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Design of Control and Human Machine Interface (HMI) for Proton Exchange Membrane Fuel Cell

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Abstract. Fuel cell is an electrochemical device that converts hydrogen and oxygen produces electrical energy continuously, water and heat as by product, which simultaneously. Proton Exchange Membrane Fuel Cell (PEMFC) operates with polymer electrolytes which are thin and proton permeable. Designing the control system, it is expected that the fuel cell operation could be in accordance with the predetermined process parameter design. In addition to the control system for fuel cell operations, a fuel cell protection or security system design is also carried out during operation in real condition. Referring to the block diagram or control system architecture and fuel cell operations that have been made, a detailed design will be made as a reference for the prototype of the control and protection system for operational and fuel cell testing and controlling. Making Standard operation procedure (SOP) is very helpful in the operation and avoids operating errors that can damage and harm caused.

Keywords: PEMFC, control system, HMI, SOP

1. Introduction

1.1 Proton Exchange Membrane Fuel Cell (PEMFC)

Fuel cells are electrochemical energy conversion devices that can convert hydrogen and oxygen into electricity, simultaneously producing water and heat in the process. Fuel cell is a form of simple technology like a battery that can filled with fuel to continue convert energy, in this case the fuel is oxygen and hydrogen and some say that fuel cell are electrochemical engine.

Fuel cells have positive electrodes called cathodes and negative electrodes called anodes. At the electrode chemical reactions occur that produce electricity. In the fuel cell there is an electrolyte that will carry an electric charge from one electrode to another, as well as a catalyst that will speed up the reaction at the electrode. In general, what distinguishes the type of fuel cell is the electrolyte material used. Electric current and heat generated by each type of fuel cell are by-products of chemical reactions that occur at the cathode and anode. Proton Exchange Membrane Fuel Cell (PEMFC) Proton Exchange Membrane Fuel Cell or Polymer Electrolyte Membrane Fuel Cell has high power density, light weight and low volume compared to other types of fuel cells. Using solid polymers as electrolytes and porous carbon electrodes containing platinum catalysts.

PEMFC only needs hydrogen, oxygen from air and water so that it is not corrosive. Because it operates at low temperatures, PEMFC can operate quickly, its heating time is low (start quickly, less warm up) as a result it has high durability (Fuel Cell Handbook, 2000).

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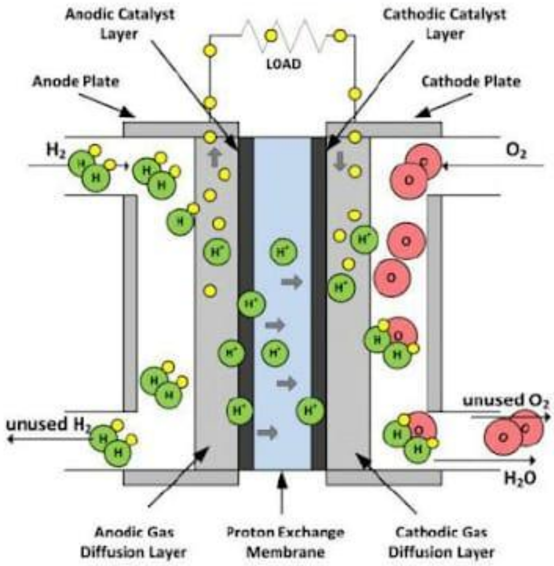


Figure 1. PEM fuel cell.

The downside of PEMFC is that the catalyst is expensive and is sensitive to CO (carbon monoxide) toxins. Therefore, if the hydrogen comes from alcohol, hydrocarbons and their derivatives, an additional reactor is needed to reduce CO levels, and of course it will increase costs. Lately catalysts that are resistant to CO have begun to be developed such as Pt / Ru. The efficiency is 40-50% and the operating temperature is 80^0C. The output of this type of fuel cell is 50-250 kW. Because electrolytes are solid, flexible, PEMFC electrolytes will not leak or break, and can operate at temperatures low enough so that it is suitable for application to vehicles and households. Unfortunately this type of fuel cell fuel must be pure and use platinum catalysts on both sides of the membrane, as a result the costs required to be very expensive at this time.

