To Study About SOFC and Its Performance in Grid Connected Mode

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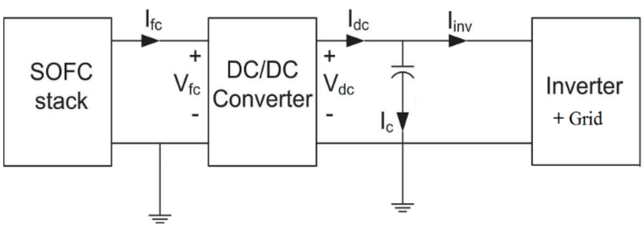
***Abstract* - The proposed dynamic model will account for the electrochemical and thermo dynamic characteristics of SOFC. Effects of temperature variations and fluid flow changes will be incorporated in the model. Voltage drops inside a fuel cell will also model. SOFC is connected to Grid through DC-DC Boost converter and a 3-phase voltage source inverter. The output of 3-phase inverter is fed to the grid with the use of AC link integration. Complete model will be formulated in MATLAB-SIMULINK environment. Simulation results will clearly depict the behavior of SOFC and also show that SOFC is a potential source for distributed generation purpose.**

***Keywords* - component sofc –solid oxide fuel cell,dc-direct current,pwm-pulse width modulation**

I. INTRODUCTION

The SOFC is electrochemical device that convert chemical energy to electrical energy (d.c). SOFC is static energy device that operate at high temperature (600°c to 1000°c) and convert chemical energy to electrical energy. SOFC is high energy conversion efficiency and absence of moving parts so it is stationary power generation. They are more advantageous as compared to the conventional power plants. SOFCs are suitable for stationary power applications with step load changes. They have the ability to integrate with other power generating systems, such as automotive engines or gas turbines of various sizes. SOFCs are flexible in the choice of fuel such as carbon-based fuels, like natural gas. A number of research have been undertaken in the modeling, control and performance of PEMFCs which are best suited to mobile and residential application because of their lower efficiency and dependence of pure hydrogen as fuel they have not found much use in stationary power application.

Fuel cell based DG system is considered an alternative to centralized power plants due to their non-polluting nature, high efficiency, flexible modular structure, safety and reliability. At present, they are under extensive research investigation as the power source of the future, due to electrical energy through an electrochemical process. As opposed to a conventional storage cell, it can work as long as the fuel is supplied to it. There are many motivations in developing this method of energy generation and it needs further development to have a realistic system analysis combining various subsystem and components. Among the various types of fuel cells discussed in the literature, PEMFC and SOFC fuel cells are in wide use and have been widely commercialized. A number of researches have undertaken in the modeling, control and performance of PEMFCs, which are best suited to mobile and residential applications. Because of their lower efficiency and dependence on pure hydrogen as fuel, they have not found much use in stationary power applications. SOFCs, which work at high temperatures, however, are ideal for DG applications, wherein power is generated at the load site itself.



[Fig 5.1 Block diagram of grid connected SOFC]

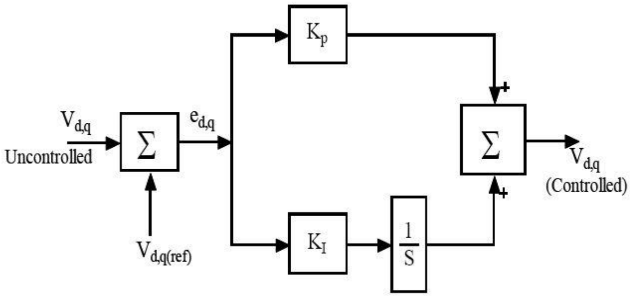
Types of fuel cells:

Fuel cells are generally classified by the type of electrolyte they use, and the choice of electrolyte dictates the range of their operating temperature and the degree of fuel processing required. Low-temperature fuel cells are generally limited to temperatures below or around 200°C because high-temperature vapor causes rapid degradation of their electrolyte material. The most common type of low-temperature fuel cells are alkaline fuel cell (AFC), phosphoric acid fuel cell (PAFC), and polymer electrolyte membrane (PEMFC). In these fuel cells all the fuel must be converted to hydrogen prior to entering the fuel cell. In addition, the catalyst used in these fuel cells (mainly platinum) is strongly poisoned by carbon monoxide (CO). Therefore, the hydrogen entering these fuel cells needs to be pure. This is a downside of the low-temperature fuel cells. In high-temperature fuel cells, CO and even hydrocarbons (e.g., CH_4) can be internally converted to hydrogen or even directly oxidized. The
most common types of high-temperature fuel cells are molten carbonate fuel cell (MCFC) with operating temperature range of 600-700°C, and solid oxide fuel cell (SOFC) operating in the temperature range of 600-1000° C. As SOFC are highly efficient combined

heat and electric power [5], they are considered for the study in this paper. Modeling of SOFC is done by using by using Nernst equation. In that the output power of the fuel cell can be controlled by controlling the flow rate of the fuels used in the process [6][7].
The different types of fuel cells have slightly different chemical reactions, but the same electrochemical reaction is the backbone of all of them. Because of the differences in their operating characteristics and fuel used, different types of fuel cells are suited for different applications.
In addition to the above types of fuel cells, there is another category of fuel cells, which can utilize non-hydrogen fuels directly without internal or external reforming process. Two common types in this category are direct methanol fuel cell (DMFC) and direct carbon fuel cell (DCFC). DMFC, also called direct alcohol fuel cell (DAFC), is a low-temperature polymer electrolyte fuel cell, which uses alcohol as fuel without reforming.

