International Journal of Engineering & Scientific Research
Vol.5 Issue 10, October 2017,
ISSN: 2347-6532 Impact Factor: 6.660
Journal Home page: http://www.ijmra.us, Email:editorijmie@gmail.com
Double-Blind Peer Reviewed Refereed Open Access International Journal - Included in the International Serial Directories Indexed & Listed at: Ulrich's Periodicals Directory ©, U.S.A., Open J-Gage as well as in Cabell's Directories of Publishing Opportunities, U.S.A

MODELING AND CONTROL OF FUEL CELL POWER PLANT USING PID CONTROLLER

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ABSTRACT:

In this paper going to represent about fuel cell. Fuel cells model going to use PEMFC 6kW-45V Vdc to boost the voltage up to 48%. This is proton exchange polymer electrode membrane fuel cell. Fuel cells are going to controlled and boost the voltage supply using DC-DC voltage converter or chopper. In this paper going to improve the efficiency of the fuel cell is 55.56%. Fuel cell is the upcoming very good resource of the energy. It has a high efficiency and reliability, due to chemical reaction low pollution. A control strategy for these system using PID controllers is simulate here, with the help of Simulink. The significance of heating section in the overall performance is also analyzed. A smart energy arrangement and get a reinforcement control arrangement as a side advantage. Using MATLAB/SIMULINK analysis of efficiency and boost output power.

Key Words: Fuel-Cell Power Plant, SOFC, DC-DC Converter, PID Controller, Smart Energy

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I. INTRODUCTION

"Earth has enough resources to meet people's needs, but will never have enough to satisfy people's greed" and “The people on earth should act as 'trustees' and use natural resources wisely, as our moral responsibility to ensure that we bequeath to the future generations a healthy planet.”- Mahatma Gandhi [1].

In now day requirement of fossil fuels is most important part in daily life. As per the increasing the passage of time. More consumption of fossil fuels will raises the greenhouse gas emissions in the environment and cause the grat pollution i.e. become the global problem. This greenhouse gas will only reduce when reducing consumption of fossil fuels and the people to use the renewable energy sources [1]. In that area of technology production of hydrogen from the renewable the sources of the energy are procedure of development and showing. In order to meet the requirement of future energy demands and eco-friendly manner, technology to developed the production for the storage and application of hydrogen transportation and generation of electricity [13]. As per daily the populations and industries are increasing day by day the emission of CO2, nitrogen, sulfur oxide and other polluted gas increases. According to data of United Nations, the word population will reach 8 billion in spring of 2024 and 9 billion by 2050 [1]. According to government data the emission of CO2 will not rise more than 450 ppm by the 2050 in the word level signed among the countries, but in 2009 it was 415ppm and will be 430ppm by 2025.

Fuel cell is defined an electrochemical cell which unlike to storage cells. Fuel cell is continuously contact with the fuel and electrical power output independently [3]. It changes over hydrogen or hydrogen containing powers, straightforwardly into electrical vitality in addition to warm through the electrochemical response of hydrogen and oxygen into water. In expansion to the energy unit stack, a power device control plant incorporates a fuel processor and subsystems to oversee air, water, and warm vitality, and power. The fuel is provided under certain weight to the anode side of the energy component [4-5].

