Fuel Cell: the Future of the Electric Power System

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ABSTRACT

Now a day's fuel cell is gaining wide importance in electrical sectors the entire world over. The electrochemical devices convert the chemical energy contained in a wide variety of fuels directly into electric energy. The electrical efficiency, of fuel cells system can be around 60%, a value that is nearly twice the efficiency of conventional internal combustion engines. The different types of fuels are used in fuel cells such as a natural gas, propane, landfill gas, diesel, methanol and hydrogen. This versatility ensures that the fuel cell will not become obsolete due to unavailability of certain fuels. The fuel cell is known connected to electrical power system and result are simulated through MATLAB/SIMULINK Software.

Keywords: Distributed Generation, Solid Oxide Fuel Cell, RES (Renewable Energy Sources),PQ inverters, VSI inverters

1. INTRODUCTION

Sustainable energy is the main driving force for all renewable energy sources applications. The electrical energy in a country is largely dependent on fossil fuel, hydro fuel or nuclear fuel. The increasing nation's dependence on imported fossil fuels, the international political instability that have been affecting the primary energy resources prices and the security of supply, together with environmental concerns and climate change issues, are compromising the current energy paradigm. The development of Distributed Generation (DG) and Renewable Electricity Generation technologies are essential in order to achieve the proposed goals.

DG and Renewable Energy Sources (RES) cover a wide range of technologies (wind generators, photovoltaic panels, fuel cells and micro turbines just to mention a few examples) that are suitable for supplying power at customers sites. With the Large-scale DG, deployment will transform the energy generation scenario from a system dominated by the centralized generation to a new one in which environmentally friendly technologies will be adopted on large scale. The exploitation of the DG sources can result in Deferral of investments on transmission and distribution systems. Secondly, distribution system losses will be reduced. A better way to realize the emerging potential of distributed generation is to take a system approach, which views generation and associated loads as a subsystem or a "Micro Grid".

1 FUEL CELLS: Now a day's fuel cell is gaining wide importance in electrical sector all the world over. The electrochemical devices convert the chemical energy contained in a wide variety of fuels directly into electric energy. Despite the wide range of fuel cell system advantages. The basic element of a fuel cell is a unit cell, as shown in Figure 2(a). These basic elements convert the chemical energy contained in fuels directly into electric energy. Each basic fuel cell unit consists of a cathode (positively charged electrode), an anode (negatively charged electrode) and an electrolyte layer.