1.2 Human-Machine Interface (HMI)

A HMI is a user interface or dashboard that connects a person to a machine, system, or device. While the term can technically be applied to any screen that allows a user to interact with a device, HMI is most commonly used in the context of an industrial process.

Although HMI is the most common term for this technology, it is sometimes referred to as Man-Machine Interface (MMI), Operator Interface Terminal (OIT), Local Operator Interface (LOI), or Operator Terminal (OT). HMI and Graphical User Interface (GUI) are similar but not synonymous: GUIs are often leveraged within HMIs for visualization capabilities.

2. Materials and Methods

2.1. PEMFC Stack

The stack used is a fuel cell stack that is no longer used by the base transceiver station (BTS) provider, but the condition is still appropriate to use for laboratory scale not for commercial use. Determination of the process parameters to be controlled is the initial step of PEMFC control and operation system design. Based on PEMFC specifications and the process, there are several parameters used in the reference in making the design, including operating temperature, hydrogen supply inlet pressure to PEMFC module, H_2O outlet pressure from PEMFC module, generated voltage, electric current, battery voltage, air temperature for cooling purposes, flow of air supply.

For safety purposes during operation, several sensors are installed that can detect hydrogen gas leaks and some actuator components that serve to protect when PEMFC operations are operating in an inappropriate manner. The main variable that is maintained is the pressure at the gas inlet controlled by the selenoid valve at the front before entering the stack and at the outlet stack with time-based purging and manipulating the purging time to get the best result for the operation. This pressure is very important to be kept so that it does not cause too much damage to the stack and also during the operation of the stack does not fuel starvation.

Table 1. Fuel cell module parameter.

Fuel Cell Module Parameter	
Stack cell	73 cells in series
Operating temperature range	5-75^{0}C
H_2 operating pressure	7psig
Cooler	Air cooled 10-300 CFM air flow
Reactant	H_2 and O_2 (air)
Purge time	Variable

2.2 Controller Board

The control board used is Outseal PLC, an arduino-based programmable logic controller (PLC) based on the board. This PLC has hardware that is open to the public, meaning that we can download and study electronic circuits freely and make it yourself at home at an affordable price. Downloader and programming is included with the software in the form of visual programs (ladder diagrams), and is also free so it's easy in the development and production stages. As for the HMI interface design using GP Editor Software which can be downloaded on the Autonics site. The main advantage is the board uses a 24 DCV supply voltage and also for input and output is compliance with industrial standard. Controller board can act as module if need more than 8 input and out, join as master and slave on i2c bus. Communication the control board using TTL and RS232 pin at HMI back side.