$H_2 \rightarrow 2H^+ + 2e^-$

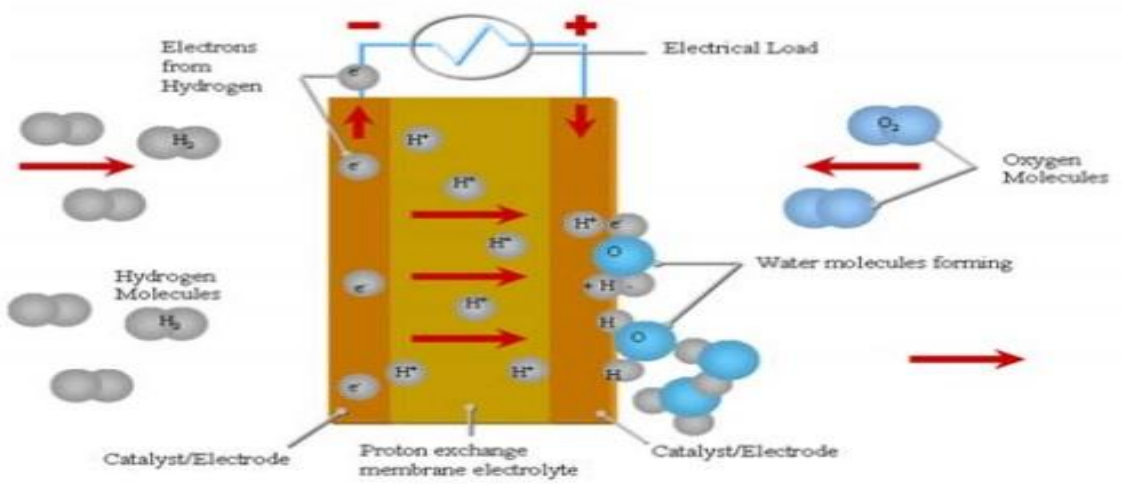

Figure 1: Working of fuel cell [7]

The protons are exchanged through the electrolyte (strong film) to the reactant layer of the cathode. On the other side of the cell, the oxidizer moves through the channels of the stream field plate and responds on the synergist layer of the cathode. The oxidizer utilized as a part of this model is air or O2. The oxygen consolidates with the protons and electrons to shape water, alongside arrival of little measure of warmth, on the surface of the reactant particles.

$2H^+ + 2e^- + 1/2O_2 \rightarrow 2H_2O$

Energy component control plant innovation is being developed, world over and outline, acknowledgment and operation techniques are being created. The paper portrays one of the conceivable approaches in actualizing control procedure for a PEM Fuel cell control plant. The idea was actualized on a test display PEM control plant effectively and extremely helpful sources of info have been determined.

I. PEM AND SOEC FUEL CELL OPERATION

Biomass gasifier-SOFC based power plants. Two unique SOFC framework setups were considered. The two coordinated frameworks have the same biosyngas generation framework utilizing a downdraft settled bed gasifier and a gas refinement framework utilizing both high and low temperature gas cleaning advancements. The contrast between these two frameworks is the SOFC framework setup. The SOFC framework has an ejector-driven anode distribution, no distribution is utilized in the energy unit framework, and however an immediate fuel conveyance

framework that supplies the biosyngas to the SOFC stack is utilized. Execution of these two frameworks was assessed regarding vitality and energy efficiencies.

The PEMFC has a many advantage in compare of other fuel cells [3].

- PEM has highest power density 300-100nW/cm2
- Easily start stop capability
- Very low temp operation for portable application
- More reliable than other fuel system
- They have very less moving part
- Easily refueling
- It is a higher energy density in compare to batteries in term of potential

III. FUEL CELL POWER PLANT

A fuel cell power plant consist of a fuel cell stack, a fuel supply system, devices like inlet and outlet solenoid valves, humidifier water heater, humidifier water pump, coolant pump, gas heaters, mass flow controllers, recirculation blowers, humidifiers and a control system. Here is the simple block diagram are shown in figure 2. In this only fuel cell stack, DC-DC converter and PID controller and other are inbuilt in the fuel cell stack.

