PLC and HMI Application for Fuel Selector Switch on Bi-fuel Vehicles (Gasoline-LPG)

Muhammad Firdaus Jauhari[1,2] (✉), Rusmini Sri Maryati[1], Raihan[1], Saberani[1], Norhafani[3], and Muhammad Arsyad[3]

[1]Department of Automotive Engineering Technology, Politeknik Negeri Banjarmasin, Banjarmasin, Indonesia
firdaus.jauhari@poliban.ac.id
[2]Center of Research, Development, and Community Services, Politeknik Negeri Banjarmasin, Banjarmasin, Indonesia
[3]Department of Mechanical Engineering, Politeknik Negeri Banjarmasin, Banjarmasin, Indonesia

Abstract. This design aims to develop a PLC and HMI application in the scope of automation in the automotive industry. The implementation of the fuel selector switch function was made as a simple project for a control system related to the use of fuel in a bi-fuel SI engine that operates with gasoline or LPG. The system development involves several stages, starting from creating a ladder diagram in the Outseal studio software. Then, writing a program, setting data according to the type of hardware PLC used, which is Mega V.2 Slim, including the appropriate com port number and baud rate, until uploading the ladder program. The next step is to set the appropriate baud rate on the Bluetooth module to synchronize communication with the Outseal PLC device using the Hercules SETUP Utility software. The final step is to create an HMI display on Android according to the desired design as a control feature, which will later be used to display the fuel selector switch on the vehicle. The testing results on the vehicle showed that the selector performance works well and no disturbance occurred.

Keywords: PLC application, HMI application, bi-fuel vehicles

1 Introduction

The development of internal combustion engines, especially gasoline-fueled SI engines, follows strict emission standards to avoid environmental pollution originating from motor vehicle exhaust gases. Alternative fuels such as liquefied petroleum gas (LPG) re used as a transitional step for the development of gas-based vehicles such as CNG or electric-based vehicles which are considered more efficient and environmentally friendly. In Indonesia, the special LPG used for vehicles is called liquefied petroleum gas (LGV) Research results related to the potential use of LGV as vehicle fuel show that cost savings are directly proportional to each liter compared to using fuel oil [1]. LPG is also an environmentally friendly fuel, free of sulfur and lead elements, and has low exhaust emissions. On the technology side, LPG kits have also been developed

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to adapt the SI engine technology to gasoline fuel, so that it can match GDI (gasoline direct injection) technology where fuel is injected directly into the combustion chamber with more precise and complex settings by the ECU [2]. However, there are still many countries that are just starting to use LPG as a vehicle fuel, depending on the government's energy policies and incentives. The conversion of fuel in spark ignition (SI) engines from gasoline to LPG is supported by the availability of LPG kits which have developed from the first to the sixth generation at this time. The LPG fuel system in vehicles can be applied with a single fuel system or dual fuel, where gasoline and LPG can be used interchangeably according to the driver's choice. In general, vehicles that do fuel conversions prefer to use the bi-fuel mode (dual fuel), by placing the fuel mode switch on the dashboard. Although it has many advantages, the bi-fuel system has a weakness in terms of vehicle weight with the addition of an LPG tank which can slightly increase fuel consumption [3]. The weight of the LPG tank can be reduced by using a composite tank for a lightweight and robust design [4].

There are many ways and options for LPG kits to convert gasoline engines into LPG [5]. In terms of exhaust emissions, better levels were also found in vehicles using LPG [6], [7]. The control system in vehicles is generally controlled by the ECU which is connected to various sensors, actuators, or modules for certain sub-sections. LPG kits are made according to the control devices set by the vehicle manufacturing plant. The fuel switch in dual fuel mode functions to change the type of fuel used to drive the SI engine, between gasoline and LPG. The commonly used fuel switch is in the form of a manual switch that is placed on the dashboard of the vehicle and is connected to the LPG ECU. This paper presents the use of PLC (programmable logic controller) and HMI (human-machine interface) applications for vehicles, which are used as fuel mode switches for dual-fuel vehicles. PLC and HMI applications are more for automation systems in the industry so that operational activities are more effective, measurable, fast, and efficient [8–10]. Utilization of the PLC and HMI functions in this paper is one step of development with the aim and scope of a broader process in terms of measurement, monitoring, control, or analysis of various performance parameters related to the internal combustion engine.