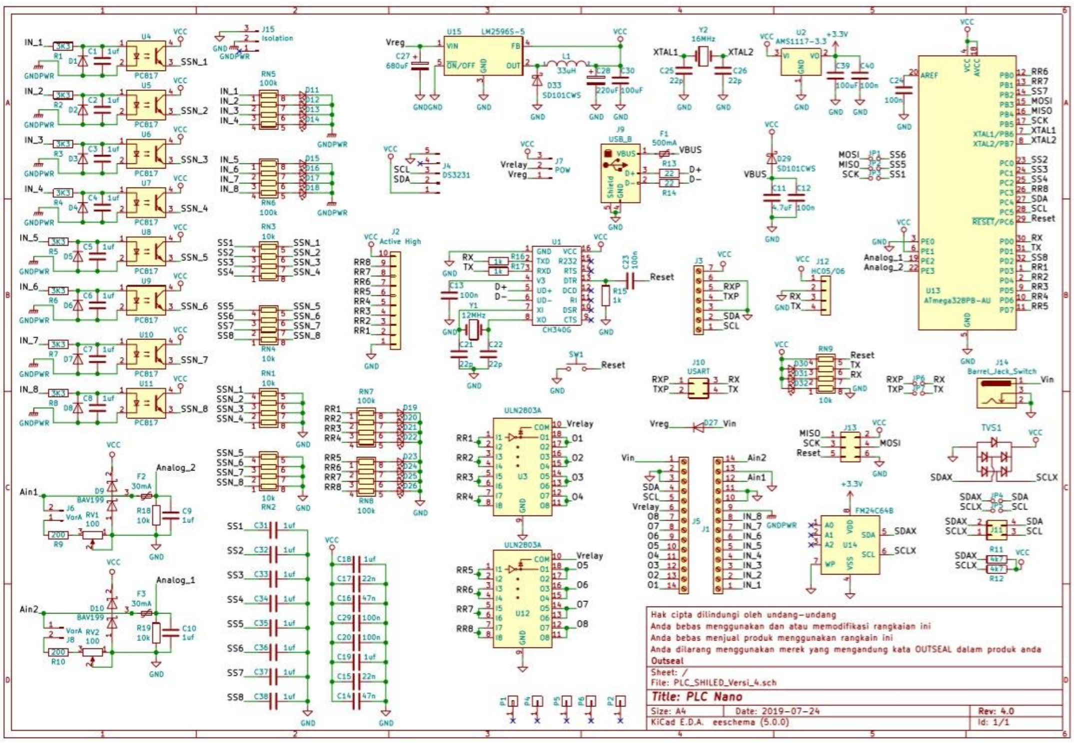


Figure 2. Outseal PLC schematic.

2.3 Human-Machine Interface (HMI)

For this project we use Autonics LP-S070 Series, 7-Inch Widescreen Color LCD displays with touchscreen function Logic Panels. The LP-S070 series logic panels are all-in-one devices featuring functions of HMI, PLC, and I/O modules. Data logger function allows data storing and backup from control devices. Users can also monitor multiple addresses and channels simultaneously. Extensive image library is provided along with support for various fonts, printer, and bar code readers. Two RS232C communication ports or RS232C/RS422 communication ports, for design and downloader using GP Editor (screen editor). Communication between HMI and a controller boards use MODBUS RTU. This protocol primarily uses an RS-232 or RS-485 serial interfaces for communications and is supported by almost every commercial SCADA, HMI, OPC Server and data acquisition software program in the marketplace. This makes it very easy to integrate Modbus compatible equipment into new or existing monitoring and control applications. The purpose of using HMI with a touch screen is expected to make it easier for operators to operate the fuel cell testing system and is also expected to reduce supporting components such as the use of many switches. The user interface is made as simple as possible so that it's easy not to mislead the user.

3. Results and Discussion

Based on the test diagram then determine the parameters measured and controlled including: fuel cell stack temperature, hydrogen inlet pressure, hydrogen outlet pressure, and fan blower, stack voltage, stack current, cleaning time. From the results of designs that have been carried out previously followed by the manufacture of prototype fuel cell operations on a laboratory scale consisting of three main sub-systems: control systems, reactant modules and fuel cells.

