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Enhancement of Voltage Stability by using Fuel Cell as Shunt Compensator

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Abstract - *As Power industry is facing many Problems in maintaining system stability; it requires the installation of compensating devices. But the price of the compensating devices adds burden to consumer consumption changes. As Fuel cell systems are enhancing due to their ability in supplying electricity in remote areas and distributed power generation mainly during peak loads. Hence utilization of fuel cell as a compensating device is proposed in this paper. Fuel cell is modeled as a shunt compensating device. The proposed compensating unit makes the system to work properly whenever more loads are added into the system. The modelling of fuel cell as a compensating device in improving the voltage profile is carried out in MATLAB Simulink environment.*

***Key Words*: Fuel Cell; Boost Converter; MOSFET; Inverter; PWM; Voltage Stability; Distribution system**

1. INTRODUCTION

Energy is being considered as one of the major requirement for the development of country. As the need of energy is increasing day by day, much more energy must be produced in order to meet the demand [1]. The task of providing electricity in the developing countries, demands for huge investment, exploitation of energy sources, energy efficient measures, energy conservation in order to make the development sustainable. Renewable energy sources are becoming popular now a days and especially the rapid developments in PV technologies is growing day by day. Due to the massive increase in the price of fossil fuels, more attention is being given towards sustainable energy sources. Amongst various sources of energy, fuel cell technology is becoming quite popular now a day. To enhance the efficiency of fuel cells, efforts are being pursued over the globe and utilize the waste heat for energy conservation by coupling with the devices. Therefore concerning to the benefits associated with fuel cell technology, security of electricity can be ensured in future. This paper presents the new concept of utilizing fuel cell to improve the voltage profile in the system, whenever more loads are added. Fig-1 shows the fuel cell system connected to grid through boost converter and inverter.

Barbosa.P. [2] grants the use of Pulse Width Modulation Voltage Source Inverter (PWM-VSI) where the concepts of instantaneous P-Q (Real-Imaginary) Power theory are followed. Nancy L.Garland. [3] addresses the global view of fuel cells and clean energy technology and also several options for hydrogen infrastructure. Zhe Zhang. [4] conferred the overview of power electronic converters and inverters for fuel cell hybrid power conversion system where the dual input DC-DC converter interfaces the fuel cell and the Auxiliary Power System (APS) such as super capacitor bank to three phase Neutral Point Clamped (NPC) inverter and manages the power flow in the system. Mohammed Abu Mallouth. [5] gives information about several intelligent control strategies that has been proposed for the optimal performance of a fuel cell hybrid auto rickshaw where a fuzzy logic control strategy was tested and compared with the Fuel Cell Load Following Strategy (FCLS) on a fuel cell hybrid electric rickshaw model using a realistic drive cycle. M. Arun Bhaskar. [6] Presents the modelling of wind farm as a fully controlled converter-inverter based doubly fed induction generator and modelling of Photo Voltaic Solar Farm (PVSF) as voltage source inverter to regulate the grid voltage. J. M.Correa. [7] shows the simulation of fuel cell stacks using computer controlled high power converter which is used to inject the power into the grid. Liang.Y. [8] proposed the idea of cascading several identical full bridge voltage source inverters where the Phase Shifted SPWM unipolar voltage switching scheme is employed to control the switching devices of each voltage source inverter. Khadkikar.V. [9] have projected the modelling of inverter as a compensator to regulate the grid voltage. The rest of the paper sorted by the following; fuel cell with boost converter design is described in section 2; inverter modelling with results is provided in section 3; Section 4 discusses the the voltage stability enhancement for the test system and results ; Section 5presents conclusions of the work.