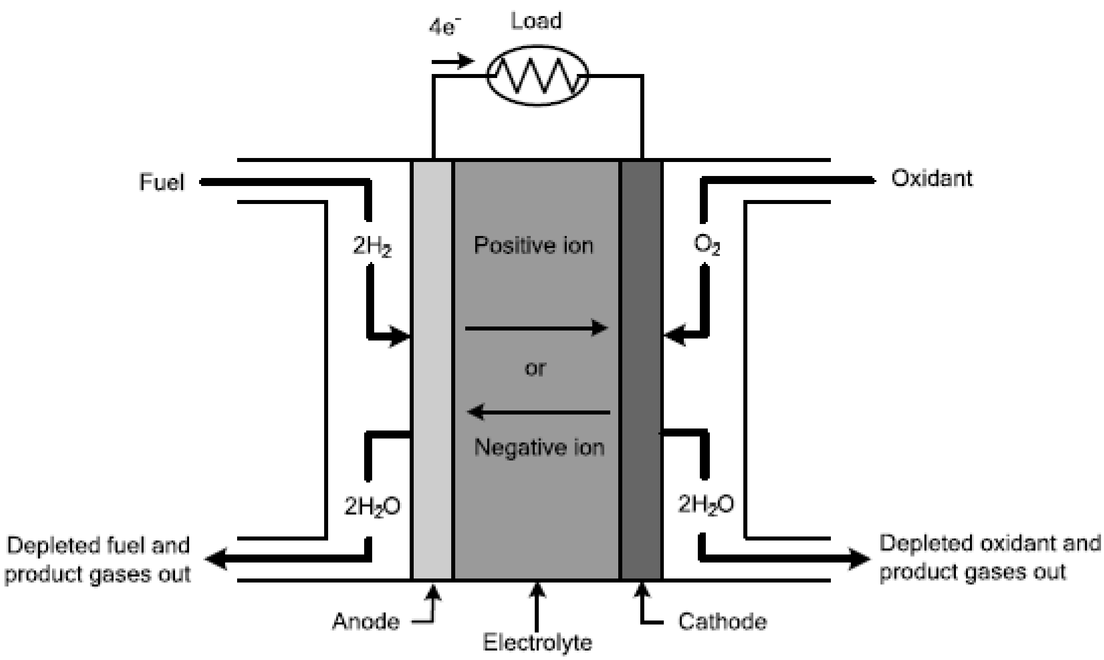

Fig 2(a) Schematic Diagram of fuel Cell plant

The cathode provides an interface between the oxygen and the electrolyte catalyzes the oxygen reaction and provides a path through which free electrons are conducted from the load to the oxygen electrode via the external circuit. The electrolyte, an ionic conductive medium (non-electrically conductive), acts as the separator between hydrogen and oxygen to prevent mixing and the resultant direct combustion. It completes the electrical circuit of transporting ions between the electrodes. Some serious shortcomings are there, one of the shortcomings is that they have very high initial cost. The fuel cells systems require a certain level of purity in their supplied fuel, making necessary the use of cleaners and filters to achieve the entailed fuel purity.

1.b) Types of Fuel Cells

There are five basic types of fuel cells under consideration for distributed generation applications, each having different electrolytes which define the basic cell type, and a characteristic operating temperature. Two of these fuel cell types, Polymer Electrolyte Membrane Fuel Cell (PEMFC) and Phosphoric Acid Fuel Cell (PAFC) have acidic electrolytes and rely on the transport of H+ ions.

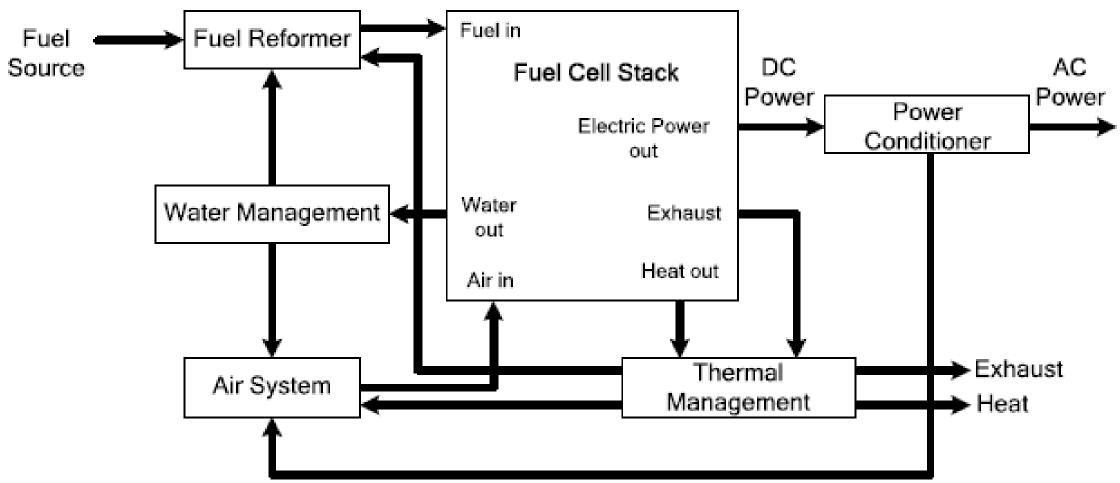

Figure 2(b) Basic processes in a Fuel Cell Power Plant

A Solid Oxide fuel Cell (SOFC) is considered now a days, for stationary power generation applications due to the following advantages:

The fuel processor requires a simple partial oxidation reforming process, eliminating the need of an external reformer. SOFC has relatively low requirements for the fuel reformation process. It can use carbon monoxide directly as a fuel, which do not require a very sophisticated reformer. As it operates at extremely high temperatures, it can tolerate relatively impure fuels.

The SOFC being a high temperature fuel cell entails some major drawbacks. Due to the high-temperature operation, it requires a significant time to reach the operating temperature and to respond to changes in the output power. The start-up time is in the order of 30 to 50 minutes. This SOFC dynamic model is also adopted in this work and is it based on the following assumptions: The gases are ideal. Assuming that the SOFC system is supplied with hydrogen in the anode and oxygen in the cathode, the reactions that take place are described by the following equations:

Anode: $H2 + O^{=} \rightarrow H2O + 2e^{-}$
Cathode: $O2 + 2e^{-} \rightarrow O$