II. CONTROL TECHNIQUE

PI Controller

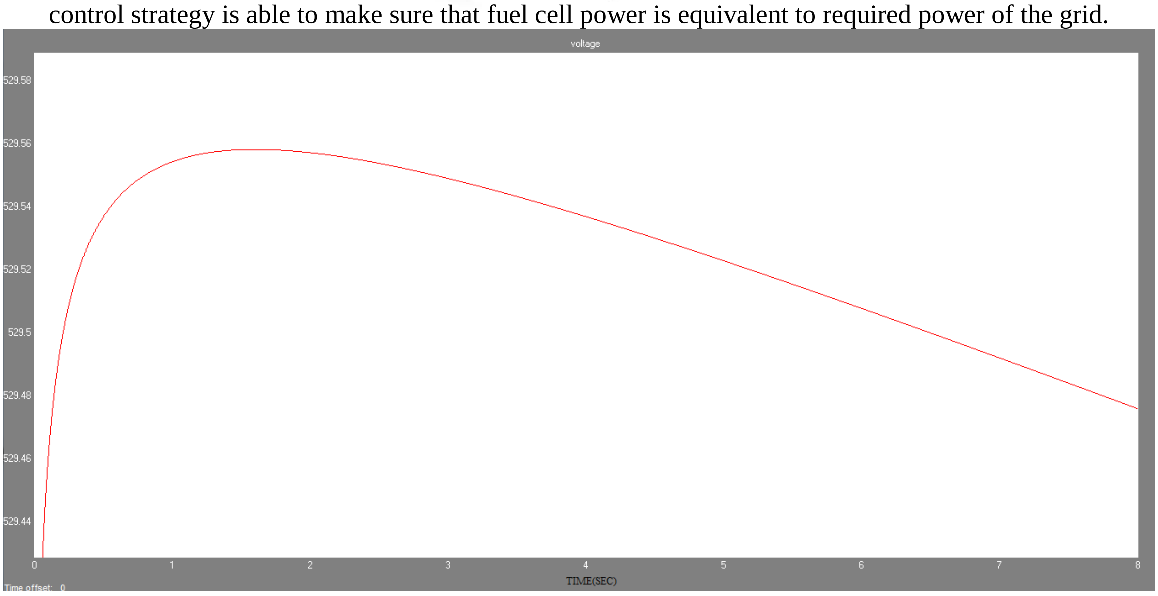


Boost dc–ac inverter naturally generates in a single stage an ac voltage whose peak value can be lower or greater than the dc input voltage. The main drawback of this structure deals with its control. Boost inverter consists of Boost dc–dc converters that have to be controlled in a variable-operation point condition. The sliding mode control has been proposed as an option. However, it does not directly control the inductance averaged-current. This paper proposes a control strategy for the Boost inverter in which each Boost is controlled by means of a double-loop regulation scheme that consists of a new inductor current control inner loop and an also new output voltage control outer loop. These loops include compensations in order to cope with the Boost variable operation point condition and to achieve a high robustness to both input voltage and output current disturbances. As shown by simulation and prototype experimental results, the proposed control strategy achieves a very high reliable performance, even inbetween the actual load currents and the desired mains currents for the three phases.

