# A Novel Grid-Connected PV-FC Hybrid System for Power-Management

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**Abstract-** Grid connected photovoltaic (PV) systems and fuel cell (FC) feed electricity directly to the electrical network operating parallel to the conventional source. This paper deals with design and simulation of a three phase inverter in MATLAB SIMULINK environment which can be a part of photovoltaic grid and fuel cell connected systems. The converter used is a Voltage source inverter (VSI) which is controlled using synchronous d-q reference frame to inject a controlled current into the grid. Phase lock loop (PLL) is used to lock grid frequency and phase. The design of low pass filter used at the inverter output to remove the high frequency ripple is also discussed and the obtained simulation results are presented.

**Index Terms-** Photovoltaic cell; Fuel cell; Grid; Islanding

## I. INTRODUCTION

Authors are encouraged to have their contribution Renewable energy sources have been taken the place of the traditional energy sources and especially rapidly developments of photovoltaic (PV) technology and fuel cell (FC) technology have been put forward these renewable energy sources (RES) in all other RES. PV systems have been started to be used widely in domestic applications connected to electrical grid and grid connected PV power generating systems have become widespread all around the world. On the other hand, fuel cell power generating systems have been used to support the PV generating so hybrid generation systems consist of PV and fuel cell technology are investigated for power generating. In this study, a grid connected fuel cell and PV power generating system was developed with Matlab Simulink. solar module was developed based on solar module temperature and solar irradiation. Output current and voltage of PV system was used for input of DC/DC converter and its output was used for the input of the inverter. PV system was connected to the grid and solid oxide fuel cell (SOFC) system was used for supporting the DC bus of the hybrid power generating system.

The work done related to PV and Fc grid connected systems published so far reveals how an inverter should bedesigned and output should be synchronized with the grid.Different control strategy to control grid current using p-qtheory and d-q theory with phase lock loop (PLL) control hasbeen discussed in those papers.

The work presented here is about the simulation of a VSI where the output current of inverter is controlled insynchronously rotating d-q reference frame. PLL is used to synchronize grid with Pv and Fc. The relevant standards and design of the entire system,simulink models and results obtained are presented in the subsequent sections.

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## 2.GRID-CONNECTED HYBRID POWER SYSTEM

The system consists of a PV-FC hybrid source with the main grid connecting to loads at the PCC .The photovoltaic and the PEMFC are modeled as nonlinear voltage sources. These sources are connected to dc–dc converters which are coupled at the dc side of a dc/ac inverter as shown in the below Figure1. The dc/dc connected to the PV array works as an MPPT controller. Many MPPT algorithms have been proposed in the literature, such as incremental conductance (INC), constant voltage (CV), and perturbation and observation (P&O). The P&O method has been widely used because of its simple feedback structure and fewer measured parameters . The P&O algorithm with power feedback control. As PV voltage and current are determined, the power is calculated. At the maximum power point, the derivative(dp/dv ) is equal to zero.

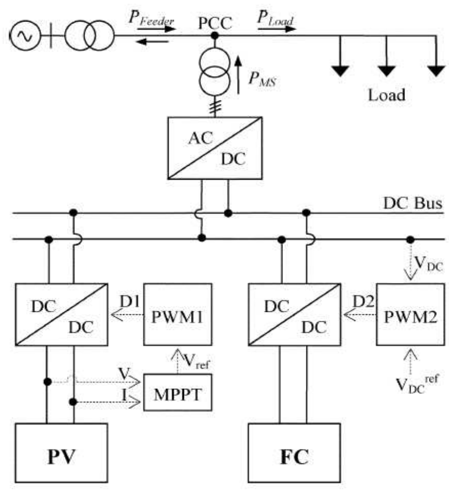



Fig1: Grid-connected PV-FC hybrid system

## 3.PHOTO VOLTAIC ARRAY

The power production capacity of single module is seldom enough to satisfy therequirements of a home or a business. Hence, the modules are linked together to form anarray . The DC power produced by the modules is converted into alternating current that can provide power to lights, motors, and other loads. Most PV arrays use an inverter to achieve this. The modules in a PV array are series connected to obtain the requisite voltage following which the individual strings are parallel connected to allow the system to generate more current. A photovoltaic array (or solar array) is a linked collection of solarpanels. Solar panels are typically measured under STC (standard test conditions) or PTC(PVUSA test conditions), and are given in watts. Panel ratings generally range from around100 watts to over 400 watts. The array rating is the sum of all the panel ratings. Its unit iswatts, kilowatts, or megawatts.

