MedCrave Step into the World of Research
Electrical & Electronic Technology Open Access Journal

Case Report

Open Access

CrossMark

Open source hardware for pem fuel cells control

Abstract

Initiatives under alternative licenses intellectual property, as is the Open Source movement, are becoming more and more relevant. This new trend is also spreading in the world of research and development which opens a new path for the collaborative development and dissemination worldwide, promoting technological advances. Open research strategies can be optimal for Hydrogen technologies research since; there are several challenges in different fields (production, storage, fuel cell…). They can be achieved by cooperation of experts sharing their know-how. Under the above criteria, Centro National del Hidrógeno (CNH2) offers the challenge of creating Open Source hardware and software for monitoring and control fuel cells, to provide a low cost open solution to the scientific community, allowing control and setting up visualization of balances of plant (BoP) for small proton exchange membrane technology (PEM) fuel cells Arduino open platform has been selected to develop a special shield that complies all the requirements to control and monitoring a fuel cell Balance of Plant (BoP). This PCB shield has been validated in the laboratory over a wide range of low power PEM fuel cells using open source software Scilab/Xcos running as SCADA to control and collect the data over a PC.

Keywords: hydrogen, fuel cell, open source, arduino

Volume 1 Issue 1 - 2017

Merino C, Hidalgo D
Centro Nacional del Hidrógeno (CNH2), Spain

Correspondence: Merino C, Centro Nacional del Hidrógeno, c/Prolongación Fernando el Santo s/n, Puertollano, Ciudad Real, Spain, Tel +34926420682, Email carlos.merino@cnh2.es

Received: September 13, 2017 | **Published:** October 04, 2017

Abbreviations: PEM, proton exchange membrane fuel cell; BoP, balance of plant; MEA, membrane electrode assembly; Arduino, open-source electronics prototyping platform; IoT, internet of the things; DAQ, data acquisition; SCADA, supervisory control and data acquisition symbols; I, current a; P, pressure bar; T, temperature ºc; U , voltage v; e-, electron

Introduction

Among a number of alternative energy sources, hydrogen is treated as one of the most promising candidates, due to the reason that it can be applied to a fuel cell as an input to provide electricity through an electrochemical reaction. On top of that, high conversion efficiency up to 40 to 60% is seen in a fuel cell. The first application of a Proton Exchange Membrane (PEM) fuel cell was as an auxiliary power source in the NASA Gemini space flights, in the 1960s. Afterwards, technological advances were very insignificant until the late 1980s, when appeared new design reconfiguration and new fabrication methods. The most significant goal that PEM fuel cell had to overcome was the costly amount of platinum required as a catalyst. The large amount of platinum in the original PEM fuel cell is one of the reasons why fuel cells were excluded from commercialization. Thus, the reconfiguration of the PEM fuel cell was targeted rather directly on the electrodes employed and, more specifically, in reducing the amount of platinum in the electrodes.[1,2] This continues to be a driving force for further research on PEM fuel cell. The power density of a fuel cell has been elevated largely, as a consequence of technology improvement and progress made in material science. Fuel cells have been turned into a competitive product in the market to a great extent owing to successful cost reduction activities on electrode catalysts and other key components.[3] Nowadays, new tools based on collaborative working, open research and open knowledge seem to represent an excellent opportunity to push the PEM fuel cell technologies, improving the research activity in the fuel cell area.[4–6]

Case presentation

Principles of PEM fuel cell operation

A PEM fuel cell is an electrochemical cell that is fed hydrogen, which is oxidized at the anode, and oxygen that is reduced at the cathode. The protons released during the oxidation of hydrogen are conducted through the proton exchange membrane to the cathode. Since the membrane is not electrically conductive, the electrons released from the hydrogen travel along the external electrical circuit.[7] These reactions and pathways are shown schematically in (Figure 1). At the heart of the PEM fuel cell is the Membrane Electrode Assembly (MEA). The MEA consists of a proton exchange membrane, catalyst layers, and gas diffusion layers (GDL). The overall reaction inside the fuel cell is

$$2H_2 + O_2 \rightarrow 2H_2O \quad (1)$$

For a proper operation of the fuel cell it is necessary control gas feeding, running temperature and electrical parameters such as cell voltage and current. The use of different control algorithms has an influence on performance of fuel cell and their lifetime. Thus, it is necessary to adjust the control variables to each fuel cell.

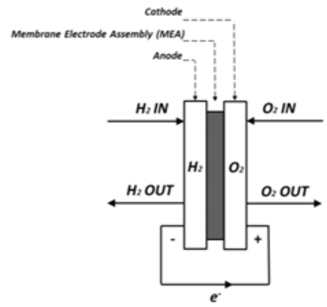

Figure 1 Fuel cell operation scheme.