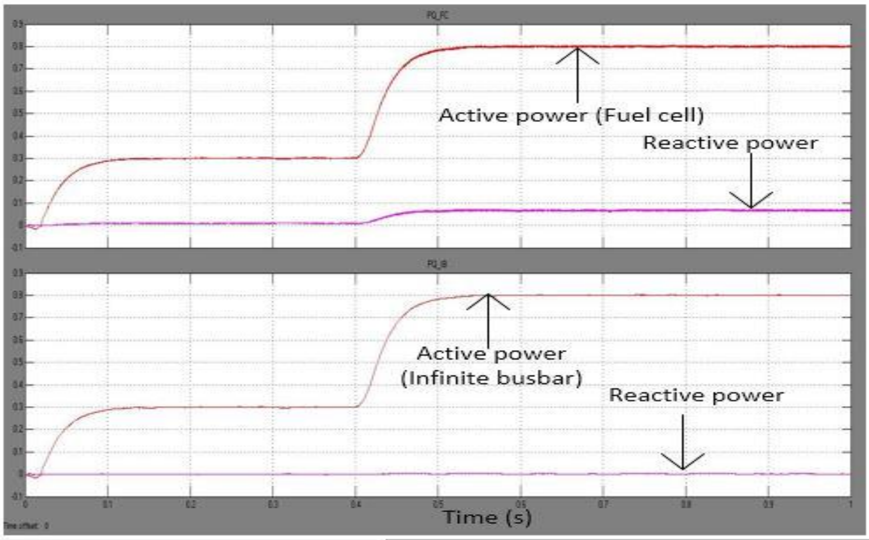
III. MATLAB/ SIMULINK SIMULATION MODEL

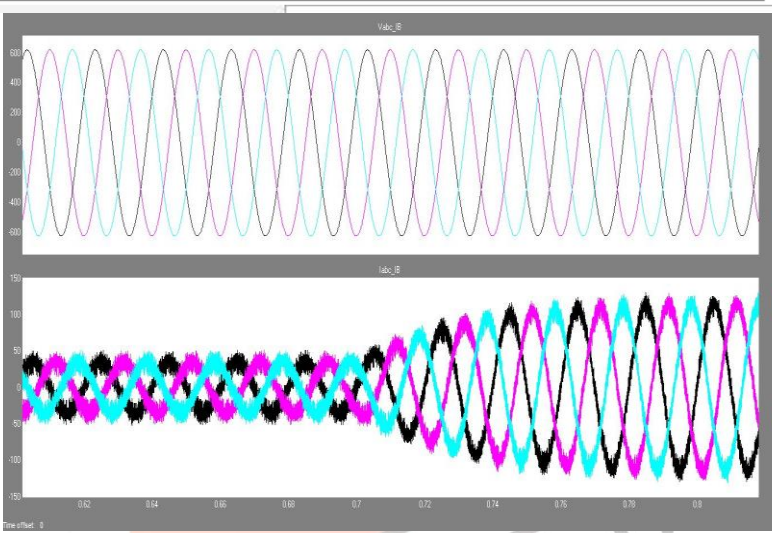
Dynamic modeling of solid-oxide fuel cell has been performed to analyze its load behavior as distributed generator in a grid connected power system. The response of the system to step changes in load demand are presented along with the analysis of the simulated results. It has been observed that the fluctuations in the output voltages in the power system due to load variations are taken care of by the SOFC very closely. An efficient dynamic model of Solid Oxide Fuel Cell has also been developed which can supply active power maintaining inverter voltage as desired. The combined system reduces the cost of power generation as well as the level of pollution reducing the fuel consumption. The Simulation results are presented for various dynamic characteristic of the Fuel system control scheme, which enables comprehensive quantitative and qualitative analysis.
according to this technique we will increase the voltage regulation [3]. The system parameters are, phase voltage = 415 volts. Simulation results are also observed.

