RESEARCH ARTICLE OPEN ACCESS

Transformer less Grid Connected Fuel Cell System to Control the Flow of Active and Reactive Power

Deepak Kumar*, Kuldeep Singh Bedi*, Ankit Goel*
*(Department of Electrical and Electronics, UIET, Panjab University, Chandigarh)

ABSTRACT
This paper presents a control scheme which controls the active and reactive power flow from the Fuel cell system to grid connected load. Fuel cell system can be connected to the grid using single stage or two stage method. In this paper we use single stage method and transformer less to reduce the cost and losses of the system. As we are injecting reactive power to grid even when there is no fuel cell power. To inject reactive power, system extracts active power from the grid even when there is no power from fuel cell. Therefore the converter has to work continuously with grid. This forces to use single stage system. Control scheme is implemented in such a manner that it provides reactive power as per the requirement of the load or grid. Fuel cell simulation is done using the basic equation. Passive filter is used to reduce the harmonic produced by inverter.
Keywords - Fuel Cell (FC), Grid, reactive, active and power.

I. INTRODUCTION

Now a day's energy is most important requirement for the development of every country. Environment issues like global warming are a hurdle for generation of electrical energy from conventional methods. Therefore world is looking for the renewable energy resources to reduce the carbon emission in the atmosphere. Most economical and feasible renewable resources are available such as wind, photovoltaic, geothermal, fuel cell. As energy need is rapidly increases for the development of any country keeping the environmental clean and safe for next generation. Fuel cells are electrochemical device which generate DC electrical energy via an electrochemical reaction. There different types of fuel cells are available such as Alkaline Fuel cells, Proton Electrolyte Membrane Fuel cell, Phosphoric Acid Fuel cell, Molten Carbonate Fuel cell and Solid Oxide Fuel cell. Fuel cell system is simulated using basic equations [5]. There are two types of techniques used in photovoltaic system (Single stage and two stage technique). In single stage technique only inverter is used to convert DC to AC. Two stages technique consist of one DC to DC converter and DC to AC converter. In this paper we use single stage system which means only one converter is connected with the grid. Control scheme uses Parks transformation to control the active and reactive power of a grid connected fuel cell stack. Parks transformation converts three phase system to two phase system without changing the power. Control strategy applied in this also controls the reactive power in [6]. Single stage grid connected fuel cell system which consists of fuel cell stack as voltage source, DC link capacitor, inverter, LC passive filter, grid source and controller.

II. MODELING AND CHARACTERISTIC OF THE FUEL CELL

In this paper a particular fuel cell stack is taken which is operating at nominal condition of temperature and pressure. The parameter of the equivalent circuit can be recalculated in reference to the polarization curve.

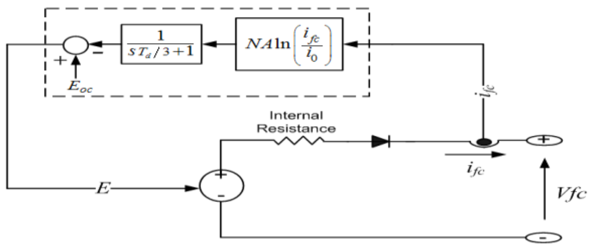

Fig-1 Simplified model of fuel cell

As per the polarization curve nominal and maximum operating points can be calculated. A typical polarization curve divided into three regions such as activation region, ohmic region and Mass transport region [5]

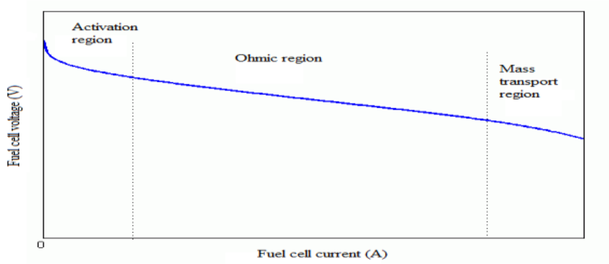

Fig-2 Polarization curve of typical fuel cell

III. SYSTEM COMPONENT

Figure-4 shows Block diagram of complete scheme which is to be implemented. This system consists of different components such as Fuel cell model which is simulated with help MATLAB using basic equation, IGBT based voltage source inverter, LC passive filter, control scheme with three PI controller and programmable voltage source as grid.

