International Journal of Engineering Works
ISSN-p: 2521-2419
ISSN-e: 2409-2770
Vol. 5, Issue 10, PP. 172-175, October 2018
https://www.ijew.io/

Analysis of Flow Rate and Humidity Effect on Polymer Electrolyte Membrane Fuel Cell Performance using MATLAB/SIMULINK

Muhammad Faisal Khan[1], M. Naeem Arbab[1], Haseeb Khan[1]
[1]Electrical Engineering, UET Peshawar

Received: 07 September, Revised: 20 September, Accepted: 28 September

Abstract— These days, the world faces glitches like energy crises, global warming and ozone depletion due to the power generation from fossil fuel. Petroleum derivative assets are diminishing with time because of which costs of traditional hydrocarbon fuel ascends in the universal market, along these lines most nations of the world are putting resources into sustainable power sources. Not at all like regular petroleum product run control age framework, is a power source that vitality effective, deliver low pollutions and being provided by boundless minimal effort fuel. The innovation of the fuel cell can handle these difficulties that are the reason as fuel cell is considered as ecological agreeable and effective innovation of future. Among different sorts of fuel cell, Polymer Electrolyte Membrane (PEM) fuel cell is the most diffused and well known kind of market because of its sound highlights, for example, low working temperature, brisk variety as per stack, high proficiency and better power density. In this paper PEM fuel cell stack is outlined and its model is executed in MATLAB/Simulink to dissect the examine the happening in PEM fuel cell stack and the variables that influence the efficiency of the fuel cell stacks. Besides, the properties of fuel cell stack are examined fluctuating flow rate of fuel and oxidants. The attributes curves are broken down with various working temperature, humidification temperatures, and mass (oxygen) exchange proportion.

Keywords— Polymer Electrolyte Membrane, Fuel Cell, Exhaust Gas Recession

I. INTRODUCTION

Energy is vital for the entire humans on globe. Modern time provisions have more enhanced its worth, while a faster life means quicker communication, more rapidly transportation, and faster industrialized processes [1].

In [2], the authors discussed the scaling up of the fuel cell. For this purpose, three types of scaling of fuel cell were done. To achieve 1kW class, PEM a serial scale-up connection with unit cell area of 25cm2 in a made of four cells was used. In second case, a parallel scale-up of single cell of 100cm2 was used. In third case, for 1KW class PEM, the parallel series scaling of PEMFC was used with an action area of 150cm2. In first case, the maximum power voltage was almost four times of the single cell while in second case that was a bit better than first case. The response characteristic of the three type stacking was equated and compared for two oxidants i.e. H2/air and H2/O2. The response characteristic of the three types of stacking were reduced. The operational result would help for stacking 20 cells for an energy storage system in smart grid. Aliasger Zaidy, Pooja Pokharkar and Rajesh Krishnan developed a dynamic model of PEMFC and simulated in MATLAB as well as LabView. The suggested model added various operating conditions i.e. variable loading, inverses of input reactant gas and temperature of the cell. The response characteristic of the PEMFC was checked. In order to validate the response an experimental testing was conducted and that the response characteristic of the modeled PEMFC were found valid [3].

The authors discussed the modality of aging mechanism of PEMFC for automobile applications. The modelling and analysis of the PEMFC played a very vital role because age will be reduced due to the transient conditions like load cycle, off cycle, high temperature or low humidification. Some aging models were discussed and the different mathematical models of the PEMFC were also considered [4]. Ahmed Mousa, Salah El-Emam and Mahmud Awad talked about the impact of cell stack introduction angle on the general execution of the energy component with H2/air. The authors concluded that they were obviously influenced by working parameters i.e. respond flow rate, oxidizer stream rate and humidity. The execution amid with expanding of the introduction point (orientation angle) of the cell stack frame the diamond cathode air flow rate were additionally considered [5]. Denise A. McKahn and Xinyi Liu discussed certain issues in the implantation of low temperature and polymers electrolyte membrane (PEM) fuel cells. These issues arrived due to thermal and water management. In this work, an experiment on two dissimilar dynamic content-oriental prototypes for open round temperature scrutiny in tiny PEM fuel cell were made under dry condition. After completing experiment, it was absent that cathode inlet relative humidity and resulting injection in a maximum estimation issues of 11% during light condition [6].

In [7], the authors discussed the water flooding and digging of membrane durability and effect of proton exchange membrane fuel cell (PEMFC) are compromised. In this paper a novel method was introduced for water management technique by exhaust gas recession (EGR). In this simulation based system experiment the water content characteristics were captured in pressure and absence of EGR. The MATLAB result demonstrated that the film will probably dry state of lost stack present and high stack temperature the far reaching EGR technique was confirmed by recreating the genuine test circumstances of PEM power module strategies.

