Grid Connected Photo Voltaic- Hydrogen Fuel Cell Hybrid System

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Abstract – *The performance, technical aspects and practical considerations of a grid connected photo voltaic-fuel cell(PVFC) hybrid system is solidly analyzed in this paper. The photo voltaic generation is the global, simplest and economical way to harvest energy, among the other renewable energy sources. As the photo-voltaic (PV) system is not that reliable with the daily atmospheric conditions, this makes the hydrogen fuel cell(FC) system which is reliable and consistent regardless of the surroundings, to co-operate with the former one. These two renewable energy sources posses the convenient energy conversion to DC electricity. An MPPT algorithm of perturb and observe(P&O) is applied to harvest maximum power by triggering a boost converter for PV system and a buck converter is controlled for FC system, then the both systems are regulated to a 400V DC bus. A sinusoidal PWM inverter control is used for DC-AC conversion, and it is connected to the national grid using phase locked loop(PLL). MATLAB/SIMULINK modeling of the described system has been done for a 12KW rating and the desired output is obtained from the simulation.*

Key Words: PVFC, P&O, MPPT, PLL, etc…

INTRODUCTION

The major problem that human race experienced in the last decades of last century and still experiencing is nothing other than the energy problem. As the conventional sources are running on it's last reel we should travel through some other ways to lengthen the life of human kind as we living now. The renewable energy sources are the clean systems which never lose its quantity, quality and availability by the continues usage of any species.

The photo-voltaic system is the economical and feasible source among the renewable energy systems. Because the sunlight is constantly available on the surface of our globe, earth during day time and can be tracked and converted into electricity without much difficulty and money, photo-voltaic system is the first choice come into the mind of technocrats when it is the matter of energy harvesting.[1][2]

The photovoltaic/solar cells are the functional stage of conversion of light energy into electricity. The series and parallel combinations of solar cells/panels makes the required voltage and power rating of the systems. An optimum power harvesting method termed as maximum power point tracking, MPPT can be applied to the PV system to enhance the efficiency. The perturb and observe (P&O) algorithm with modified structure is widely used now in power tracking. The MPPT pulse drives the DC-DC converter at the PV system and the output is connected to the common DC bus where all other sources are fed their power.[3]

As the PV system is not that linear and trustworthy with every atmospheric condition, it should be in co-operate with some other energy sources which offers a consistent working characteristics like a battery/cells to supply a continuous power to the load. The hydrogen fuel cells are the best choice which offer a constant working characteristics and wide operating ranges.

Because of good efficiency, rapid response to load and flexibility, Fuel cell system with PV has a wide area of applicability in recent days. The fuel cell system works on the principle of electro-chemical reaction of hydrogen with oxygen. Due to the reaction of hydrogen and oxygen it generate electricity, heat and byproduct as water. The voltage and power rating of the fuel cell system is defined by the flow of hydrogen and oxygen from the storage tank and the concentration of hydrogen molecules. The FC system also need to have a DC-DC converter to convert the required DC level voltage which is fine with the constant DC bus.[2]

An inverter system which is used to convert the DC power into AC which most of the industrial and domestic loads consume. For the proper conversion into AC with required voltage level, frequency and phase sequence, proper inverter control has to be made. A three phase locked loop drive PWM pulse generator efficiently do this purpose.[2]

1. SYSTEM DESCRIPTION

In the proposed system both the PV and FC systems are designed and simulated to provide a 6 kW power delivering capacity each. The PV system is comprise of a number of parallel and series connections of PV panels in which each panel consist of numerous number of PV cells which are arranged to generate the required voltage and power rating.

1.1 MATHEMATICAL MODELING OF THE PV AND FC SYSTEMS

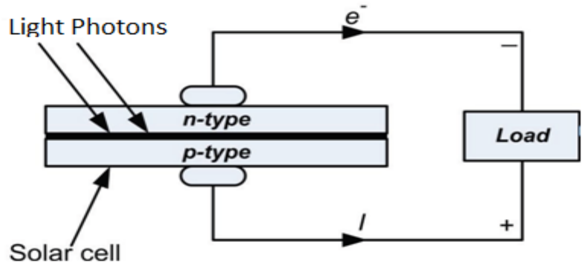

Fig 1. Structure of PV Cell

The parameters of PV system described in the proposed system is as given in table 1.