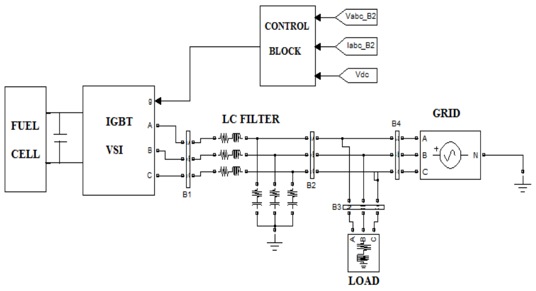

Fig-3 Block Diagram

IV. CONTROL SCHEME

This system is operated as a controllable voltage source connected in parallel with the power grid. In order to control the active power (P) as given by the equation (3) phase angle between two different sources. Active power can be vary by controlling phase angle between the inverter output voltage and grid voltage. Reactive power (Q) is a function of the magnitudes of inverter and grid voltages as given by equation (4). Phase angle (□) varies with change in power generated by the fuel cell system. Whenever inductive or capacitive load is connected with grid connected fuel cell system. The system will generate the required reactive power by increasing or decreasing the voltage level of the inverter output voltage. The inverter output voltage can be changed by changing the modulation index of the inverter. When the output voltage of inverter is higher than the grid voltage the reactive power is supplied by the FC system to grid. Reactive power is absorbed when inverse of inverter voltage is lower than the grid voltage. Active power is transfer from leading to legging [2-3]. Therefore when inverter output voltage is leading the grid voltage active power will transfer from FC system to grid.

$$P = \frac{V_i^2}{Z}\cos\delta - \frac{V_i}{Z}\cos(\phi - \beta + \delta) \quad (1)$$

$$Q = \frac{V_i^2}{Z}\sin\delta - \frac{V_i}{Z}V_g\sin(\phi - \beta + \delta) \quad (2)$$

For unity power factor operation at grid, β = 0, assuming R is very small for only inductive coupling, $\delta = 90°$, $Z = jX$, become

$$P = \frac{ViVs}{X}\sin\phi \quad (3)$$

$$Q = \frac{Vi^2 - ViVs}{X}\cos\phi \quad (4)$$

To transfer maximum power a single stage grid connected FC system is used. To vary DC link voltage according to reference signal generated for a particular load, modulation index of the inverter is varied. Using Parks transformation three phase signals are converted to two phase signal. One of the phase represent the direct axis components which is real parts of three phase system and another phase represent the quadrature axis which is imaginary part of three phase system.

$$\text{Modulation index (m)} = \sqrt{V_d^2 + V_q^2} \quad (5)$$

$$\text{Phase angle } \phi = a\tan 2\left(\frac{V_d}{V_q}\right) \quad (6)$$

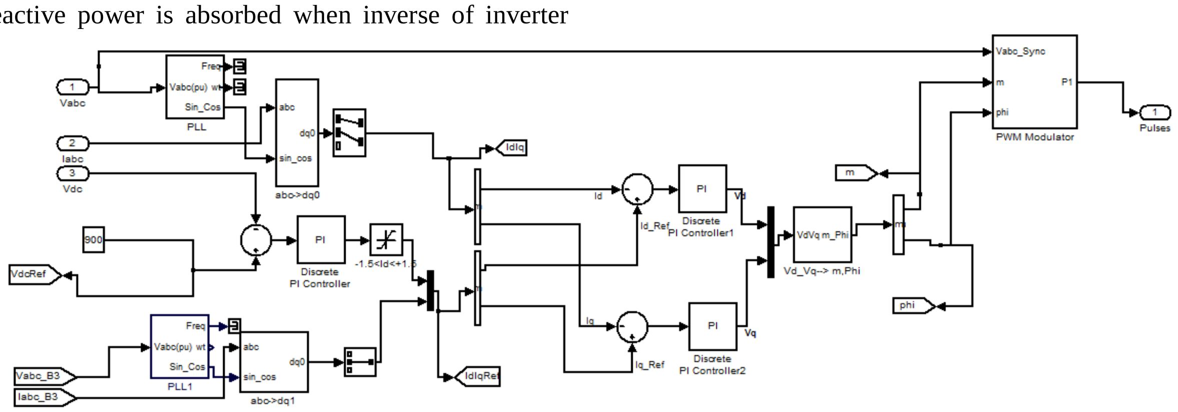

Fig 4- Control scheme

DC link and DC link reference voltage are compared to generate error signal. Error signal given to (DC voltage regulator) PI controller which generates I_{dref} as shown in figure-4. To control reactive power I_{qref} signal is generated from the load side in order get unity power factor across load. I_{qref} signal is compare with the actual signal from inverter side I_q to generate an error ΔI_q. Similarly I_{dref} signal is compare with the I_d signal of the inverter. Error signal are given to PI controller (current controller) through which signal are converted into V_d, V_q as shown in the figure-4. V_d, V_q signal which are further converter in phi (□) and modulation index (m). Using below given equations, atan2 is four-quadrant inverse tangent.