Shubham Chaudary and Yogesh K. Chauhan had discussed different FC technologies, their operating principles and applications. Mathematical modelling and Simulink model of PEMFC and solid oxide FC and operating characteristics was discussed. The effect of permeation, hydrogen and oxygen were analyzed. The V-I and P-V characteristics of the PEMFC and SOFC were analyzed. The outcomes demonstrate the validity of developed MATLAB/Simulink models of FCs [8]. The authors developed a model for understanding the effect of humidification temperature on oxygen mass fraction in the cathode for PEMFC. The model was developed by using times conservation equation and gratuity was considered as source the model was stimulated and can justified that the oxygen carry fraction even affected by either putting cathode upward or anode [9]. Jose David Rojas, Christian Kunusch, Carlos Ocampo-Martinez had discussed the role of flow field designs and current collector dimension next on PEMFC performance. A three dimensional computational mathematical model for the investigation of flow fluid design of current collector were discussed. Three different designs were used with aspect ratio verifying from 0.42 to 9. The good current collector design having aspect ratio was almost 1.5 [10].

In [11], the authors examined the steadiness and phase dynamic of the equilibrium water distribution is PEMFC using first and 2nd order parabolic function based stability was used by physics and mathematics based arrangement. The amount of water inside the fuel cell specifically influenced the execution, effectiveness and solidness. The unsteady states speaking to unbounded development of fluid water mass was discovered adequate for stable fluid dissemination. In [12], the authors studied the upgraded and improved controlled-oriented modelling technique by discussing the thermal dynamics of water-cooled PEMFC. It was examined that they not just advantageous for anticipating for control applications anyway it likewise can be useful for computing the temperature variety for the stack by letting to check the stack. For both the stationary and transient expresses, this method was approved. This methodology was experimented for actual 600W, 20 cells PEMFC system but this could be employed for any number of cells. It was concluded that the system responded for a huge number of operative levels with high precision. The rest paper is organized as: Section II includes Modelling and Simulation of fuel cell. Section III focuses on the results. In Section IV, the conclusions of the research work are discussed.

II. Modelling and Simulation of fuel cell

FC Stack block is shown in the figure. It prototypes a 45Vdc, 6kW PEM Fuel Cell Stack coupled to a DC/DC converter rated at 100 Vdc. This DC/DC converter has been loaded by means of a 6kW RL element with a 1 second time constant. For the duration of the 10 seconds, the consumption of the hydrogen gas is kept constant to the nominal value of Uf_H2 = 99.56% consuming a fuel flow rate controller. After the time equal to 10 seconds, the regulator has been avoided and the fuel proportion will be amplified to 85 litre per minute (Maximum Value) so that the variation in the voltage of stack is detected and observed, affecting the efficiency of the stack, the air and fuel consumption. In Scope 2, the voltage (V), current (I) of the Fuel cell, the voltage and current signals of DC/DC converter are presented while on the Scope 1, the Fuel flow rate, H2 / O2 consumption, air and fuel utilization, and efficiency are presented.

The fuel cell is modelled out in Matlab/Simulink, the model is shown in Figure 1.