In order to calculate the open circuit voltage *E* of a stack with No cells connected in the series, the Nernst equation is used:

$$E = N_o \left[E_o + \frac{RT}{2F} In \frac{p_{H2} \sqrt{p_{o2}}}{p_{h2o}} \right] \text{------------------------------} \qquad (1)$$

Where *Eo:* voltage associated with reaction free energy of the cell (V)
R: universal gas constant (8314.51 J.kmol-1.K-1)
T: channel temperature (assumed to be constant) (K)
F: Faraday constant (96.487×106 C. kmol-1)

p_{o2}, p_{H2o}, p_{H2} : partial pressures of hydrogen, oxygen and water vapour, respectively (atm).All the reactions occurring in the fuel cell stack have some inherent time delays. The chemical response in the fuel cell processor is usually slow and it is associated with the time to change the chemical reaction parameters after a change in the flow of reactants. This dynamic response function is modelled, as a first order, transfer function with a time delay *Tf* . The Figure 2.3 shows block diagram of the adopted SOFC dynamic model.

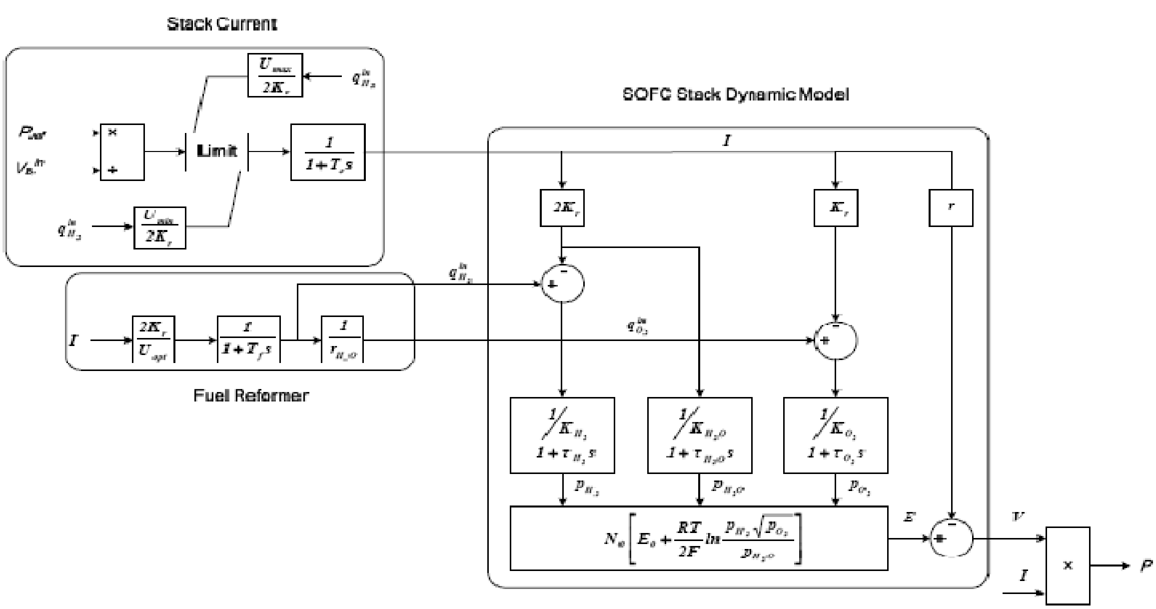

Fig.2.3 Simulation of Solid Oxide Fuel Cell

2. SIMULATION OF MICROGRID COMPONENTS

The figure 3.0 shows the Simulation of the Micro Grid components the dynamic simulation platform was developed under the MatLab /Simulink environment. In the simulation platform it is possible to analyse the dynamic behaviour of several Micro sources (Solid Oxide fuel Cell) and its connection to PQ inverters. Here in the given Fig.3.0 the dynamic model of Solid Oxide fuel Cell is being described.