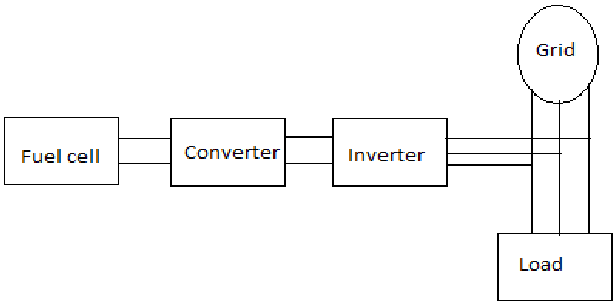

Fig-1: Fuel cell system connected to the grid

2. FUEL CELL WITH BOOST CONVERTER DESIGN

Fuel cell is a device that converts chemical energy stored in gaseous molecules of fuel and oxidant into electrical energy. The pressurized input fuel passes over the anode (and oxygen over the cathode) where it catalytically splits into ions and electrons. The electrons go through an external circuit to serve an electric load while the ions move through the electrolyte toward the oppositely charged electrode. The byproducts of fuel cell are water and heat when hydrogen is the input. The amount of power produced by a fuel cell depends upon several factors, such as fuel cell type, cell size, the temperature at which it operates, and the pressure at which the gases are supplied to the cell. There are five types of fuel cells based on the type of electrolyte used: 1) Proton Exchange Membrane Fuel Cell (PEMFC), 2) Solid Oxide Fuel Cell (SOFC), 3) Molten Carbonate Fuel Cell (MCFC), 4) Phosphoric Acid Fuel Cell (PAFC), 5) Aqueous alkaline Fuel Cell (AAFC). Among the types of fuel cell, PEMFC is being used in this paper because of its low working temperature, high energy density and simple structure. The DC output voltage obtained from the fuel cell is 90V. Fuel cell can be implemented as Shunt compensating device by connecting the fuel cell stack to the voltage source converter. The converter used here is the boost converter to increase the voltage level. Boost Converter consists of inductor, switching device (MOSFET). This boost converter has the values of L, C, R as 12μH, 1000μF and 34Ω. Fig-2 shows the Fuel cell with boost converter. Fig-3 shows the Fuel cell output.

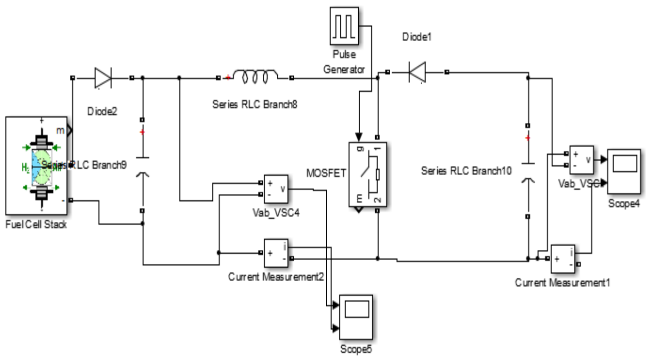

Fig-2: Fuel cell with Boost Converter

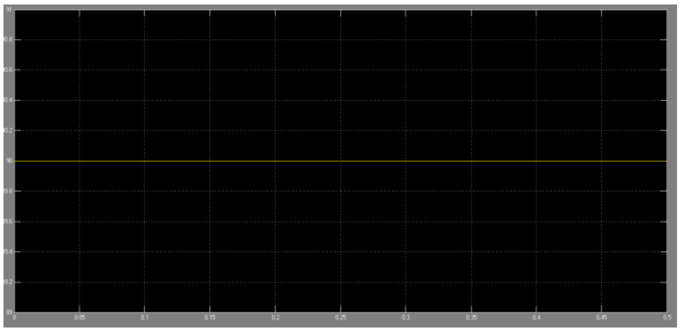

Fig-3: Fuel cell output

3. INVERTER MODELLING

The dc-ac converter, also known as the inverter, converts dc power to ac power at desired output voltage and frequency. A power inverter is an electronic device or circuitry that changes direct current (DC) to alternating current (AC). The DC output voltage from the boost converter is converted into AC output voltage using three phase inverter. Switching device used is MOSFET with a switching frequency of 20 kHz. Fig-4 shows the inverter modelling consisting of six MOSFET switches. Each switch is energized from the Pulse Width Modulation (PWM) gate pulses. A pulsed output waveform is obtained from the inverter which is shown in Fig-5. The pulsed output waveform from the inverter is filtered by LC filter of values L=10mH and C=20μF. Fig-6 shows the pure sinusoidal waveform obtained from the inverter.