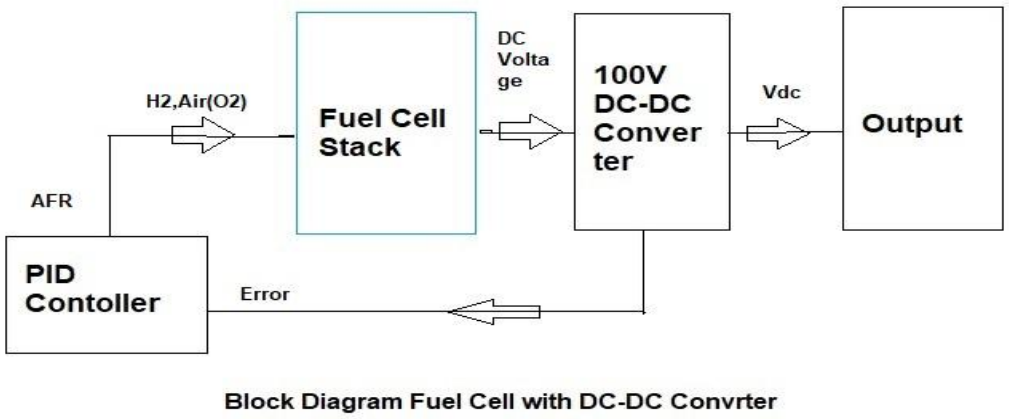

Figure 2: Basic Block Diagram of Fuel Cell with DC-DC Converter

A. Fuel Cell Stack:

The subsystems engaged with the energy unit control plant incorporates predominantly the accompanying: Electrode Stack, Gas Administration System, Water Management System, Gas Warming System, Thermal Management System, Operation furthermore, Control conspire.

The water heating consist of electrically power heater. The water inlet and maintain the suitable level. Then water outlet into the humidity section. Fuel cell load power deliver to the load.

$P = E \cdot I$

Power = Voltage · Current

$$watt = \frac{joule}{s} = volt \cdot \frac{coulomb}{s}$$

Intel reactant gasses are to be humidified before going into the power module stack. This is too fundamental to guarantee the conductivity of the film electrolyte in the cell. Humidification of stack channel gasses is mandatory with a specific end goal to draw current from energy unit stack. The humidification of fuel and oxidizer fills two needs; rising of temperature of the gas and humidification from 0%RH to 100%RH.

Gibbs free energy given by $E = -\frac{\Delta G}{nF}$

Here n is the moles of electrons released for every mole of hydrogen reacted (2 mol e^-/ 1 mol H_2). Maximum voltage E.

The sub system of fuel cell stack that increase the humidity gas temp by 2-3^oC, furthermore, cut down the relative moistness of gasses keeping in mind the end goal to maintain a strategic distance from buildup due to warm

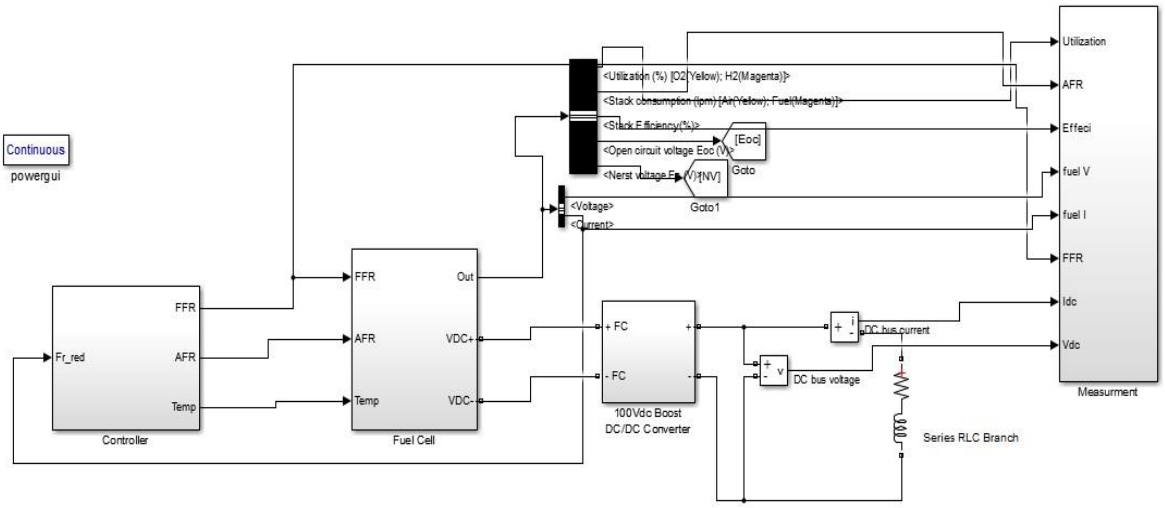

Figure 3: Power Fuel Cell Matlab/Simulink Model

misfortune in the gas tubing line from humidifier to stack [6]. The buildup in the gas line may cause water flooding and discourage the gas stream in bipolar plate channels.