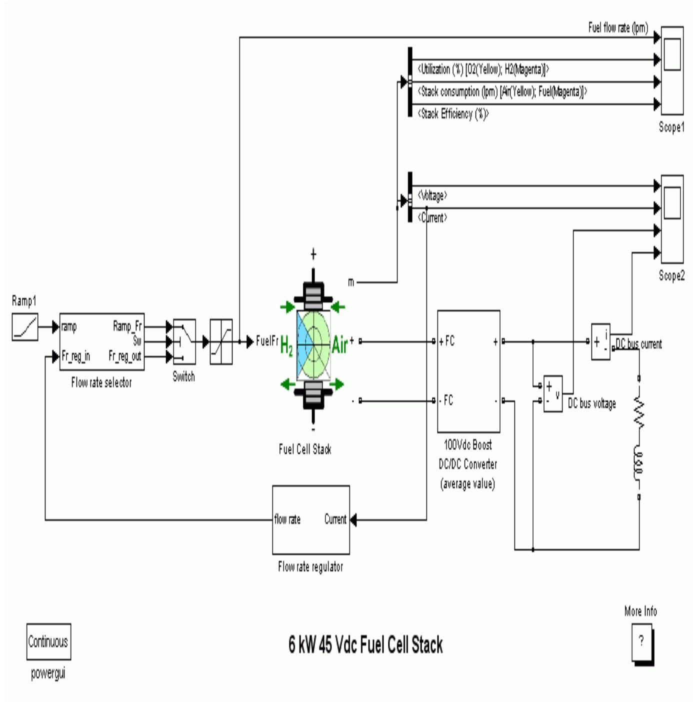

Figure 1. Simulink Model of PEM Fuel Cell

III. Results

At t = 0 sec, the current of the load is 0 Ampere, and the DC/DC converter does apply 100Vdc near the load (RL). The fuel consumption is established to the nominal rate of 99.5 %. The current escalates and reaches to 133A. The fuel flow rate has been usually fixed so that it can keep the nominal fuel consumption. On Scope 2, we see that the DC bus voltage is controlled through the converter. The voltage regulator transient occurs for the initial state of simulation for the highest voltage value of 122Vdc.

At t = 10 seconds, the flow rate of fuel consumption raises from 50 to 85 litres per minute. For 3.5 second, the hydrogen utilization is reduced, as a result the cell current lessens by increasing Nerst voltage. On Scope 1, a decrease in the efficiency and stack consumption occurs. Simulation is simulated for period of 20 seconds, the system values remain unchanged till 10 seconds of simulation, the value of fuel rate, air flow, humidity and temperature are varied through Ramp Function till rest of the simulation after 10 seconds. The variation in fuel cell stack efficiency in response to the parameters changed above are shown in the Figure 2.