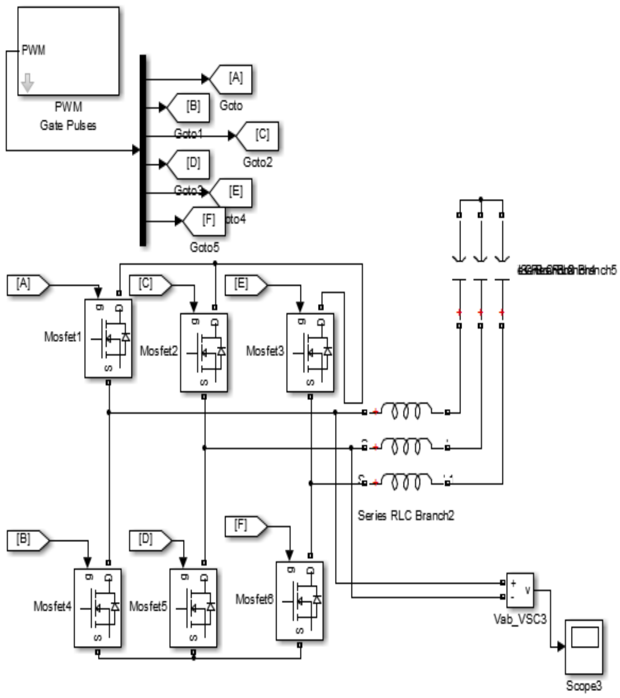

Fig-4: Inverter modelling

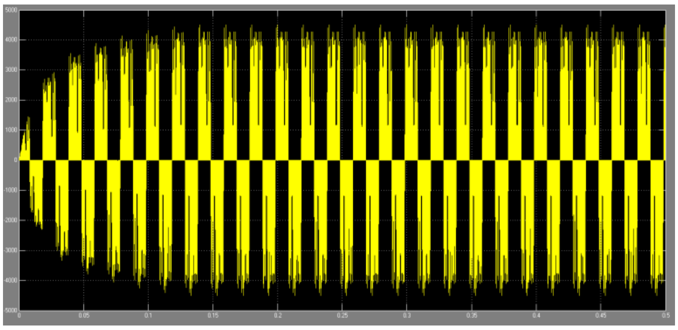

Fig-5: Pulsed output waveform

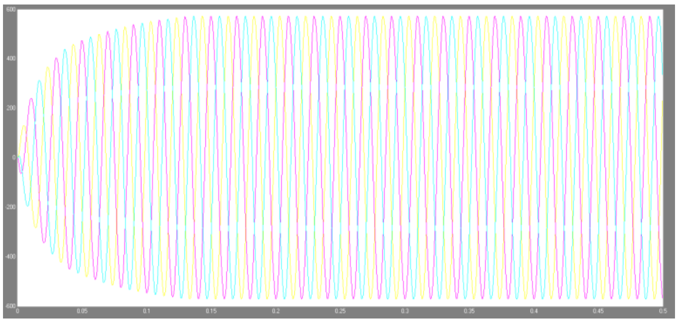

Fig-6: Sinusoidal waveform

4. VOLTAGE STABILITY ENHANCEMENT

The objective of voltage stability is to maintain acceptable voltages at all buses in the system under normal operating conditions and after being subjected to a disturbance. A system enters into a state of instability when there is a disturbance, an increase in demand or inability of power system to meet the demand for reactive power. In the normal operating condition the voltage of power system is stable, but when the disturbance occurs in the system, voltage become unstable. This results in a progressive and uncontrollable decline in the voltage. Voltage stability is sometimes also called as load stability. The acceptable voltage range is between (0.95-1.05) p.u.

4.1 System without Fuel cell based compensator

Fig-7 shows the single line diagram of the test system consisting of three phase source of 415V supplying voltage to the load of 9kW through a distribution line. A fuel cell based compensator is connected at the load side through a transformer at the point of common coupling. The voltage instability is created by adding additional loads. Fig-8 shows the voltage level when load 1 is connected. The load 2 of 5kW is connected by using a circuit breaker. The transition time of load 2 circuit breaker is between (0.22s-0.36s). This creates a drop in voltage which is shown in Fig-9. Fig-10 shows the grid side output voltage when load 3 is connected.