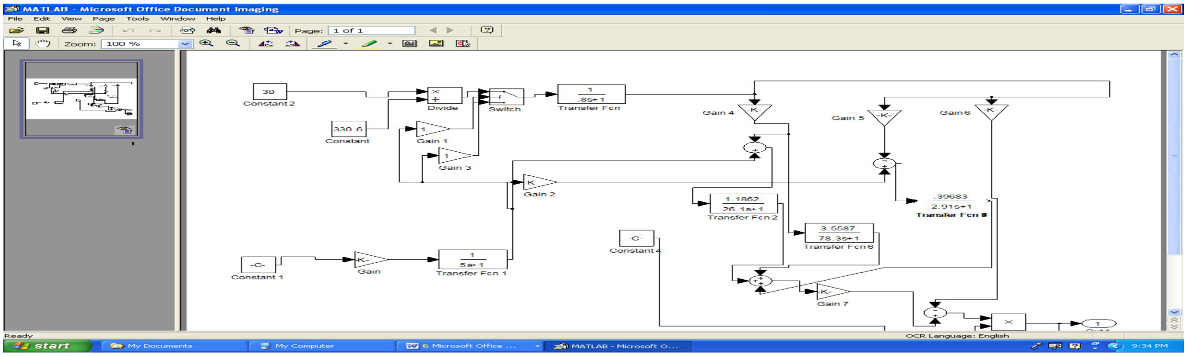

Figure 3.0: Simulation of Fuel Cell

The Solid Oxide fuel consisting of the three parts fuel processor, power section and power conditioner .The Solid Oxide fuel Cell is developed in a modular way where the control parameters and models are included in a Matlab/ Simulink.The parameters of the Solid Oxide fuel Cell are included in appendix .A The Fig.3.1 shows the results of the active power's time.

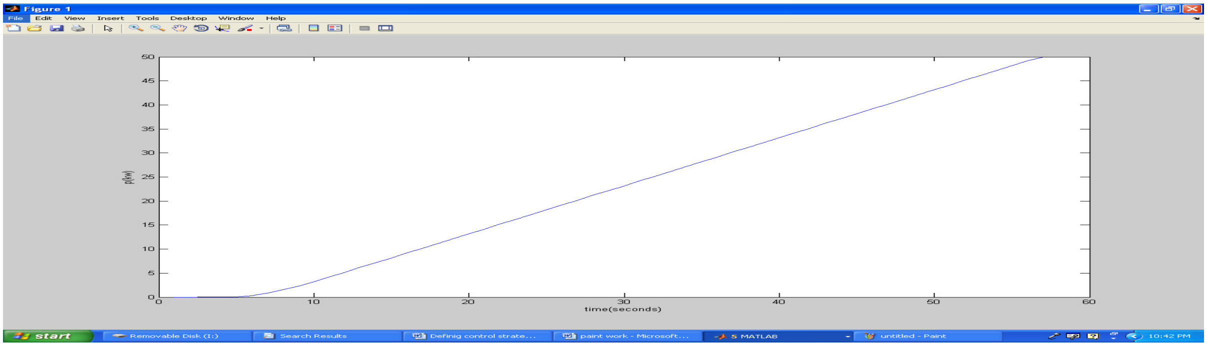

Figure 3.1: Solid Oxide fuel Cell

time. The Figure 3.2 show the PQ control of the inverter is shown here in it is implemented as a current controlled voltage source as shown in the Figure 3.3. Current components in phase (i_{act}) and quadrature (i_{react}) with the inverter terminal voltage are computed as similar to single phase inverters. Power variation in MS induces a dc-link voltage error corrected via the PI-I regulators by adjusting the magnitude of the active current output delivered to the grid. The reactive power output is controlled via PI-2 regulator by adjusting the magnitude of the inverter reactive current output.

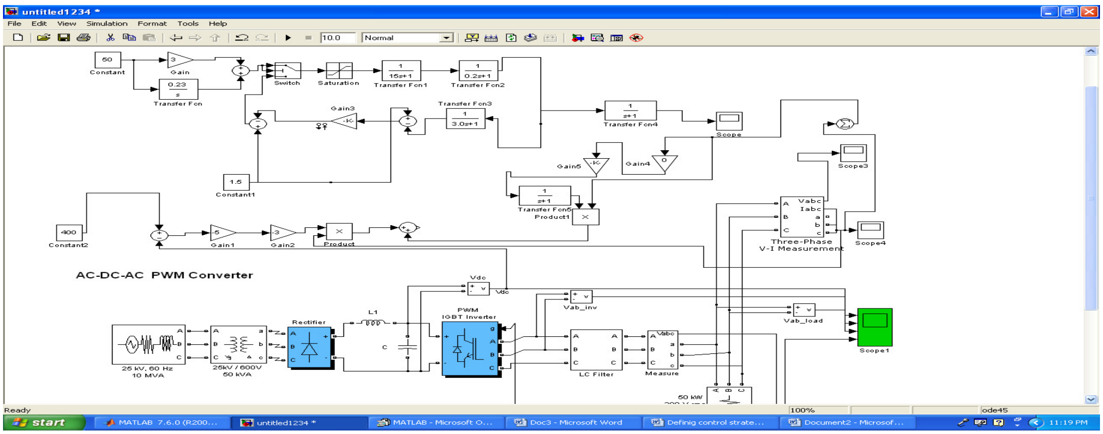

Figure 3.2: PQ Control of the Inverter

The Figure 3.3 shows the waveform of the PQ control of the inverter & load.