2 Method

2.1 System Overview

In the design of the PLC and HMI devices using experimental methods, the treatment of the independent variables is carried out in a controlled manner and the effect is observed on the outcome variables. Previously, several pieces of equipment and components supporting the system were determined according to the design concept. The PLC we use is the Outseal PLC Mega V.2 Slim as the control unit for the fuel mode switch feature. The Outseal Mega V.2 Slim model uses an Atmega 128a CPU, with digital inputs of 8 channels/sinking/10-30 Volts, and digital outputs of 8 channels/NPN regulated 50 mA. Outseal PLC has all the basic hardware facilities that are owned by PLCs in general and is suitable for use on an industrial scale. The Outseal PLC is programmed using the Outseal Studio software. Outseal studio is programmed using a PC in the form of visual programming and using ladder diagrams. The ladder diagram that has been made is then sent via USB cable to be embedded in the outseal PLC hardware and will run the program independently without being connected to a computer [11]. One of the advantages of Outseal PLC is that it is more economical than other types of PLC.

The control flow of the PLC application and HMI for Fuel Mode Switch in this design can be seen in Figure 1. The fuel system in the vehicle uses gasoline and LPG, so that when the driver starts the vehicle's engine, he must first choose the type of fuel to use. By default, the vehicle uses gasoline, if the driver wants to use LPG he can choose the next mode, namely LPG mode, where the On/Off function is controlled by PLC and HMI connected to Bluetooth media.

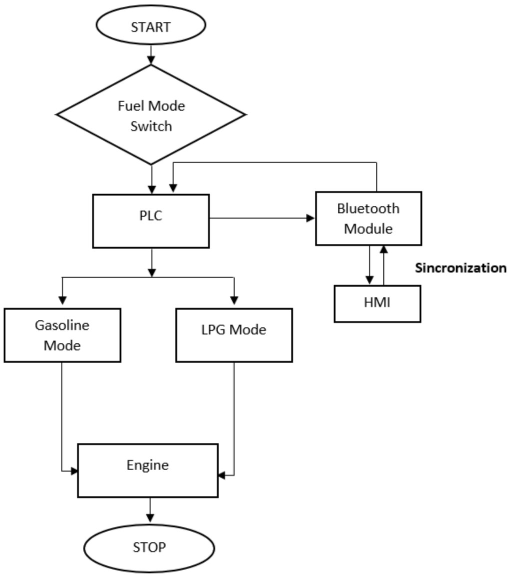

Fig. 1. Control flow of the proposed system

The hardware and software that make up the architecture of the fuel mode switch gasoline-LPG system can be seen in Fig. 2. Outseal PLC Mega V.2 Slim becomes the control unit for Gasoline-LPG mode and activates the fuel pump to pump gasoline from the fuel tank to the injectors or activates the converter Solenoid so that the LPG flow flows from the LPG tube to the vehicle's intake manifold. The PLC is programmed using Outseal Studio software which is provided free of charge. Several other main components used in the design of this fuel mode switch are the Bluetooth module, relay module, HMI (android), Outseal studio, HMI Modbus, and Hercules SETUP Utility.

Making the system includes several stages, the first step is to make a ladder diagram on the Outseal Studio software. Before writing the program, data settings are made according to the type of PLC hardware used, namely Mega V.2 Slim, including the appropriate com port number and baud rate. If the ladder diagram has been written, it can be uploaded to the PLC. The next stage is setting the correct baudrate on the HC-

05 Bluetooth module to be able to synchronize communication with the Outseal PLC using the Hercules SETUP Utility software [12]. The final stage is to make the HMI display on Android according to the design we want as a control feature, which will later be used to display the fuel mode switch on the vehicle.