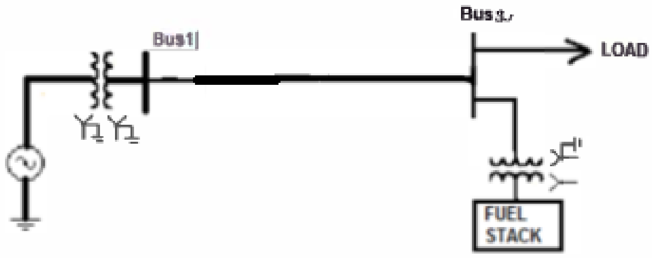

Fig-7: Single Line Diagram for the Test System

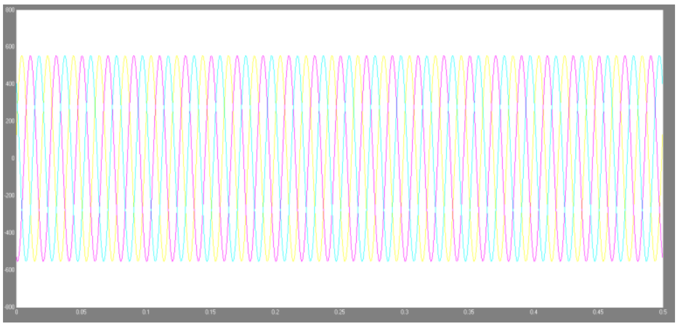

Fig-8: Grid side voltage when load 1 is connected

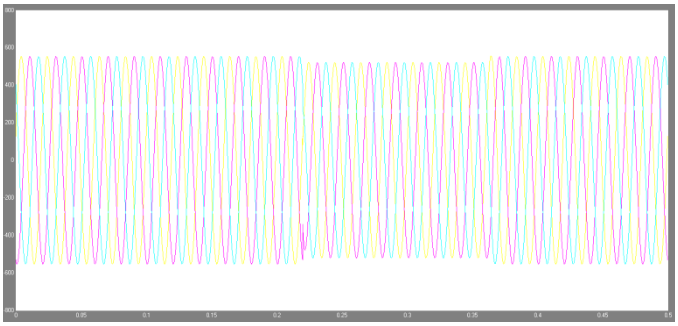

Fig-9: Grid side voltage when load 2 is connected

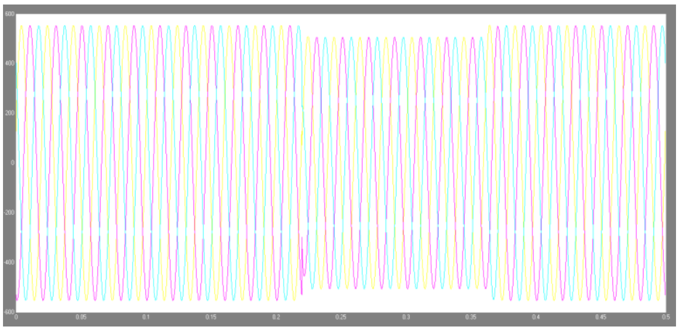

Fig-10: Grid side voltage when load 3 is connected

4.2 System with Fuel cell based compensator

Fuel cell based compensator is connected to the system at the load side. This injects additional voltage at the load side and thereby enhances the voltage stability which is shown in

Fig-11. Thus Fuel cell based compensator enhances the voltage stability even after adding additional loads.

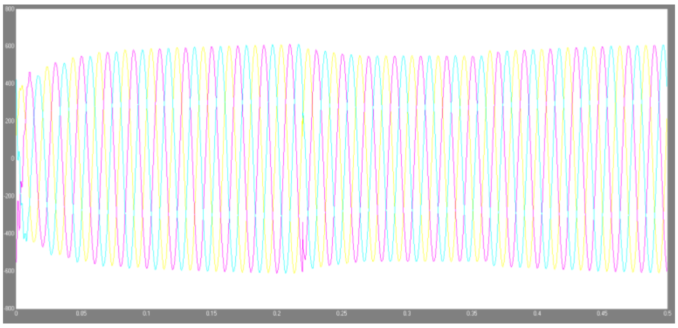

Fig-11: Grid side voltage after adding Fuel cell based compensator

Table-1: Different types of voltage level

Case	Voltage level (p.u)
Base case	1.00
After connecting load 1	0.94
After connecting load 2	0.88
After connecting load 3	0.86
After connecting Fuel Cell	0.96

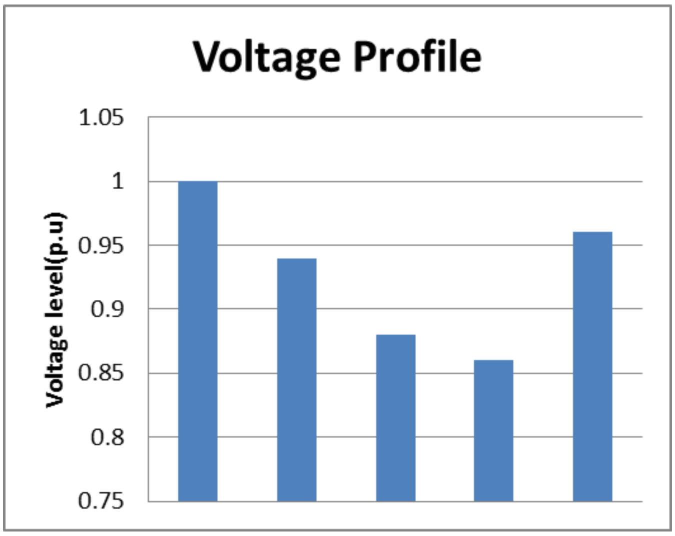

Fig-12: Voltage profile for different cases

5.CONCLUSIONS

The trend for Fuel Cell is high energy conversion efficiency. In this paper, a new approach of utilizing Fuel cell as a shunt compensator has been projected to improve the voltage profile of the system whenever additional loads are added. The test carried out in MATLAB Simulink software shows that the proposed model enhances the voltage stability to a satisfactory level and attains the system stability at a faster rate.

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BIOGRAPHIES

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