B. DC-DC Converter

The output of the DC-DC controller is used to control the gate pulse of the switch in converter so that the output will match the reference value of voltage. Output of the converter is connected to the load the boost converter is higher efficient to the other DC-DC converter. In this paper the DC-DC converter 100V converter that produced a power up to 6kW. As shown in figure 4.

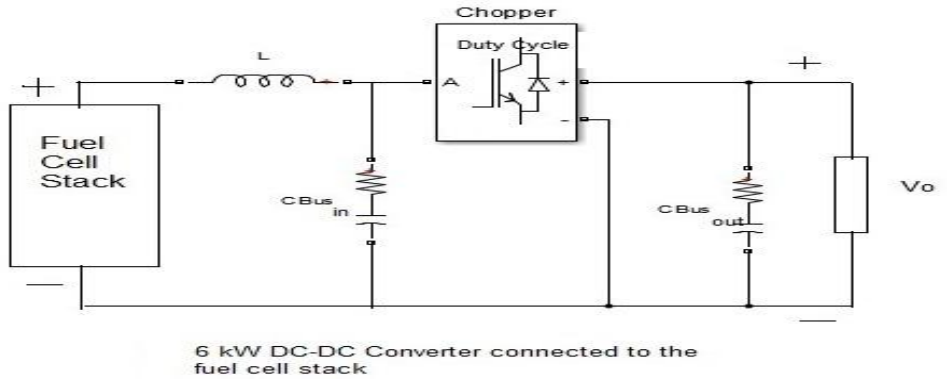

Figure 4: 6kW DC/DC converter connected with Fuel Cell Stack

$$\begin{bmatrix} \frac{di_L}{dt} \\ \frac{dv_{dc}}{dt} \end{bmatrix} = \begin{bmatrix} \frac{-R_L}{L} & \frac{(1-d)}{L} \\ \frac{(1-d)}{C} & 0 \end{bmatrix} \begin{bmatrix} i_L \\ v_{dc} \end{bmatrix} + \begin{bmatrix} \frac{d}{L} & 0 \\ 0 & \frac{1}{C} \end{bmatrix} \begin{bmatrix} v_{fc} \\ i_{ac} \end{bmatrix}$$

where *Vfc* and *Vdc* respectively stand for the voltage of energy unit and DC Bus, iL and iac speak to the current of inductor and yield current of inverter, L is the inductor with equal arrangement resistance R_L, and C is the capacitance. At the point when the turn is on or off, the topology will venture down or up the yield voltage.

Today the larger part of high power PCSs are acknowledged with the DC/DC idea. Since the DC voltage created by a energy unit stack shifts generally and is low in size (<50 V for a 5 to 10 kW framework, <350 V for a 300 kW framework), a voltage balancing out stride up DC/DC converter is fundamental to produce managed higher DC voltage (600 V ordinary for 3×400 Air conditioning yield). A DC/AC inverter is basic for change of the DC to valuable AC control at 50 Hz recurrence. A yield LC channel associated with the inverter channels the exchanging

recurrence sounds and produces an excellent sinusoidal AC waveform appropriate for the committed burdens.