Frequency of grid	50Hz

Vdc	Variable (800to1100 volts)
Cdc	1500µF
Voltage of grid (Vg)	440Volts
Voltage of inverter (Vi)	440Volts
DC voltage controller • Proportional gain Kp • Integral gain Ki	 0.6 20
Current controller • Proportional gain Kp • Integral gain Ki	 0.2 10
LC filter • Reactor • Capacitor	 1.8mH 20µF
Inverter switching frequency	15KHz

TABLE-1 System parameters

V. RESULTS AND DISCUSSION

In fig-13 it is shown that at the initial stage transient and system get stable at 0.04 seconds this shows that controller working effectively. Fuel cell generates 49.62KW at 900V and 62.15KW at 860V of DC link voltage. A 30KW resistive load and 10 KVAR inductive load is connected to grid and fuel cell system through inverter. In the fig-15 it can seen that local load is supplied through the inverter and rest of the power is transfer to the grid. In 0 to 0.25 seconds power transfer to grid is 19.62KW and 32.15KW at 0.25 to 0.5 seconds by fuel cell system. Grid and inverter both partially supply the load. As per the power quality is concern harmonic are reduce by using the passive filter. From the result it can seen that inverter current varies as DC link voltage changes and its THD (Total Harmonic Distortion) is 0.72% as shown in fig-(5-6). Load current remain same even when there change in DC link voltage or power change in fuel cell and its THD is 0% as shown in fig-(9-10). Total harmonic distortion of load, grid and inverter voltage is also 0%. Grid current varies with respect to inverter current and its total harmonic distortion is 1.56% as shown in fig (7-8). Fig-13 shows reactive power supplied by Fuel cell system. The FC system generates reactive power as per the requirement of the load only or it can also generate more reactive power if required by the grid as shown in control scheme. Sudden change in DC link voltage level effect the reactive power which can be seen in fig-13 and also the reactive power supply the grid. Fig-14 shows the DC link voltage which varies according to the reference signal. The phase angle phi (□) changes with change in the I_{dref} signal. According to phase angle phi (□) active power transfer from PV system to grid.