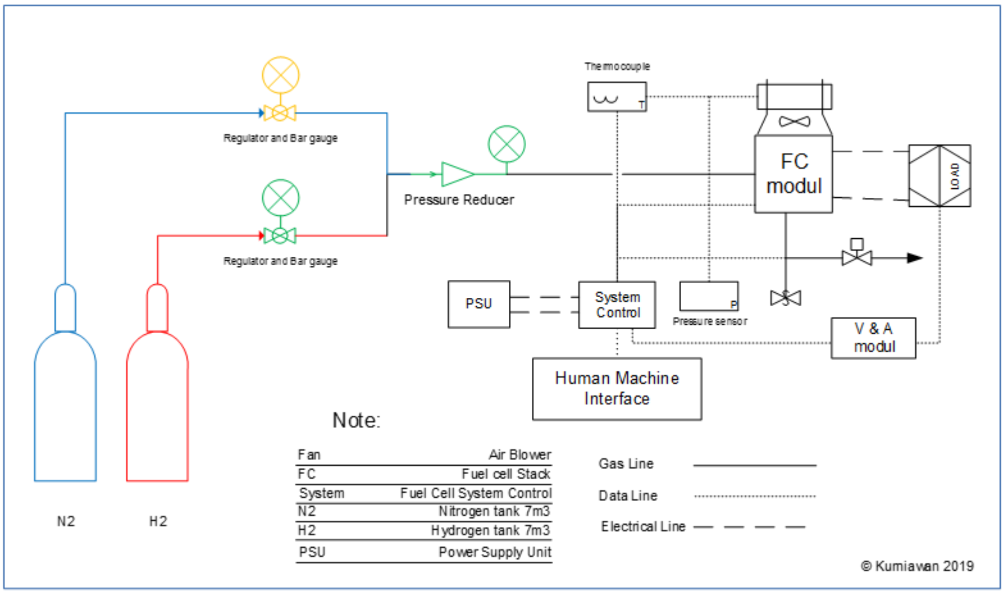


Figure 3. Fuel cell testing diagram.

3.1 Design and Prototyping

From the results of a simple sketch on paper then developed through the Gpeditor program on a personal computer including its logic control. The following three HMI displays have been created.

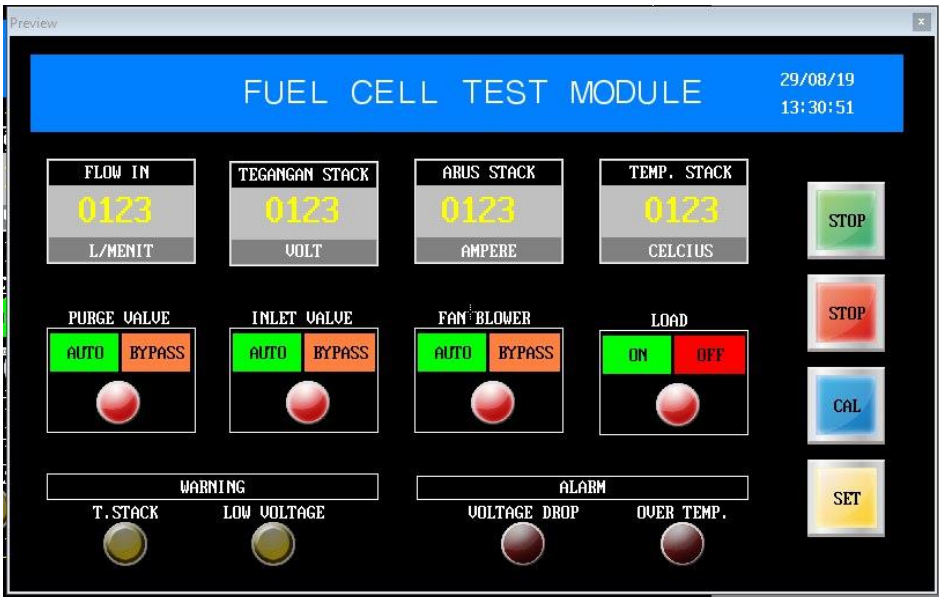
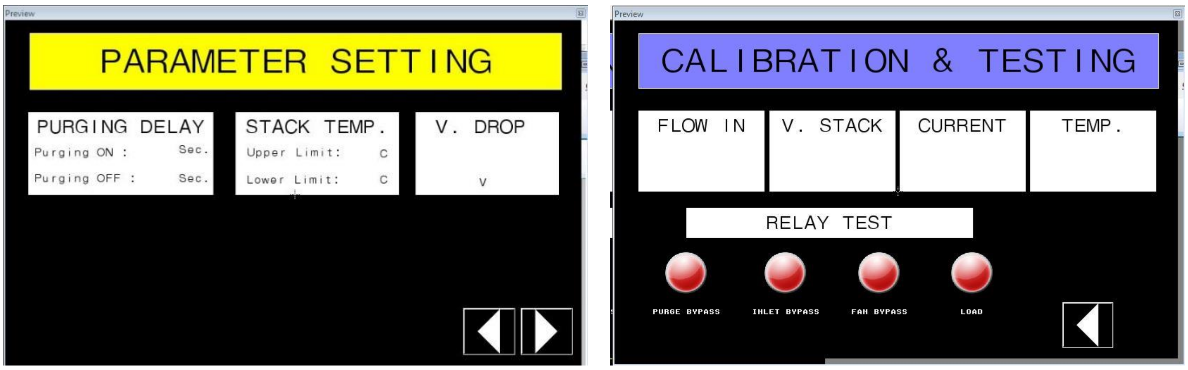