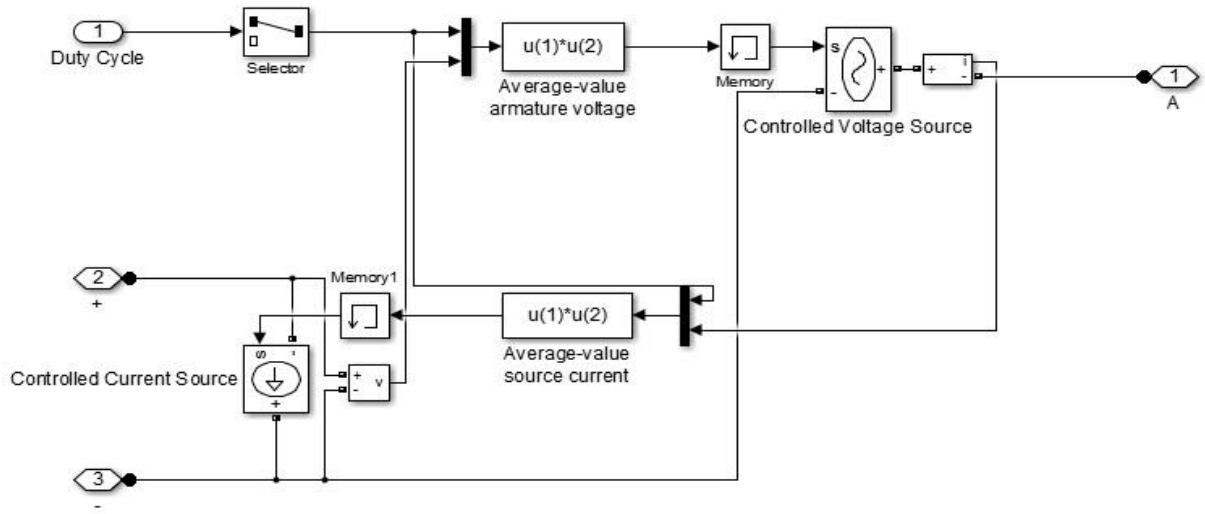

Figure 5: Internal SIMULINK Diagram of Chopper

C. PID Controller

This is the control loop feedback technique that used in industrial control system and a variety of other application requiring continuously modulated control. In the PID controller there are three term proportional- integral-derivative.

In this paper PID controller control the temperature of the fuel cell stack system. This temperature sensor in controlled by using thermocouple or RTD as input and compare with the actual temperature to the desired control temperature or a set point or it will provided an output to control element. In this paper the control set pint temperature is 338^{o}C. A dc bus capacitive energy set pint was defined by YbusREF. This is control a flow rate H2 and air (O2). This is shown in figure 4.

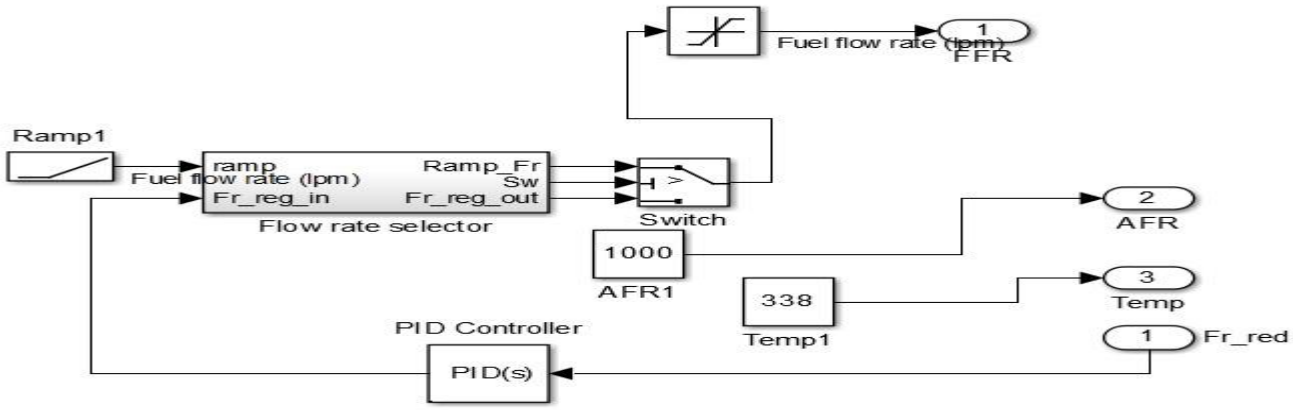

Figure 6: PID Controller

IV. SMART ENERGY

As per the "International Electrotechnical Commission" (IEC), "Savvy Grid is the idea of modernizing the electric lattice. The Smart Grid is coordinating the electrical and data advances in the middle of any purpose of Generation and any purpose of Consumption".