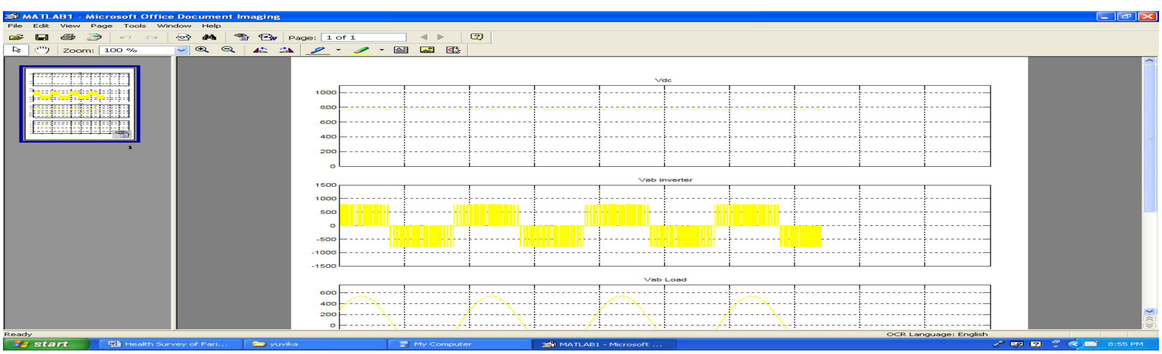

Figure 3.3: Waveform of the PQ Controlled Inverter

3. RESULT DISCUSSION

The Dynamic Simulation of the Solid Oxide fuel Cell, and PQ control of inverters are shown and the result obtained are compared with the result of the paper [2]. The active power graph shown in the Fig .3.0 Fig 3.1 shows the local PI control. In order to analyses the behaviour of an MG, the dynamics of the primary energy sources are neglected due to the high storage capacity assumed to be installed at their dc link. Due to the existence of a high storage capacity, the system frequency is restored faster to its nominal value. The PQ inverter is used to supply given active and reactive set points.

4. CONCLUSION

In this work study of the Micro Grid Concept has been made. The Micro Grid consists of a low voltage distribution network with distributed energy sources (the Micro sources) together with storage devices and controllable loads, operating in a controlled coordinated way through the use of advanced management and control systems supported by a communication.

REFERENCES

[1] Fang.Gao" A Control Strategy for a Distributed Generation unit in Grid connected and autonomous modes of operation." *IEEE Transactions on Power Systems*.vol.23 no.2, pp-850-859 April 2008.

[2] J.A Pecas Lopes C.L Moreira, and AG Madureia "Defining Control Strategies for Micro Grids Islanded Operation." *IEEE Transcations on Power Systems*.vol.21 no.2, pp-916-920 May 2006.

[3] F.Katirae" MicroGrid Autonomous Operation during and subsequent to islanding process. "IEEE *Transcations on Power systems.* vol.20.no.1, pp-248-257 January 2008.

[4] J.A. Peças Lopes, N. Hatziargyriou, J. Mutale, P. Djapic, and N. Jenkins, "Integrating distributed generation into electric power systems: a review of drivers, challenges and opportunities."*Electric Power Systems Research*, vol. 77, no. 9, pp. 1189-1203, July 2007.

[5] F.Katiraei and M.Iravani, "Power management strategies for a Micro Grid with multiple distributed generation units." *IEEE Transactions on Power Systems*, vol. 21, no.4, pp. 1821-1831, November 2006.

[6] Y. Zhu and K. Tomsovic, "Development of models for analyzing the load-following performance of Micro turbines and fuel cells." *Electric Power Systems Research*, vol. 62, no.1, pp. 1-11, May 2002.

[7] J. Padullés, G. W. Ault, and J. R. McDonald, "An integrated SOFC Plant dyamic model for power systems simulation." *Journal of Power Sources*, vol. 86, pp.495-500, March 2000.

[8] Cashing Wang "A Physically based dynamic model for Solid Oxide fuel Cell" *IEEE Transactions on Energy Conversion*, vol. 22, no. 4, and pp.887-896. December 2007.