### *3.1 PV Array Modelling*

The solar cell arrays or PV arrays are usually constructed out of small identical building blocks of single solar cell units. They determine the rated output voltage and current that can be drawn for some given set of atmospheric data. The rated current is given by the number of parallel paths of solar cells and the rated voltage of the array is dependent on the number of solar cells connected in series in each of the parallel paths. A solar cell is basically a p-n junction fabricated in a thin substrate of semiconductor. When exposed to sunlight, some electron-hole pairs are created by photons that carry energy higher than the band-gap energy of the semiconductor. The figure 2 shows the typical equivalent circuit of a PV cell.

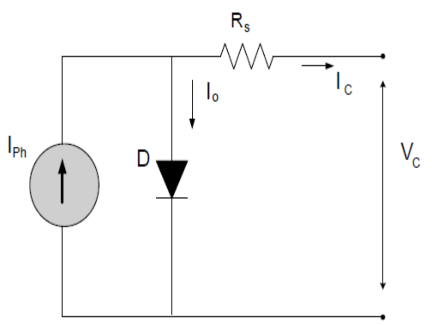



Fig 2: PV cell single diode equivalent circuit diagram

The typical I-V output characteristics of a PV cell are shown by the following equations:

Module Photo current ( Iph):

$$Iph = [Iscr + Ki(T - 298)]G/100$$

Module reverse saturation current Irs:

$$Irs = \frac{Iscr}{e^{(\frac{qVoc}{Ns})KAT} - 1}$$

Module saturation current Io:

$$Io = Irs = [\frac{T}{Ts}]e^{\frac{qEgv}{BK(\frac{1}{Tr} - \frac{1}{T})}}$$

The current output of PV module Ic:

$$Ic = NpIph - NIo[e^{\frac{q(Vc+Iph)}{NAKT}} - 1]$$

## 4.FUEL CELL MODEL

The PEMFC steady-state feature of a PEMFC source is assessed by means of a polarization curve, which shows the nonlinear relationship between the voltage and current density.

$$Vout = Enerst - Vact - Vohm - Vconc$$

where Enerst is the "thermodynamic potential" of Nerst, which represents the reversible (or open-circuit) voltage of the fuel cell.

Activation voltage drop Vact is given in the Tafel equation as

$$Vact = T[a + b\ln(I)]$$

where are the a,b constant terms in the Tafel equation (in voltsper Kelvin)

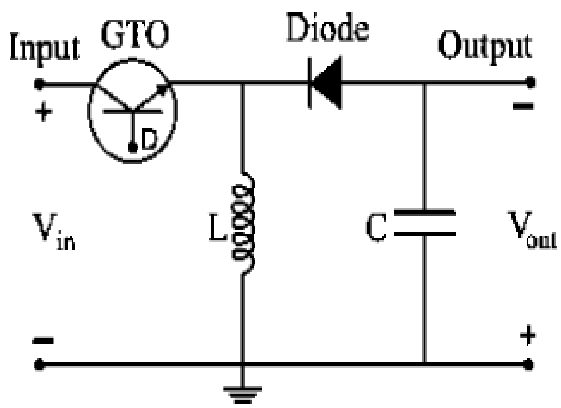



Fig 3: The overall ohmic voltage drop Vohm can be expressed as

$$Vohm = IRohm$$

The ohmic resistance Rohm of PEMFC consists of the resistance of the polymer membrane and electrodes, and the resistances of the electrodes.