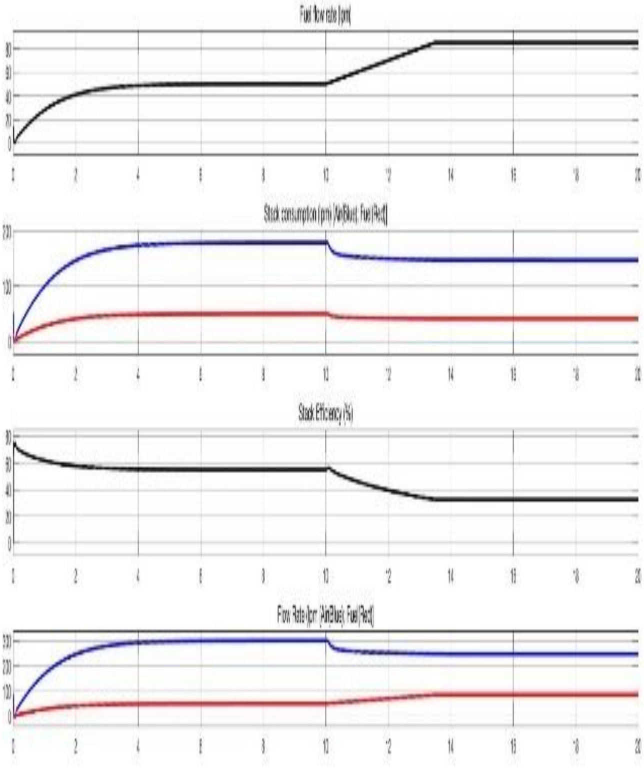

Figure 2. Flow rate, Humidity and Temperature Effect on stack efficiency

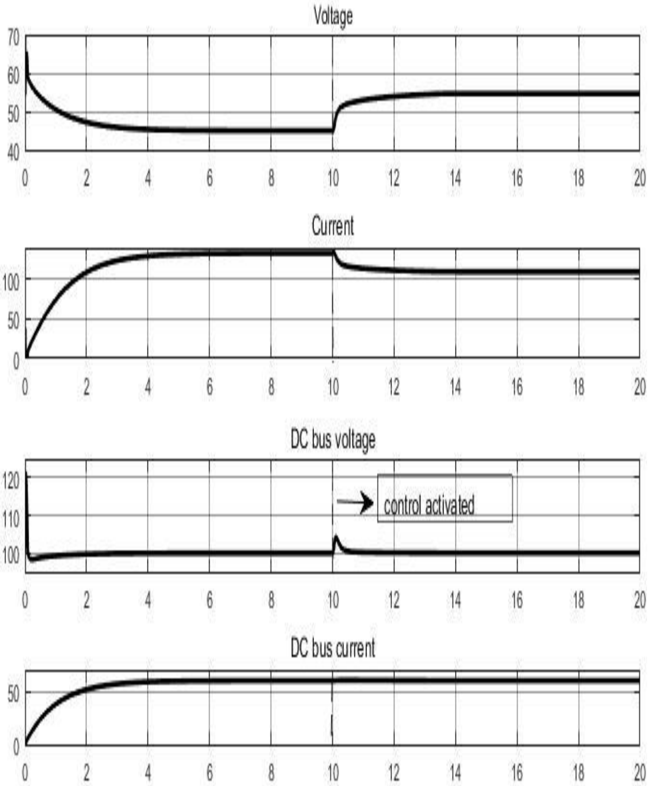

Figure 3. Current/Voltage of PEMFC

The first curve in Figure 3 is showing fuel cell output voltage, if we see the curve at startup we observe a transient behavior the rated output voltage of the stack is 45volts-DC but due to transient behavior we getting about 65volts which decreases and reach rated 45volts after about 1 seconds as shown in curve. After 10seconds when the fuel flow regulator is eluded and fuel rate is the maximum we see an increase in the fuel cell voltage about 5 volts.

The fuel cell current is reacting according to the voltage initially when voltage of stack is maximum the current is minimum but with a decrease in voltage current increases because current is drawn by the load. The DC/DC converter which is linked to the fuel cell stack is 100 volts DC rated. Initially for few milliseconds the bus voltage showing imbalance but later on we observe 100V pure DC from the DC converter.

Similarly, the DC bus current is initially zero which increase when current is drawn by the load and reaches about 60A maximum.

CONCLUSION

It is evident that increasing fuel flow rate and humidity inversely affect the efficiency of FC stack. The efficiency of FC gets degraded with increase in flow of fuel rate and humidity as well as temperature from their nominal values. The load is interfaced with fc through buck-boost converter. the variation in fuel rate, humidity and temperature also effects the output voltage and current of fc. the output voltage and current should be stabilized for onward supply to load. the fluctuation in fuel cell is regulated through buck-boost converter. The output voltage and current of FC and its regulated DC current and voltage through Buck-Boost converter, it is clear from simulation that after 10 second, due to variation in fuel rate and other associated parameters, the voltage and current of fuel cell also experiences variations. The buck-boost converter driven by PI controller effectively regulates the output voltage and current to it set reference values.

REFERENCES

[1] Brain Cook, “An Introduction to fuel cells and hydrogen technology”, Canada, Dec 2001

[2] EG & G Technical Services, Inc, “Fuel Cell Handbook”, 7th Edition, Nov 2004

[3] J. A. J. L. N. D. V. H.-M. K. K. P. G. H. Kap-Seung Choi, "An Experimental Study of Scale-up, Oxidant,and Response Characteristics in PEM Fuel Cells," IEEE TRANSACTIONS ON ENERGY CONVERSION, vol. 29, no. 3, pp. 729-734, SEPTEMBER 2014.

[4] P. P. R. K. D. S. Aliasger Zaidi, "Dynamic Modeling and Simulation of A PEM Fuel Cell: MATLAB and LabVIEW Modeling Approach," in Proceedings of 2014 1st International Conference on Non Conventional Energy (ICONCE 2014), 2014.

[5] F. G. A. M. T. Elena Breaz, "A Short review Of Aging Mechanism Modeling Of Proton Exchange Membrane Fuel Cell In Transportation Applications," in IEEE, 2014.

[6] M. Ahmed, E.-E. Salah and A. & Mahmud, "Effect of Stack Orientation on the Performance of H2/Air PEM Fuel Cell," in IEEE, 2010.

[7] D. A. M. a. X. Liu, "Comparison of Two Models for Temperature Observation of Miniature PEM Fuel Cells Under Dry Conditions," in IEEE TRANSACTIONS ON INDUSTRIAL ELECTRONICS, 2015.

[8] X. L. L. J. O. M. C. S. a. F. C. Hu Junming, "Water management in a self-humidifying PEM fuel cell system by exhaust gas recirculation," in ITEC Asia-Pacific , 2014.

[9] S. C. &. Y. K. Chauhan, "Studies and Performance Investigations on Fuel Cells," in IEEE International Conference on Advances in Engineering & Technology Research (ICAETR - 2014), India, 2014.

[10] Y. W. Shizhong Chen, H. Sun and Z. Sun, "Simulation of Humidification Temperature Impact on Oxygen between Anode-upward and Cathode-upward in PEM Fuel Cell," in IEEE, 2010.

[11] A. B. Y. Z. F. H. A. B. Youcef Kerkoub, "Channels design and dimensions Effect on performance of proton exchange membrane fuel cell (PEMFC)".

[12] B. M. a. A. S. a. I. Kolmanovsky, "Stability Analysis for Liquid Water Accumulation in Low Temperature Fuel Cells," in Proceedings of the 47th IEEE Conference on Decision and Control, Cancun, Mexico, 2008.