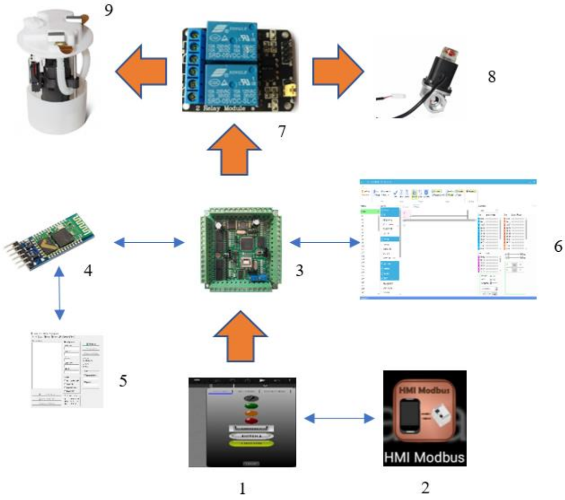

Fig. 2. Fuel mode switch architecture

2.2 Block Diagram Description

The block diagram in Fig. 3 below explains how the PLC and HMI system applications are proposed in this paperwork. Vehicles use dual fuel, namely gasoline and LPG, if the driver is going to start the engine then first choose the type of fuel used. System power requirements use a 12V vehicle battery, battery current will flow if the ignition switch is activated according to the procedure we do to run the vehicle. Outseal PLC uses a power range of 9-24 Volts, if the PLC is active, the Bluetooth transmitter can receive connections from other devices, namely the android driver which functions as an HMI (Human Machine Interface) through frequency synchronization between the two devices (PLC and HMI). Commands from the HMI will be forwarded to activate the actuator in the form of a relay module connected to the fuel pump for gasoline and the converter solenoid for LPG. The final stage of the vehicle engine will be started as usual.

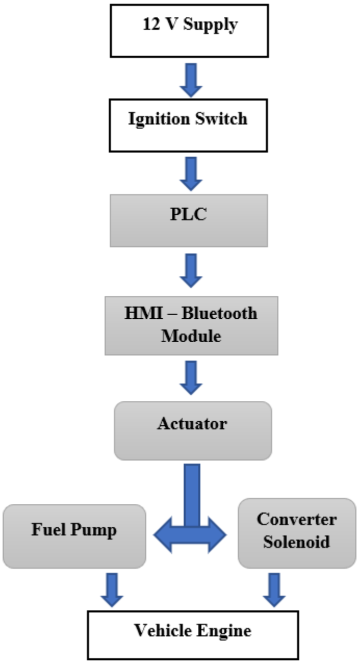

Fig. 3. Block diagram of proposed system

3 Result and Discussion

Based on the tests carried out on the vehicle, it was found that the fuel mode switch based on PLC and HMI could work according to the design made. The function of the fuel mode switch is a step in the development of PLC applications in the automotive field related to the control of the work of a component. The next development step using a PLC can be carried out with the aim and scope of a broader process in terms of measurement, monitoring, control, or analysis of various performance parameters related to the internal combustion engine [13]. Fig. 4 shows the PLC and HMI application trials on vehicles, the vehicle engine used is the K14B 1.4L type with gasoline fuel. The LPG cylinder is placed at the rear of the vehicle, and the LPG converter is installed side by side with the vehicle's engine using the first-generation converter (1-2). In the cabin, on the dashboard, a manual switch type fuel mode switch is used for fuel selection. This fuel switch was later replaced with an HMI (android) and used a PLC as the control system (3-4). HMI as a fuel mode switch works using a Bluetooth connection, with the switch feature made on the android display. By adding a Bluetooth module to the PLC, several adjustments are needed, including the baudrate value on the module so that it can synchronize with the program embedded in the PLC. The vehicle driver needs to pair the PLC-HMI devices before starting the engine, if it is connected and selects the fuel to be used on the HMI display, the vehicle can run. In this fuel mode switch design, by default, the vehicle will run on gasoline fuel. So that LPG is the second choice of fuel, for the function of saving costs and reducing exhaust emissions.

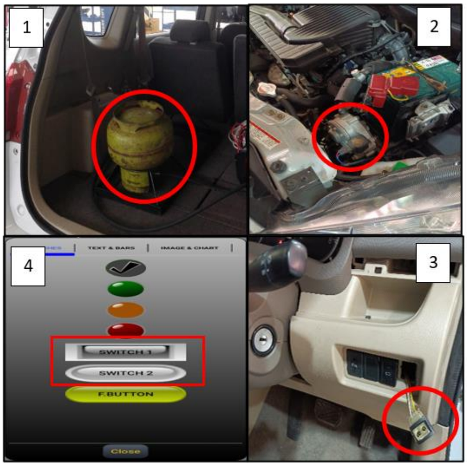

Fig. 4. Fuel installation in vehicle

In bi-fuel vehicles that use gasoline and PLG, the choice of gasoline remains the main fuel that drives the SI engine because of its initial design and convenience factor. Meanwhile, LPG as a second fuel alternative was chosen to save on vehicle operating costs and to reduce exhaust emission levels. In the first generation of LPG kits, as used in the vehicle above, generally there is a decrease in engine power when using LPG compared to gasoline, even though the ignition timing is set [14]. The application of PLC as a control device in one vehicle sub-system was chosen because it is more robust against noise from various frequencies that appear. PLCs can be used in rugged environments with great risks as well. The real-time operability character is also good for generating output to specific inputs in a short period of time. When compared to the Arduino microcontroller application for control systems in vehicles, it is found that Arduino is less robust against noise such as noise, temperature, or vibration [15], so the PLC is preferred in this case.