According to "NIST" has moreover developed the Smart Grid Conceptual Model which gives an anomalous state framework to the sharp cross section that portrays seven key zones: Bulk Generation, Transmission, Distribution, Customers, Operations, Markets and Service Providers where control quality has been acknowledged as a crucial part in the Smart Grid Network. The amount of system structures like Wind Energy Systems and Photovoltaic are by and by sharp more into the grid and furthermore the amounts of non-coordinate burdens are moreover growing. Keen vitality matrices potential assume an extraordinary part for the biogas. Biogas framework might be help to build the extents of variable on inexhaustible power on the power network by utilizing of two unique advances [10].

- Biogas structures which augment the era of energy at the period of ubiquity for the power, or store the biogas unexpectedly at the period of low power ask.
- This take steps to biogas plant if the less enthusiasm for control low than supply of energy to system, pleasing surplus energy to gas.

Numerous segments in a telecom control arrangement can be either associated into the brilliant matrix world or can be a direct part of the brilliant matrix. The present power frameworks, counting energy components, have insightful controllers and system interfaces bringing about

keen, remotely reasonable gadgets with interfaces that give standard conventions to Machine to Machine Interfaces or Human to Machine Interfaces [9].

A Smart Energy arrangement in telecom must have the capacity to be overseen by means of conventional operations strategies. In the models displayed in this paper, the operations focus ought to have the capacity to control and deal with various power frameworks at any given time utilizing direct charges or preset contents [8]. When utilizing little control frameworks like energy units at cell locales there is should be ready to oversee possibly many gadgets to move up to a control level that has any kind of effect on the matrix. Five or ten locales at 6kW won't intrigue the utility and truly does nothing for the broadcast communications administrator's vitality utilization.

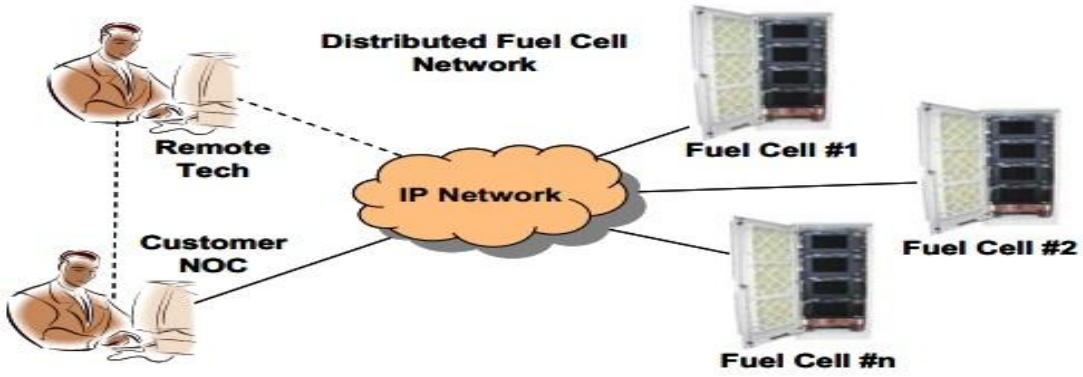

Figure 7: Network of fuel Cell [8]

Organized and gathering of energy components that are overseen from the Network Operations Center (NOC) or by an outsider administrations organization. At the point when there is a need to create control, the summon can be issued by means of the system to begin era, stop era and assemble measurements about the generation of vitality [8]. Fuel cell IP network are connected to the different generation of the fuel cell in the term of distributed fuel network and connect remote tech and customer NOC as shown in figure 7.