Tools review

It was necessary to review the tools available to successfully meet the proposed objective of designing a control PCB for proton exchange membrane technology fuel cell. It is first necessary to select the work environment, including available alternatives. Kicad software for PCB design and Arduino control platform are selected for its widespread use as an open platform.[8,9] Therefore, a specific control board (fuel cell control shield) is connected as an additional module that takes advantage of all the features created for the rest of the Arduino community. Arduino PCB has an 8-bit microcontroller ATmega2560, 256KB and operates at 16 MHz. These features are enough so as to implement basic control strategies.[10]

Fuel cell control shield design

The designed fuel cell control shield comprises the instrumentation and basic actuator elements for control and monitors a small power fuel cell that it is usually used for didactics. Electric current and cell voltage are measured and it included an on/off relay connection. Operating temperature of the stack is monitored and stack cooling is controlled by using PWM over the fan. Gas feeding in the anode and cathode are switched by the solenoid valve, with the possibility of implementing dead-end or flow through mode with the use of a valve in the hydrogen exhaust. Open cathode fuel cell configurations could be controlled by fan, which complied two functionalities: temperature control and oxygen feeding (Figure 2). The acquisition and signal adaptation implemented over fuel cell control shield allows complete monitoring system providing information of the power generated, an energy meter supplied, the operating time, the estimated gas consumption based on performance models, and collecting data for representing the polarization curve of the cell under experimentation. As for microcontroller programming, it has been used Open Source tool Arduino IDE.[11,12] In this way, it is achieved to be opened to users control strategies and they can be modified by any researcher in order to test different control techniques. The PCB design and signal conditioning schematic can be modified by any advanced user with knowledge in electronics design, to include new features in, to upgrade it and to contribute to the community with a new version based on the original fuel cell control shield (Figure 3).

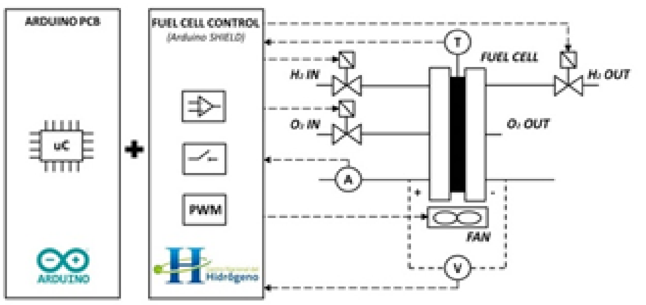

Figure 2 PCB and fuel cell layout.

Experimental validation of prototype

A PCB has been developed to control and to acquire the main variables of fuel cell operation, together with the Arduino platform. This shield has been designed and built with the possibility of controlling up to 30W small stacks and monocells (Table1). The shield has different reconfigurable outputs and inputs in order to adapt air feeding configurations (open or closed cathode) and cooling (external fan or liquid system) (Figure 4). The control algorithms over the fuel cell are easily programmed by Arduino IDE interface, so it has been obtained a low cost tool of embedded control that allows the fuel cell integration with smart fuel cell applications. We can use a third-party Ethernet shield with a fuel cell control shield and the Arduino control board if we are interested in collecting data and online programming, being now available Internet of the Things (IoT).[13] The fuel cell control validation has been done over HeliocentrisTM training and demonstration. It is equipped with a double PEM fuel cell that can be electrically connected in series or parallel. The whole system runs together (Figure 5). The fuel cell control shield has been connected to PC by serial communication and it has implemented a Scilab/Xcos interface to control and monitoring the variables. A model of a fuel cell is running at the same time that data collection. Fuel cell model data and real data are compared to evaluate the performance of fuel cell (Figure 6).

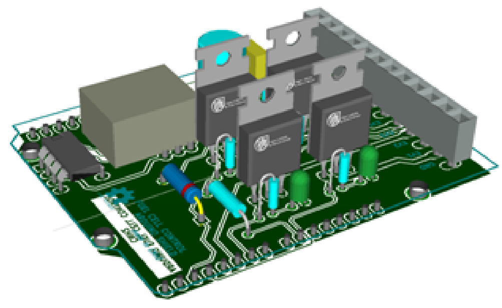

Figure 3 Preliminary PCB design (Kicad software).

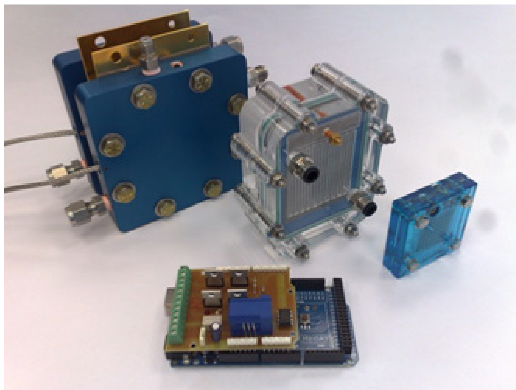

Figure 4 Range applications.

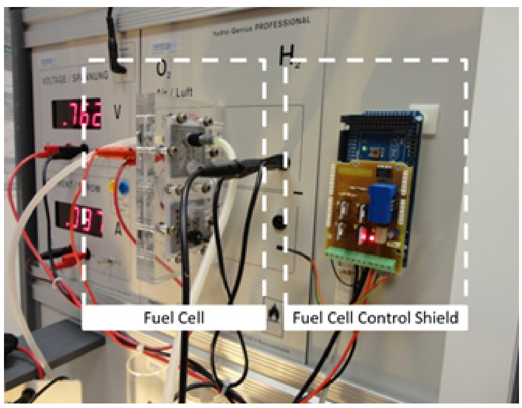

Figure 5 Fuel cell control validation.