The concentration voltage drop Vconc is expressed as

$$Vconc = -\frac{RT}{zF}\ln(1 - \frac{I}{Ilimit})$$

## PHASE LOCK LOOP (PLL):

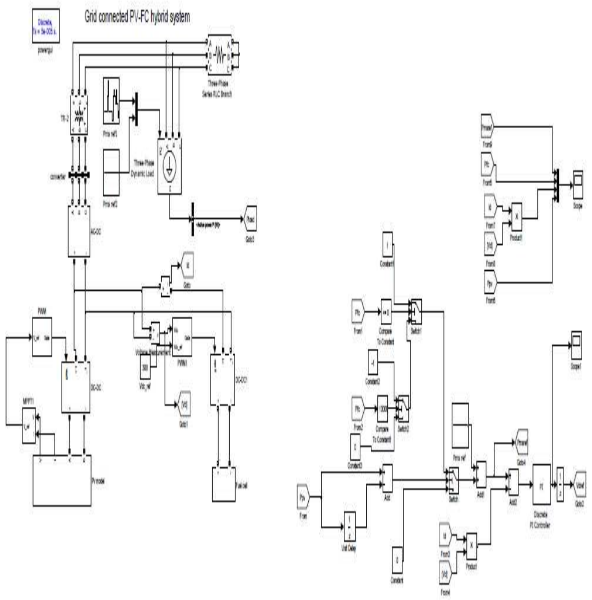
*E-ISSN: 2321-9637*

Grid synchronizations plays important role for grid connected systems. It synchronizes the output frequency and phase of grid voltage with grid current using different transformation. Different methods to extract phase angle have been developed and presented in many papers up to now PLL techniques causes one signal to track another one. It keeps an output signal synchronized with a reference input signal in frequency and phase. In three phase grid connected system PLL can be implemented using the d-q transformation and with a proper design of loop filter. Vabc is the sensed grid voltage which is transformed in to DC components using coordinate transformation abc-dq and thePLL gets locked by setting Vd* to zero. The loop filter PI is a low pass filter. It is used to suppress high frequency component and provide DC controlled signal to voltage controlled oscillator (VCO) which acts as an integrator. The output of the PI controller is the inverter output frequency that is integrated to obtain inverter phase angle θ. When the difference between grid phase angle and inverter phase angle is reduced to zero PLL becomes active which results in synchronously rotating voltages Vd = 0 and Vq gives magnitude of grid voltage.

**LC Fiter:**

Output voltage wave is synchronized with the grid voltage. So the PWM inverter will inject ripple current in to the grid. The output LC filter is connected to remove high switching frequency components from output current of inverter. The filter is designed taking into account the following parameters for the grid and inverter . The value of L is design based on current ripple. Smaller ripple results in lower switching and conduction losses

**5.SIMULATION DIAGRAM & RESULTS**



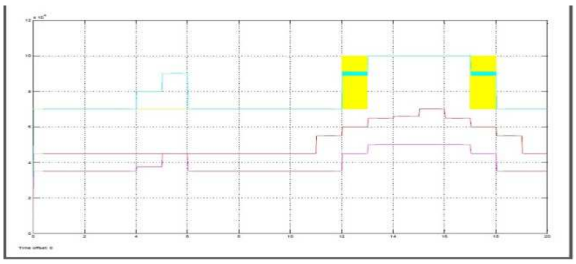



Fig : (4a)

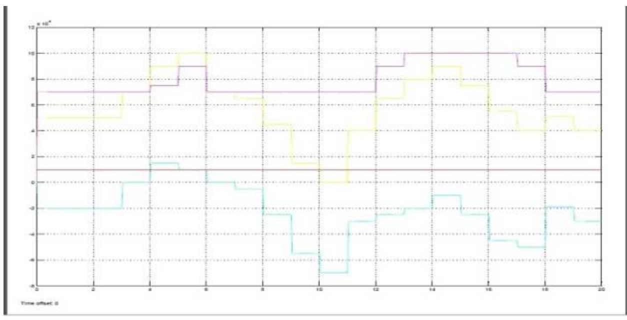


Fig : (4b)

Fig 4(a,b) : Active Power Simulation result without hysteresis. (4a) Operating strategy of the hybridsource. (4b) Operating strategy of the whole system

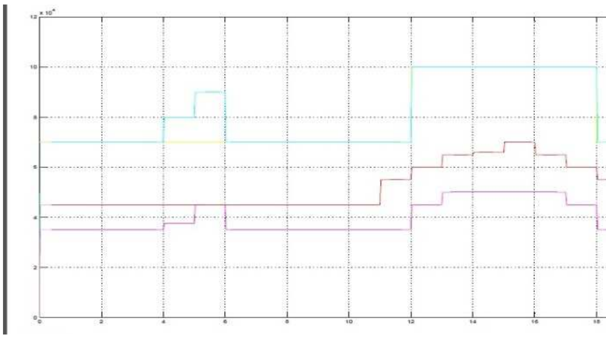


Fig : (4c)

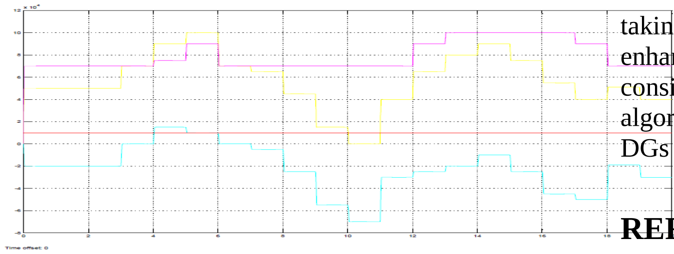


Fig : (4d)

Fig 4(c,d): Active Power Improving operation performance by using hysteresis: (4c) The operating strategy of the hybrid source; (4d) Operating strategy of the whole system.

