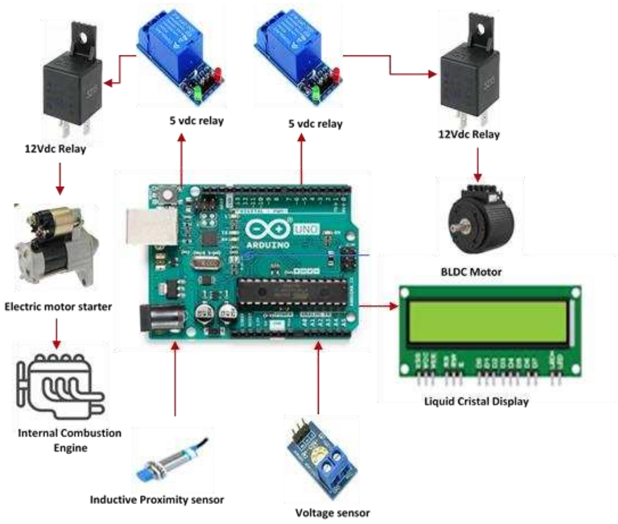

Fig. 9. Block diagram

C. Testing of Inductive Proximity Sensor

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 as shown in Fig. 10.

An inductive proximity sensor is a non-contact sensing device used to detect an approach target [7], This non-contact proximity sensor detects iron targets. The ideal steel thickness for detection is more than one millimeter.

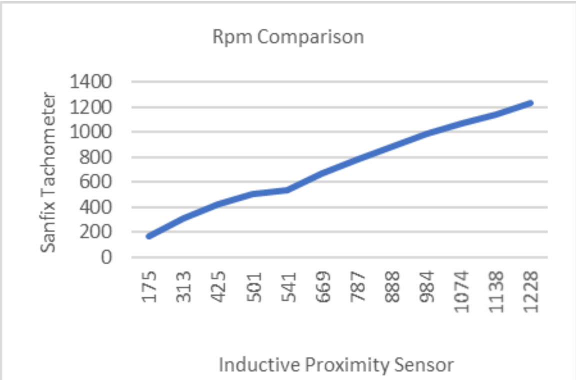

Fig. 10. Rpm comparison

The Sanfix tachometer has an accuracy of 0.05% + 1 digit, in the comparison of measurements using an inductive proximity sensor with a Sanfix tachometer the accuracy is 0.4% this is because of its poor sensor's capabilities and low price compared to the Sanfix measuring instrument.

D. Testing of 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 [8], The voltage sensor used in this study is 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 [9], the result of this input will be given to the Arduino microcontroller.

Voltage sensor testing is done by comparing the result of measurement of the output voltage from the voltage sensor using the Sanwa CD800a digital Voltmeter with the measurement results using Arduino. Thus, it is expected that the results of the comparison of these measurements are the same (Fig. 11).

The ccomparison of the two measurements using a voltmeter and using the Arduino program looks to form a 45-degree angle so that the validation of these measurements is good; Sanwa CD 800A voltmeter has an accuracy of 0.7% while the comparison between the voltmeter and the voltage sensor has an accuracy of 0.5%.

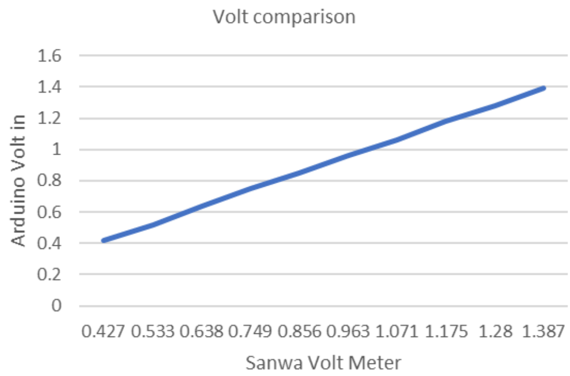

Fig. 11. Volt comparison

III. RESULT

A. Switching Strategy

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.

And to get a smooth and precise power transfer from an electric motor to an ICE or from an ICE to an electric motor, an electric motor and ICE test is carried out by comparing the RPM and the speed to find out where the gear is in the right position in power transfer.

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 the changes in speed and RPM at each gear change can be seen.

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.

Electric motor ratio data is collected by comparing rpm with speed because the vehicle pedal to activate the electric motor with the engine changes to one pedal. First, start the hybrid vehicle engine and put the transmission in neutral position then turn on the electric motor manually, press the pedal to see the vehicle rpm through the monitor on the dynamometer, then see the changes in rpm and wheel speed output from the electric motor, data collection is carried out four times with the last data as the reference.