Table 1

Parameters of PV system	Specification
number of cell in a panel	64
number of series panels	24
number of parallel panels	4
open circuit voltage of panel	21.24 V
short circuit current of panel	2.55 A
irradiance level	1000w/m2
temperature level	298.15 K
maximum output voltage	500V
maximum output power	6 Kw

The PV system is a non-linear current source, that defined as load current that depends on the photo current and the saturation current, which depend on the atmospheric temperature and irradiance.[4][5]

The load current from the PV panel can be defined as,

$$I_L = [(I_{ph} * N_P) - I_d - I_{sh}] \quad (1)$$

Where,

The photo current and shunt current are given by

$$I_{ph} = [(T_{OP} - T_{ref})KI + I_{sc}] \quad (2)$$

$$I_{sh} = (V + IR_s)/R_p \quad (3)$$

In the case of fuel cell system there is also the parallel and series connections of fuel cells has been done to obtain the required voltage and power rating. The tank characteristics can be implemented to get the complete operation of the hydrogen fuel cell system. [5][6]

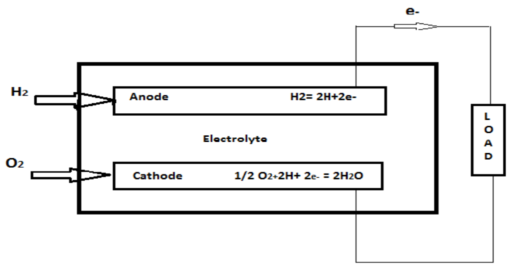

Fig 2. Structure of FC Cell

The parameters of hydrogen FC system is given in the table 2.

Table 2

Parameters	Specification
individual voltage of a cell	6 V
operating temperature	343
output voltage	510
output power	6 Kw

The fuel stack voltage and power can be controlled by the concentration of hydrogen and oxygen from the fuel tanks.

The voltage generated can be written as,

$$V\text{cell} = E + \eta\text{act} + \eta\text{ohmic} \quad (4)$$

Where,

$$\eta_{act} = -B\ln(CI) \quad (5)$$

$$\eta_{ohmic} = -R_{int}I \quad (6)$$

Now, the Nernst voltage in terms of gas molarities may be expressed as

$$E = N_0 \left[E_0 + (RT/2F)\log[P_{H2} P_{O2}^{0.5}] \right] \quad (7)$$

The modeling the PV and FC systems are based on these basic equations written above.

1.2 CONVERTERS

- DC-DC converters

In the proposed system there are two DC-DC converters and a DC-AC converter is co-operated to meet the objective of the entire system. The DC-DC converter used in PV system is a boost converter topology which is driven by the MPPT pulses from the P&O algorithm. Thus the boosted output voltage of PV panel is fed to the DC common bus and regulated at a value of 400V. [2]

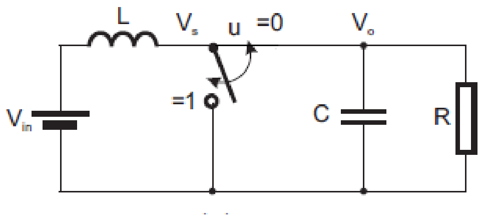

Fig. 3 Boost converter

The inductor value can be found as,

$$L_1 = (V_{out} - V_{in}) / (f_{sw} \Delta I_L) \quad (8)$$

On the other hand, the fuel cell side, a DC-DC converter of buck topology has used. Then the output voltage of the described converter is regulated to the common dc voltage at 400V.

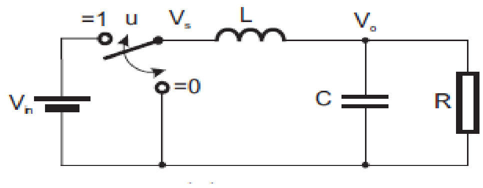

Fig. 4 Buck converter

The designed value of inductor can be expresses as,

$$L_2 = V_{out} (1-D) / (f_{sw} \Delta I_L) \quad (9)$$

- DC-AC converter

The DC-AC converter that used in the described system is three phase sinusoidal PWM controlled inverter which is coupled with a properly designed filter to generate the sinusoidal output with 50 Hz frequency. For grid synchronization three phase PLL is used in co-operate with the inverter control. [2]