Figure 4. Following is the appearance of the HMI design using GPEditor which is then downloaded to the HMI unit.



(a) (b)

Figure 5. Display of sub screen: (a) parameter setting, (b) calibration and testing.

Three screen displays and functions:

1. The main display, to display reading data and also the pilot light indicator to find out what components are working.
2. The second display is the display setting several parameters such as purging time, stack temperature and voltage drop (Figure 5(a)).
3. Third display for calibration and also test whether the regulating relay works properly or not (Figure 5(b)).

3.2 Startup Procedure

Dilution fan starts, providing O_2 (air) to Cathode, H_2 supply valves open; stack voltage increases to open circuit voltage (OCV) ~70 volts. Initial anode purge is performed, introducing fresh H_2 to stack. Stack output is ready to load with dummy load or with electronic load discharge. Stack temperature is monitored by thermistor; shuts down system at 78^0C to shuts down system. Purges used gasses from stacks in order to maintain sufficient H_2 and for stack operation.

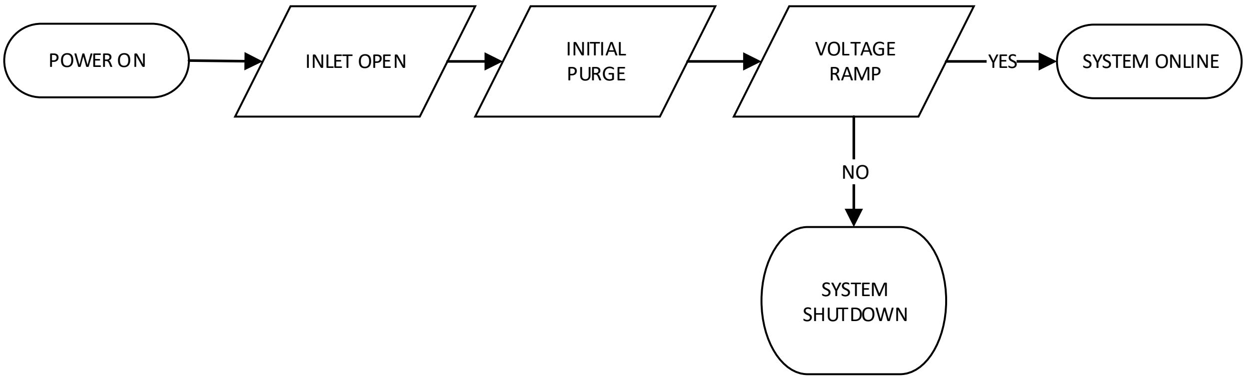


Figure 6. System operation.

3.3 Testing and Operating the Fuel Cell

For the operation and testing of all subsystems used, i.e., hydrogen supply systems, control systems and fuel cell modules are arranged into one complete system. Testing is done by activating the control panel and fuel cell panel and preparing hydrogen gas from the tube with an input pressure of 7 psig that has been set using a pressure regulator that is also regulated in the logic program. Observing the parameters of temperature, input pressure, stack voltage, current, and component status at the start of the test also ensures that there is no gas leak before the test can be carried out. After all conditions and parameters for the test are fulfilled, the test can be carried out according to the diagram in Figure 2 above, by opening the solenoid valve to flow hydrogen gas to the fuel cell module. After the hydrogen gas is flowed into the fuel cell module, the inlet gas pressure is observed. The operating pressure of the inlet gas is maintained between 0.6-0.7 psig. Temperature of the fuel cell module through the temperature display on the panel which must not exceed 75 ^{o}C. Observations and measurements of the voltage and current in the fuel cell module through the indicator HMI display on the fuel cell controller panel.