Citation: Merino C, Hidalgo D. Open source hardware for pem fuel cells control. *Electric Electron Tech Open Acc J.* 2017;1(1):29‒31. DOI: 10.15406/eetoaj.2017.01.00006

Table 1 Fuel Cell Control Shield features

Fuel Cell Control Shield Features			
Outputs	Relay	x1.(Fuel cell)	$Current: 6A_{max}$
	MOSFET	x4.(BoP Aux)	$Current: 6A_{max}\ (PWM\ available)$
Inputs	Voltage	x1.(Fuel cell)	$Voltage: 0\text{ to }5\text{Vmax}$
	Current	x1.(Fuel cell)	$Current: 0\ \ to\ \ 6A_{max}$
	Temperature(LM60)	x1.(Fuel cell)	$Temp: -25^{\circ}C\ \ to\ \ 125^{\circ}C$

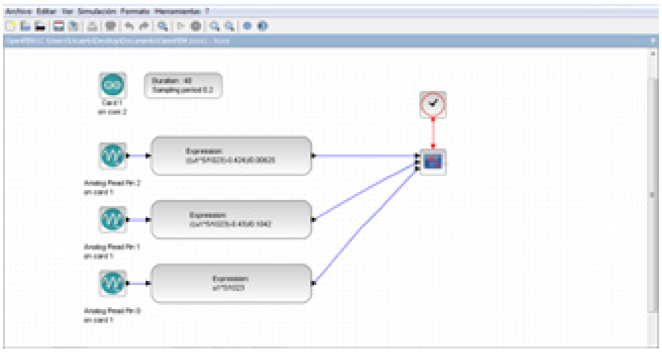

Figure 6 Scilab/Xcos window.

Discussion

A low-cost prototype of control and DAQ for PEM fuel cells has been designed and produced. This prototype has been validated over a small and reconfigurable didactic cell, where excellent results have been obtained. Therefore, the development of this low-cost solution, with high potential, offers the scientific community a new tool for researching and disseminating of knowledge in fuel cells and hydrogen technologies.

Acknowledgements

The work described in this paper has been developed in the facilities of the Centro Nacional del Hidrógeno (CNH2), whose financial supporters are Ministerio de Economía, Industria y Competitividad (MINECO, Spain), Junta de Comunidades de Castilla-La Mancha (JCCM, Spain) and European Regional Development Fund (ERDF).

Conflict of interest

The author declares no conflict of interest.

References

1. Andújar JM, Segura F. Fuel cells: History and updating. A walk along two centuries. *Renewable and Sustainable Energy Reviews*. 2009;13(9):2309–2322.
2. Ball M, Wietschel M. The future of hydrogen- opportunities and challenges. *Int J Hydrogen Energy*. 2009;34(2):615–627.
3. Larminie J, Dicks A. Fuel Cell Systems Explained. USA: John Wiley & Sons; 2003. p. 1–428.
4. Woelfle W, Olliaro P, Todd MH. Open science is a research accelerator. *Nat Chem*. 2011;3(10):745–748.
5. Pampel H, Dallmeier-Tiessen S. Open Research Data: From Vision to Practice: opening Science. In: Bartling S, Friesike V, editors. Springer International Publishing, Switzerland; 2014. p. 213–224.
6. Daniel Dietrich. Open Data Handbook Documentation. Open Knowledge Foundation, UK; 2012.
7. Mahapatra MK, Singh P. Chapter 24-Fuel Cells: Energy Conversion Technology. In: Letcher TM, Boston, editors. Future Energy. 2nd edition. Elsevier, Netherlands; 2014. p. 511–547.
8. Yan XT, Eynard B, Ion WJ. Global Design to Gain a Competitive Edge: An Holistic and Collaborative Design Approach based on Computational Tools. 1st edition. Springer-Verlag London, UK; 2008. p. 1–888.
9. Kemp. The Makerspace Workbench: Tools, Technologies, and Techniques for Making. Maker Media Inc, USA; 2013. 300 p.
10. Rubio J, Bravo AG. Optimal Control of a PEM Fuel Cell for the Inputs Minimization. Mathematical Problems in Engineering. 2014;2014(2014):698250.
11. Schmidt M. Arduino. 1st edition. Pragmatic Bookshelf, USA; 2011.
12. Banzi M. Getting Started with Arduino. O Reilly Media, USA; 2009. p. 1–128.
13. McEwen, Cassimally H. Designing the Internet of Things. USA: John Wiley & Sons; 2013. 336 p.

Citation: Merino C, Hidalgo D. Open source hardware for pem fuel cells control. *Electric Electron Tech Open Acc J*. 2017;1(1):29–31.
DOI: 10.15406/eetoaj.2017.01.00006