## 6. CONCLUSION

This paper has presented an available method to operate a hybrid grid-connected system. The hybrid system, composed of a PV array and PEMFC, was considered. The operating strategy of the system is based on the UPC mode and FFC mode. The purposes of the proposed operating strategy presented in thispaper are to determine the control mode, to minimize the number of mode changes, to operate PV at the maximum power point, and to operate the FC output in its high-efficiency performance band.

The main operating strategy is to specifythe control mode;With the operating algorithm, PV always operates at maximum output power, PEMFC operates within the high-efficiency range , and feeder power flow is always less than its maximum value . The change of the operating mode depends on the current load demand, the PV output, and the constraints of PEMFC and feeder power. With the proposed operating algorithm, the system works flexibly, exploiting maximum solar energy; PEMFC works within a high-efficiency band and, hence, improves the performance of the system's operation. The system can maximize the generated power when load is heavy and minimizes the load shedding area. When load is light, the UPC mode is selected and, thus, the hybrid source works more stably. The changes in operating mode only occur when the load demand is at the boundary of mode change otherwise, the operating mode is either UPC mode or FFC mode. Besides, the variation of hybrid source reference power is eliminated by means of hysteresis. In addition, the number of mode changes is reduced. As a consequence, the system works more stably due to the minimization of mode changes and reference value variation. In brief, the proposed operating algorithm is a simplified and flexible method to operate a hybrid source in a grid-connected microgrid. It can improve the performance of the system's operation.The system works more stably while maximizing the PV output power.

For further research, the operating algorithm, taking the operationof the battery into account to enhance operation performance of the system, will be considered. Moreover, the application of the operating algorithm to a microgrid with multiple feeders and DGs will also be studied in detail.

## REFERENCES:

[1] T. Bocklisch, W. Schufft, and S. Bocklisch, "Predictive and optimizing energy management of photovoltaic fuel cell hybrid systems with shorttime energy storage," in Proc. 4th Eur. Conf. PV-Hybrid and Mini- Grid, 2008, pp. 8–15.

[2] J. Larmine and A. Dicks, Fuel Cell Systems Explained. New York: Wiley, 2003. [3] W. Xiao, W. Dunford, and A. Capel, "A novel modeling method for photovoltaic cells," in Proc. IEEE 35th Annu. Power Electronics Specialists Conf., Jun. 2004, vol. 3, pp. 1950–1956.

[4] D. Sera, R. Teodorescu, and P. Rodriguez, "PV panel model based on datasheet values," in Proc. IEEE Int. Symp. Industrial Electronics, Jun.4–7, 2007, pp. 2392–2396.

[5] C. Wang, M. H. Nehrir, and S. R. Shaw, "Dynamic models and model validation for PEM fuel cells using electrical circuits," IEEE Trans. Energy Convers., vol. 20, no. 2, pp. 442–451, Jun. 2005.

[6] C. Hua and C. Shen, "Comparative study of peak power tracking techniques for solar storage system," in Proc. 13th Annu. Applied Power Electronics Conf. Expo., Feb. 1998, vol. 2, pp. 679–685.

[7] A. Hajizadeh and M. A. Golkar, "Power flow control of grid-connected fuel cell distributed generation systems," J. Elect. Eng. Technol., vol. 3, no. 2, pp. 143–151, 2008.

[8] C. Hua and J. R. Lin, "DSP-based controller application in battery storage of photovoltaic system," in Proc.22nd IEEE Int. Conf. Industrial Electronics, Control, and Instrumentation, Aug. 5–10, 1996, vol.3, pp. 1750–1810.

[9] C. Hua, J. Lin, and C. Shen, "Implementation of a DSP-controlled photovoltaic system with peak

*E-ISSN: 2321-9637*

power tracking," IEEE Trans. Ind. Electron., vol. 45, no. 1, pp. 99–107, Feb. 1998.

[10] E. Koutroulism and K. Kaalitzakis, "Development of a microcontroller- based, photovoltaic maximum power point tracking controlsystem," IEEE Trans. Power Electron., vol. 16, no. 1, pp. 46–54, Jan.2001.

[11] N. Mohan, T. M. Undeland, and W. P. Robbins, Power Electronics,Converters, Applications and Design, 2nd ed. New York: Wiley,2003.

[12] R. H. Lasseter, "Microgrids," in Proc. IEEE Power Eng. Soc. Winter Meeting, Jan. 2002, vol. 1, pp. 305–308.

[13] R. H. Lasseter and P. Piagi, "Control and design of microgrid components,"Jan. 2006, PSERC final pro