The design of the HMI display design and the Outseal Studio program for the control board are done simultaneously so that the control board can communicate well with the HMI. In the process of downloading the program to HMI make sure the J10 jumper on the PLC outseal is uninstalled first, after downloading the program to the board and to the HMI the J10 jumper is re-installed, here we use 57600 baudrate and can be enlarged to 115200 depending on needs. Make sure both of these settings are made on the control board and logic panel.

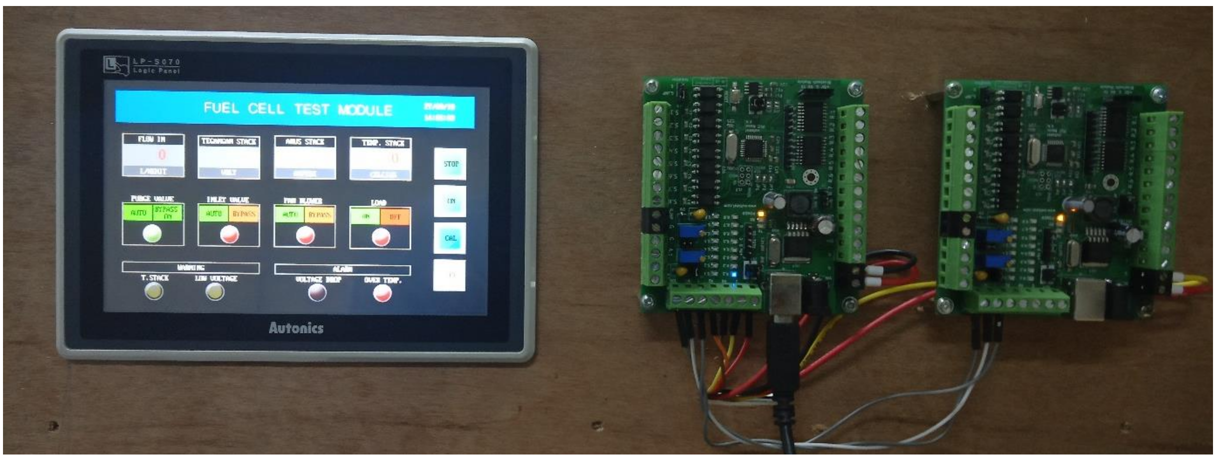


Figure 6. This picture shows HMI and two outseal plc installed modularly, one functions as a master and one as a slave so it has 4 analog inputs, 16 switches and 16 relay outputs. Communication between HMI and outseal PLC via RS232 port with Modbus RTU.

The emergency procedure call when the fuel cell stack having drop voltage on certain value, the procedure will automatically close the fuel inlet to prevent flamable gas, load relay will be cuttoff and purge valve and blower still on the secure the stack reaction and decrease the temperature. This procedure is done to eliminate the damage of fuel cell stack.

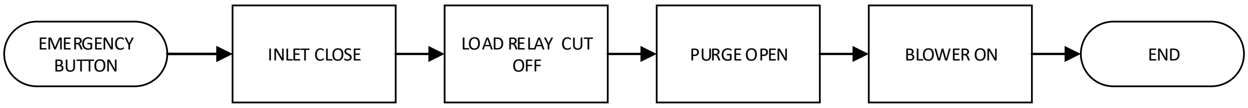


Figure 7. Emergency shutdown.

4. Conclusion

This experiment is still under development and will soon be integrated with other sub system that has been created separately but it can be said that design of the fuel cell operating control system using touch screen HMI and outseal PLC has many advantages including:
- Easy to use and operate
- Space saving so that it can be entered in the control box
- Various data information can be displayed and more informative
- Communication with standardized Modbus RTU

The combination of HMI and outseal PLC is an economical solution as a control system, with a 24 DCV supply voltage and also programming with a ladder logic system is compliance with industrial standard.

Acknowledgments

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