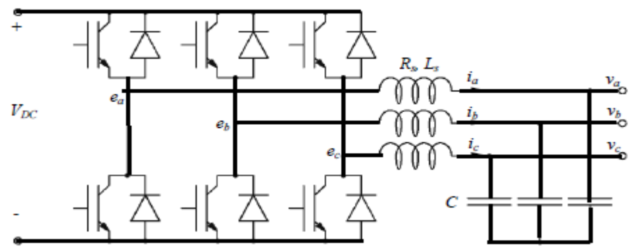

Fig. 5 Inverter with filter

1.3 MAXIMUM POWER POINT TRACKING

A number of MPPT algorithms are now widely applied on the photo-voltaic systems. Some of them are perturb and observe (P&O) method, incremental conductance(INC) method, ripple co-relation method, etc. The often used methods are P&O and INC algorithms which has more flexibility and reliability over others. Although the INC method has good performance over vibrant climatic conditions, it has a disadvantage of number of sensors needed is more, thus the conversion time which will affect the accuracy of the algorithm to track the maximum power. But, in the case of P&O, the sensors required is two and the conversion time is less. So, comparing the both methods, P & O has got more reliability and efficiency than the other methods.[3]

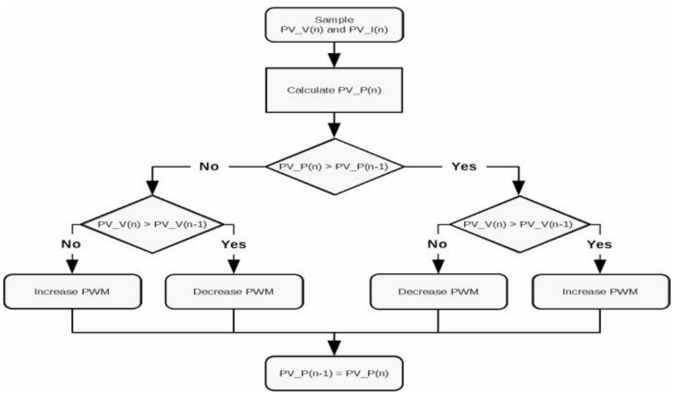

Fig. 6 P & O Algorithm

P&O method is based on the power calculation of the step intervals of very small time, and checking whether the power is increasing with the voltage or in reverse action. When it has checked once, then the algorithm starts to control the output impedance in order to maintain the output voltage of the PV panel at the required level. [3]

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2. IMPLEMENTATIONS AND SIMULATIONS

2.1 SYSTEM PARAMETERS

A 12kW PVFC hybrid system has been designed with considering ancillary parameters and limitations. The national grid, two renewable energy sources of PV and FC, inverter, filters and load is clearly given in the simulation diagram 3.1. The load sharing has done by controlling breaker switches across the transmission lines.

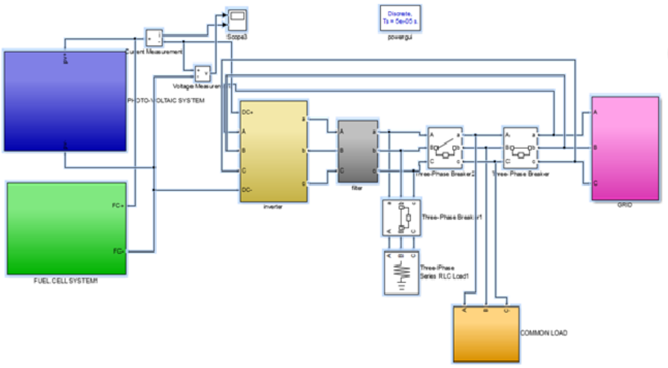

Fig. 7 PVFC System

The both of the DG sources are regulated at a common DC bus of 400V. It is done by the DC-DC conversion with controller. The fuel cell system model is built by utilizing the relationship between the output voltage and potential pressure of hydrogen and oxygen.

Three phase PLL technique have been used for synchronization between grid- interfaced converters and the utility network. An ideal PLL can provide the fast and accurate synchronization information with a high degree of immunity and insensitivity to disturbances.

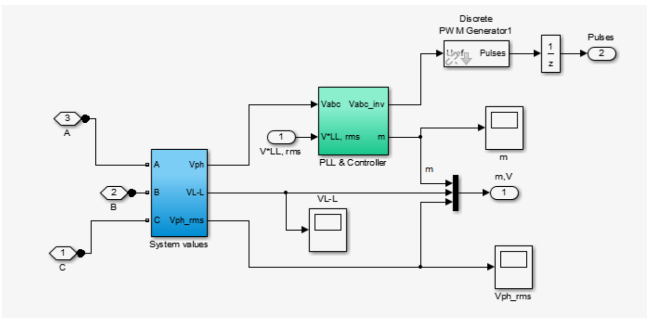

Fig. 8 Inverter control

2.2 MPPT

An MPPT algorithm of perturb and observe method is employed in the system simulation. As PV voltage and current are determined, the power is calculated. At the maximum power point, the derivative dP/dV is equal to zero. The maximum power point can be achieved by changing the reference voltage by the amount of ΔV_{ref}.