V. SIMULATION RESULT

A. DC Bus Voltage:

The main task to convert the regulate voltage to the constant DC voltage from 48V to 100V. This is boost done by using the DC/DC converter. The stability of voltage checked. Figure 8 is shown that the boost voltage.

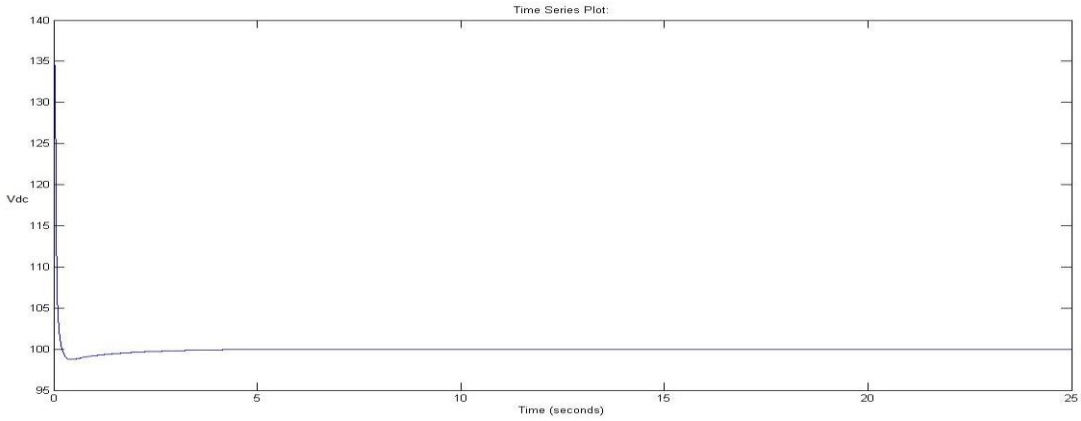

Figure 8: DC/DC Converter Bus DC Voltage

B. Power Flow:

The output power can be controlled by the converter, and under the reference control requests, the yield energy of fuel cell takes after the power requests. The model of energy unit control plant utilized as a part of the paper is the power device of PEM what's more, gas turbine. It implies that energy component control plant creates more energy to give the matrix at beginning time, and the gas turbine produces control gradually due to the dormancy of gas turbine. In spite of the fact that there are some distinction between the reference and reenactment, the model tracks the reference nearly. The DC power flow of the from the system is reach up to the 6kW as show in figure 9.

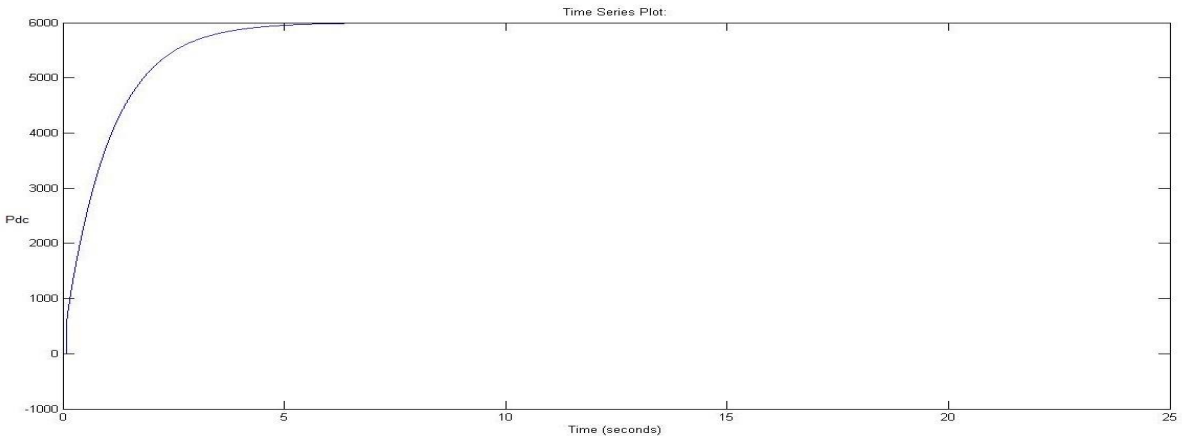

Figure 9: DC Power Flow

C. Efficiency and Utilization:

The electrical effectiveness of cogeneration frameworks is an essential paradigm in biogas ventures [12]. This kind of extend is financially practical just if there is a huge need of warmth close to the power plant. The diverse current sorts of power module cogeneration framework create arrived at the midpoint of half of their aggregate control into warm and their electrical proficiency is up to 60% [11].