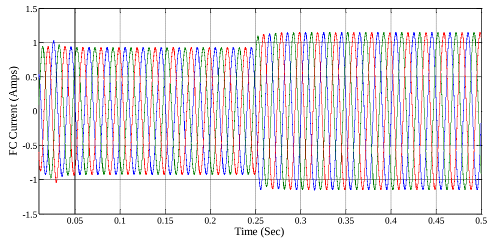

Fig-5 Inverter current

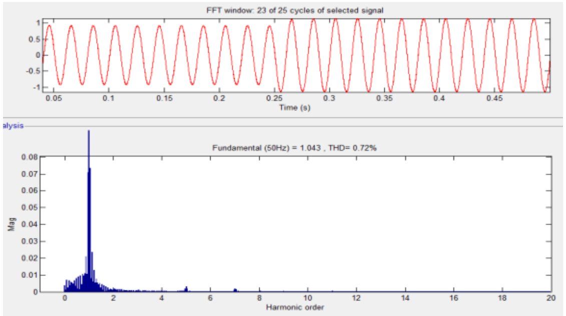

Fig-6 THD of Inverter current

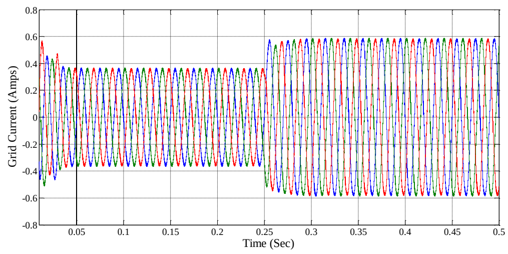

Fig-7 Grid current

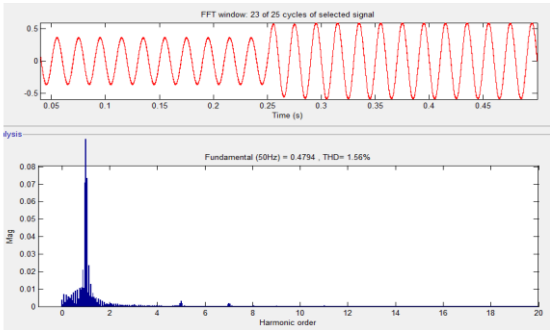

Fig-8 THD of Grid current

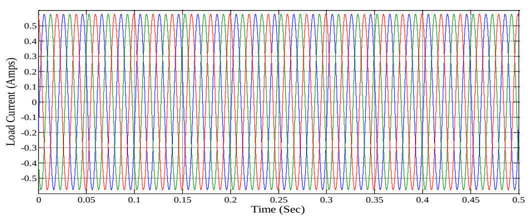

Fig-9 Load current

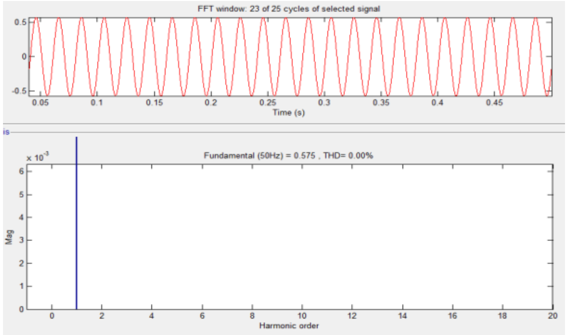

Fig-10 Load current

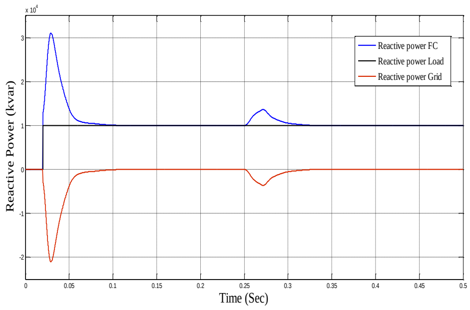

Fig-11 Reactive power

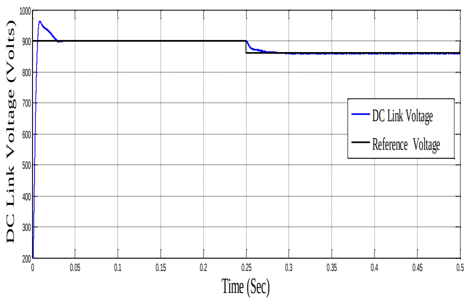

Fig-12 DC link Voltage

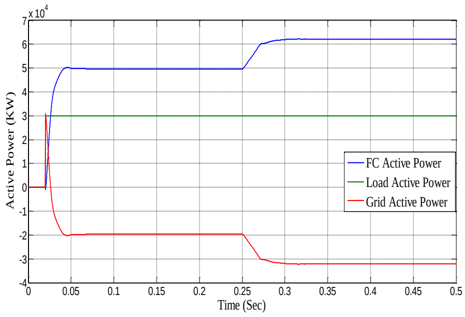

Fig-13 Active power

VI. CONCLUSION

This paper has presented active and reactive power flow control approach for a single distributed generation unit connected to the utility grid with a local load. Single stage method and transformer less system is used to reduce the cost and losses of the system. Control technique uses Parks transformation. Reactive power is supplied as required by local load or grid. Active power is varied in order to fulfill the local load and to supply power to grid when more power is generated. Passive filter is implemented in order to reduce maximum possible harmonic produce by inverter. Interconnected system's grid current THD is bellow the permissible limit as per the IEEE 519-1992 recommended limits (< 5%). The proposed scheme is implemented in MATLAB Simulink software, tested and good results are obtained.

REFERENCES

Journal Papers:

[1] A. Cruden, T. Houghton, S. Gair, M. Duerr, G. D. Agnew, E.M. Stewart, and A. Lutz, "*Fuel cells as distributed generation*," *Journal of Power and Energy*, vol. 222, Aug. 2008 pp.707-720.

[2] Saeed Jahdi, Loi Lei Lai, *"DC-DC Converters Application in Fuel-Cell Stack Grid Integration*," Electrical Power Quality and Utilization, 2011, 1-6.

[3] Min Dai, Mohammad Nanda Marwali, Jin-Woo Jung, Ali Keyhani, "*Power Flow Control of a Single Distributed Generation Unit*," IEEE TRANSACTIONS ON POWER ELECTRONICSVOL.23, NO. 1, JANUARY 2008.

Books:

[4] N. Mohan, T. M. Undeland & W. P. Robbins. New York:John Wiley & Sons "*Power Electronics Converters, Applications and Design*," 1989.

Proceedings Papers:

[5] Gitanjali Mehta, S P Singh, "*Grid interfacing fuel cell system with active and reactive power flow control*," SEICON 2011, pp.554-559.

[6] Kuldeep Singh Bedi, Dr. Tilak Thakur, "*Data based MPPT technique for Photovoltaic system*," INDICON 2011, pp. 1-5.