4 Conclusion

PLC and HMI applications can be made for many things related to control systems, including their use in the scope of component control on internal combustion engine-type vehicles. In this paper, PLC and HMI applications are made that function as a fuel mode switch in bi-fuel vehicles, which operate on gasoline and LPG fuel. HMI replaces the manual switch used before and becomes a fuel switch based on an Android device. By default, vehicles operate on gasoline, and drivers can change to LPG mode by connecting the HMI to the PLC via Bluetooth. In terms of reliability, PLC can be more robust against various noises that arise in vehicles so that optimal performance is obtained according to the expected function.

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References

1. Kurniaty, I.; Hermansyah, H. POTENSI PEMANFAATAN LPG (LIQUEFIED PETROLEUM GAS) SEBAGAI BAHAN BAKAR BAGI PENGGUNA KENDARAAN. **2016**, 1–5.
2. Muji Setiyo, B.W. EVOLUSI SISTEM BAHAN BAKAR LPG: TINJAUAN LITERATUR. *Rekayasa Mesin* **2019**, *12*, 199–207.
3. Werpy, M.R.; Burnham, A.; Bertram, K.; Werpy, M.R.; Burnham, A.; Bertram, K. Propane Vehicles: Status, Challenges, and Opportunities. **2010**.
4. Ştefan Ţălu, M.Ţ. Constructive CAD Variants of Toroidal LPG Fuel Tanks Used in Automotive Industry. **2018**, *159*, 27–30.
5. Mustaffa, N.; Tukiman, M.M.; Fawzi, M.; Osman, S.A. CONVERSION OF A GASOLINE ENGINE INTO AN LPG-FUELLED ENGINE. **2016**, *11*, 8568–8572.
6. Baek, S.; Kim, K.; Cho, J.; Myung, C.; Park, S. Assessment of Gaseous , Particulate , and Unregulated Emissions from Diesel Compression Ignition and LPG Direct Injection Spark Ignition Minibus Vehicles under the World Harmonized Vehicle Cycle on a Chassis Dynamometer. **2021**, *294*, 2021–2023.
7. Purnomo, B.C.; Widodo, N.; Munahar, S.; Setiyo, M.; Waluyo, B. Karakteristik Emisi Gas Buang Kendaraan Berbahan Bakar LPG Untuk Mesin Bensin Single Piston. **2017**, 7–12.
8. Moftah, A. The Higher Institute of Comprehensive Professions — Qaminis P Rogrammable L Ogic C Ontroller Paint Industry Application. **2020**, *4*, 27–32.
9. Ardanza, A.; Moreno, A.; Segura, Á.; de la Cruz, M.; Aguinaga, D. Sustainable and Flexible Industrial Human Machine Interfaces to Support Adaptable Applications in the Industry 4.0 Paradigm. *International Journal of Production Research* **2019**, *57*, 4045–4059, doi:10.1080/00207543.2019.1572932.
10. Zhang, W.J.; Zhang, F.; Zhang, J.; Zhang, J.; Zhang, J. Application of PLC in Pneumatic Measurement Control System. *IOP Conference Series: Materials Science and Engineering* **2018**, *452*, doi:10.1088/1757-899X/452/4/042074.
11. Bakhtiar, A. *Panduan Dasar OUTSEAL PLC*; www.outseal.com, 2020;
12. Patil, S.M.; Gaikwad, P. V Bluetooth Based Smart Automation System Using Android. *Proceedings of National Conference on Relevance of Engineering and Science for Environment and Society* **2021**, *6*, 273–276, doi:10.21467/proceedings.118.45.
13. François, M.; Osiurak, F.; Fort, A.; Crave, P.; Navarro, J. Automotive HMI Design and Participatory User Involvement: Review and Perspectives. *Ergonomics* **2017**, *60*, 541–552, doi:10.1080/00140139.2016.1188218.
14. Purnomo, B.C.; Widodo, N. Torque and Power Characteristics of Single Piston Lpg-Fueled Engines on Variations of Ignition Timing. *Automotive Experiences* **2019**, *2*, 22–27, doi:10.31603/ae.v2i1.2632.
15. Jauhari, M.F.; Abdurahman, D.; Triono, Y. Motorbikes Automatic Module for Hand Brake and Fuel Cut Off Relay. **2021**, *203*, 302–305.