This wave form shows active and reactive power of the fuel cell and grid here in this wave form we are able to see that our control strategy is able to make sure that fuel cell power is equivalent to required power of the grid.



This wave form show dc link output voltage and current. these voltage and current are output of fuel cell with dc to dc converter with use of converter it makes sure that both quantities are remain constant for particular conditions





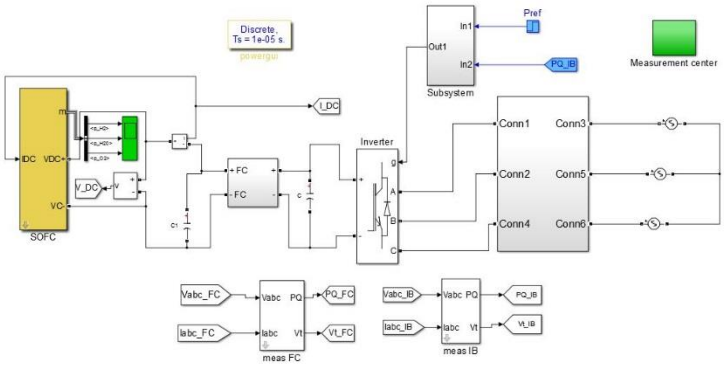


Fig 4. Grid connected SOFC

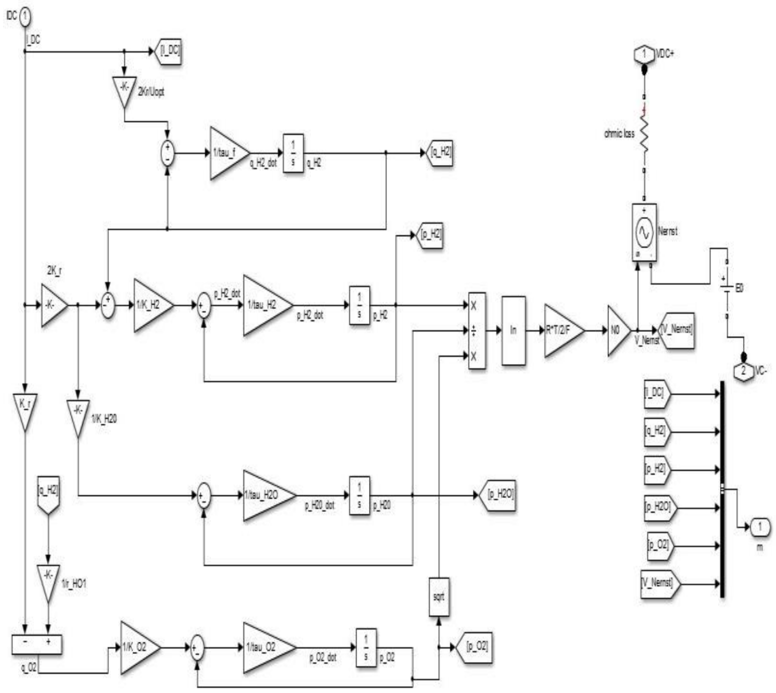


Fig 5.SUB SYSTEM SOFC

IV. CONCLUSION

A dynamic model of SOFC based DG system has been developed in MATLAB /SIMULINK environment to supply power to an isolated load. The model incorporates the electrochemical reaction dynamics and major voltage losses in SOFCs. An over view of the operating principle of SOFC and its V – I characteristic has been discussed taking into account the various voltage losses. A constant utilization mode has been adopted for the operation of fuel cell in which the control of constant utilization is implemented using current feedback to adjust the hydrogen input flow rate. Various power electronic interface topologies that convert the power generated by the FCs into a usable form have been discussed. A DC-DC PWM boost converter model is developed and interfaced to fuel cell to boost SOFC voltage to a regulated dc voltage required for DC/AC PWM inverter to serve for an isolated load.

V. REFERENCES

[1] SOFC-based Fuel Cells for Load Following Stationary Applications Nagasmitha Akkinapragada, and Badrul Chowdhury, Senior Member, IEEE

[2] A Comparative Study of Fixed Speed and Variable Speed Wind Energy Conversion Systems Feeding the Grid S.S. Murthy* Senior Member, IEEE, Bhim Singh** Senior Member, IEEE

[3] SOLID OXIDE FUEL CELL TECHNOLOGY. J. T. Brown IEEE Transactions on Energy Conversion, Vol. 3, No. 2, June 1988 .

[4] Dynamic and Transient Analysis of Power Distribution Systems With Fuel Cells—Part I: Fuel-Cell Dynamic Model Kourosh Sedghisigarchi, *Student Member, IEEE, and Ali Feliachi, Senior Member, IEEE* VOL. 19, NO. 2, JUNE 2004.

[5] Modeling design of solid oxide fuel cell power system for distributed generation application.(N.PREMA KUMAR, Nirmala Kumari, K.M Rosalina) International journal of advanced research in computer engineering & technology(IJARCET)VOLUME 1,ISSUE 9, NOVEMBER 2012

[6] Distributed generation application of fuel cell Published in Montana state university, Bozeman, MT USA.

[7] Power flow control of a solid oxide fuel cell for grid connected operation.(Ankur Goel S.MISHRA)IEEE.

[8] Dynamic modeling of solid oxide fuel cell(Muhammad Salik) published in NED University of ENGG ,lahore

[9] Novel Inverter Flux Control for Fuel Cell Using Fuzzy Logic Francisco Jurado, Member, IEEE, Manuel Valverde.

[10] An Analysis of the Control and Operation of a Solid Oxide Fuel-Cell Power Plant in an Isolated System Y. H. Li, S. S. Choi, *Member, IEEE, and S. Rajakaruna, Member, IEEE* VOL. 20, NO. 2, JUNE 2005.

[11] Dynamic Integration of a Grid Connected DFIG Wind Turbine with a Fuel Cell Bhaskara Palle Colorado School of Mines Golden, CO, USA

[12] A Physically Based Dynamic Model for Solid Oxide Fuel Cells Caisheng Wang, *Member, IEEE, and M. Hashem Nehrir, Senior Member, IEEE* VOL. 22, NO. 4, DECEMBER 2007

[13] Rapid Load Following of an SOFC Power System via Stable Fuzzy Predictive Tracking Controller Tiejun Zhang, *Member, IEEE, and Gang Feng, Fellow, IEEE* VOL. 17, NO. 2, APRIL 2009.

[14] Solid Oxide Fuel Cell: Perspective of Dynamic Modeling and Control Biao Huang Yutong Qi Monjur Murshed *Canada, T6G 2G6*

[15] Fuel cell system: Efficient, flexible, energy conversion for the 21 st century DOUGLAS J.NELSON VOLUME 89 NO 12 DECEMBER 2011,IEEE