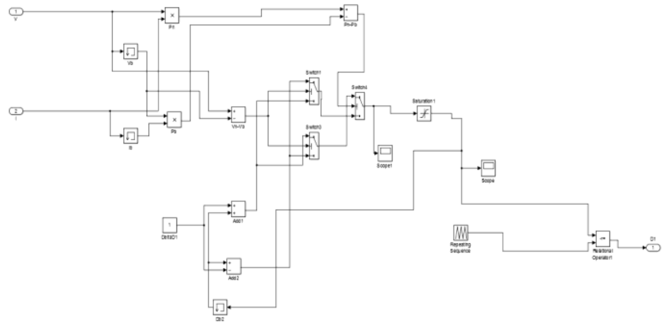

Fig. 9 MPPT

2.2 RESULTS AND DISCUSSION

The output voltage waveform of the PWM inverter is as shown in figure 4.6. The average sinusoidal wave is converted into pure sinusoidal one, by passing through a appropriately designed filter.

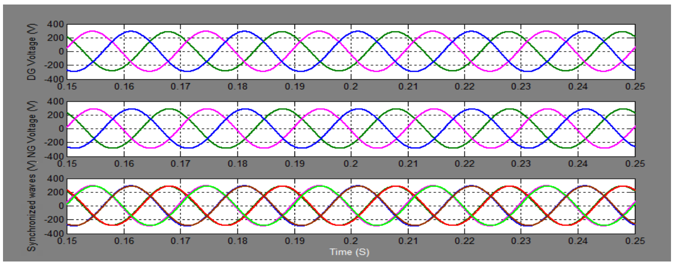

Fig. 10 Synchronized Voltages

The load current drawn from the DG is shown. It is in phase with the DG voltage as the common load is not having any reactance property. The current waveform shown below is drawn by a load of 12kW.

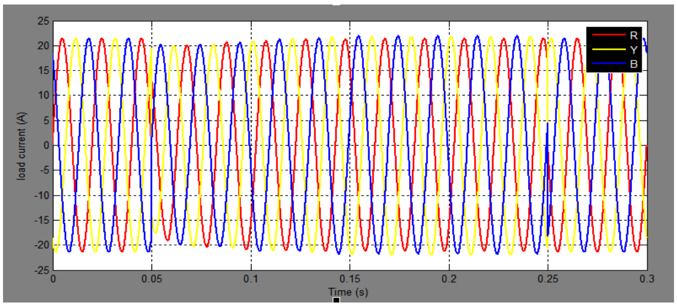

Fig. 11 Current at Load

The power contribution at the load is either by national grid or distribution generator. The portion from 0s to .05s shows the power provided by the national grid. From .05s to .25s, power is provided by DG. Then again national grid plays the role of power contribution.

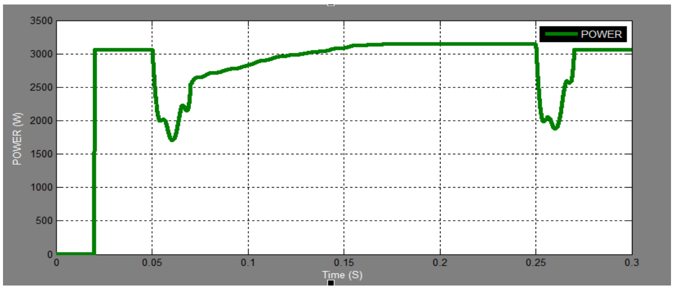

Fig. 12 Power Feeding by Single phase at common load

3. CONCLUSIONS

Obviously, a hybrid power system of the described system is too expensive and too labor intensive for the power industries and generation field. In this hybrid system with using fuel cell is more efficiency, long life and cheapest compare to hybrid system with using battery. The use of PVFC hybrid power generation is an especially vivid and relevant choice for as these are power sources of technological, political, and economic importance in their state. We can use any of the renewable energy sources for the hybrid system, but the described one shows the optimal control and power regulation. The key element concepts presented in this work are two renewable power sources connected to a power grid with complex electrical interactions.

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BIOGRAPHIES

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