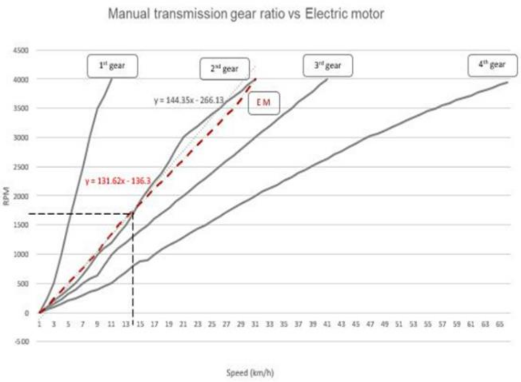

Fig. 9. Power switching strategy

In Fig. 12 it can be seen that the comparison between the electric motor and the ratio in the second gear shift is at one point of intersection by entering the calculation of Y = 131.62x. 136.3, input the value of x at 14 km/h, then the result of Y or rpm is 1706 rpm, then at a speed of 14 km/h with 1700 RPM, it is expected that the process of power transferred from the electric motor to the engine can run smoothly.

B. *Electric Motor ON Mode*

The speed and rpm ratio data on the electric motor and engine are the basis for making power transfer control using Arduino, this table shows Arduino control is carried out.

TABLE I
ELECTRIC MOTOR ON MODE

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

When the electric motor is ON mode, the control is done by reading the battery voltage (> 70Vdc) and the vehicle speed (<15km/h), the Arduino control will turn off the ignition engine and motor starter, then the driver must shift the transmission lever to the neutrals position.

C. *ICE ON Mode*

When the Internal Combustion Engine is in ON mode, control is done by reading the battery voltage (< 70 Vdc) and the vehicle speed (> 15 km/hour), if in these conditions the Arduino control will turn on the Ignition Engine and the motor starter (3 seconds) so that the engine can start 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, if the speed increases, the driver then can shift to 3rd and 4th gears.

TABLE II
ICE ON Mode

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

IV. CONCLUSIONS AND RECOMMENDATIONS

A. *Conclusions*

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

The results of this study are that the transfer of power from an electric motor to an ICE or from an ICE to an electric motor that looks smooth and precise by paying attention to the speed and changes in the right gear lever, the test is carried out without a vehicle load (road testing was not carried out due to the COVID-19 pandemic constraints).

B. *Recommendations*

This research uses a manual transmission vehicle that makes it difficult for the driver when the 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 maximally and the transfer of power from the electric motor to the ICE becomes smooth and precise.

The placement of the inductive proximity sensor must be better because this sensor is sensitive if there is a high vibration, if the placement is not correct then the inductive proximity sensor will be an 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.

The next Step is testing a hybrid vehicle prototype with the vehicle load and carried out on the road.

References

[1] D. A. Sumarsono, D. W. Utama, and G. Kiswanto, "Design and development of simple control system for small hybrid electric vehicle," *Appl. Mech. Mater.*, 165, pp. 73–77, 2012, doi: 10.4028/www.scientific.net/AMM.165.73.

[2] C. C. Chan, "The State of the Art of Electric, Hybrid, and Fuel Cell Vehicles With their superior fuel economy and performance, hybrid vehicles will likely increase in popularity in coming years; further development of control theory for hybrids is essential for their," *Fellow IEEE*, 95 (4), pp. 704–718, 2007, doi: 10.1109/JPROC.2007.892489.

[3] H. Zhao and A. Burke, "Modelling and Analysis of Plug-in Series-Parallel Hybrid Medium-Duty Vehicles," December, 2015.

[4] F. R. Kalhammer, H. Kamath, M. Duvall, and M. Alexander, "Plug-In Hybrid Electric Vehicles : Promise , Issues and Prospects," February, 2014

.

[5] Z. Chen, R. Xiong, K. Wang, and B. Jiao, "Optimal energy management strategy of a plug-in hybrid electric vehicle based on a particle swarm optimization algorithm," *Energies*, 8 (5), pp. 3661–3678, 2015, doi: 10.3390/en8053661.

[6] E. A. Ehsani Ehrdad, Gao Yimin, *Modern Electric,Hybrid Electric and Fuel Cell Vehicle*. 2010.

[7] T. Mizuno *et al.*, "Extending the operating distance of inductive proximity sensor using magnetoplated wire," *IEEE Trans. Magn.*, 45 (10), pp. 4463–4466, 2009.

[8] D. D. Tung and N. M. Khoa, "An Arduino-based system for monitoring and protecting overvoltage and undervoltage," *Eng. Technol. Appl. Sci. Res.*, 9 (3), pp. 4255–4260, 2019, doi: 10.48084/etasr.2832.

[9] G. Makan, R. Mingesz, and Z. Gingl, "How accurate is an arduino ohmmeter?," *arXiv*, 2019.