The maximum efficiency limit of a fuel cell, often referred to as the thermodynamic efficiency, is calculated as follows.

$$\text{Maximum Efficiency} = \eta_{\max} = \frac{\Delta G^{\circ}_{rxn,T}}{\Delta H^{\circ}_{rxn,298}} \times 100$$

But in this paper the efficiency of this model near to the 55.56% that near about the maximum. As shown in figure 10. The industrialization of cogeneration with high electrical productivity, the PEM framework, could in this manner serve numerous new power module ventures.

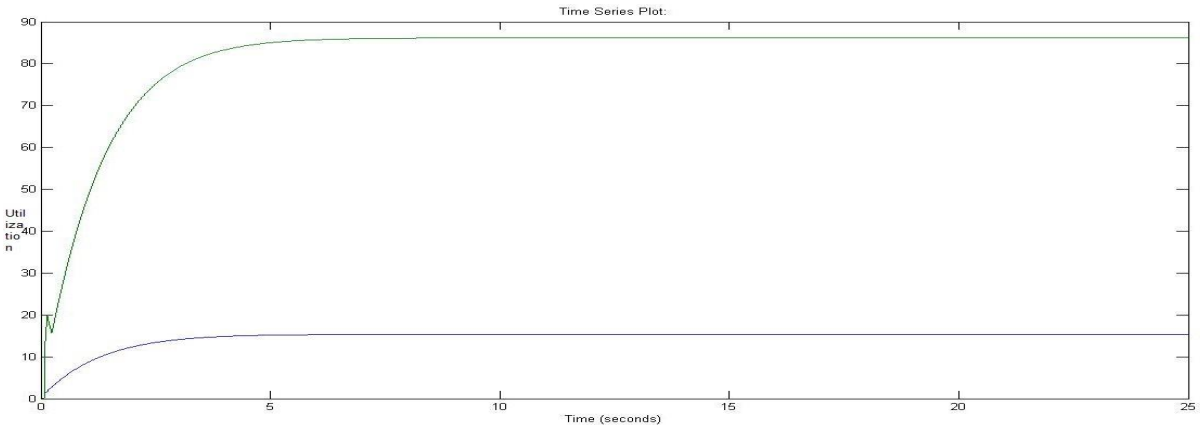

Figure 10: Efficiency of the fuel Cell Stack at the level of 6kW

CONCULUSION

In this paper Smart energy programs come in numerous varieties and are developing in prominence because of progressing electrical network issues. Overall electrical request keeps on expanding bringing about limit deficiencies and strain on network foundation. Disappointments also, flimsiness is inescapable without rectifications. Smart energy also, request side projects are venture toward amendment. Smart energy arrangements alongside savvy gadgets offer important apparatuses for the media communications administrator to use their reinforcement control resources for monetary and natural esteem. The administrators can turn into a "prosumer" both creating and expending energy. They are presently dynamic in the arrangement rather than absolutely a buyer of assets. The present power devices offer a feasible answer for help the need of reinforcement control and the smart energy arrangements. The broadcast communications administrator has a decision: they can purchase a vigorous reinforcement control arrangement and get a smart energy arrangement or they can purchase a smart energy arrangement and get a reinforcement control arrangement as a side advantage.

In this paper improve the efficiency of the fuel power model. Also improve in the utilization of voltage and power. This system is used in the distribution system to connect to the grid at rural area or hilly area.

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