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Active Power Control Toward Grid using Hybrid PV/Fuel Cell System

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Abstract—*To minimize emission of pollution and green house gases, encouragement of using non- pollution fuel are focused which boost the use of alternative resources like wind, sunlight or fuel cell. In this Paper, Hybrid PV/Fuel/Battery system has been demonstrated by using MATLAB/SIMULINK.PV and Fuel Cell are non polluting energy and also fuel used by both system are found in abundance. Battery bank is integrated together with PV and Fuel as backup to generate power for load as well as for grid. In this paper load prefer primary source of power from hybrid system and secondary from grid, by this way burden on grid is decrease and also customer can sell power to utility grid if excess power is generated. Simulation result at different load is shown in this paper using MATLAB/SIMULINK. These hybrid systems also control active power flow towards grid.*

1. INTRODUCTION

Everyday increasing electrical energy consumption, rapid advancement in wind, PV and fuel power generation technologies, and the rising public awareness for environment protection (like pollution and source of fuel) have turned alternative energy source and distribution generation as promising technology as a research interest for engineers and researchers. Due to natural intermittent properties of wind, water and solar irradiation these are most clean and easy available fuel available on earth for power generation. PV/Wind/Fuel cell used as standalone normally require a energy storage system (like Battery) or with some other form of generation to form a hybrid system. Because some of the renewable energy are compliment to each other like Fuel cell-Solar, Solar-Wind ad Wind- Fuel, multi-source alternative electrical energy system have more potential to produce high quality of electrical power and more reliable to consumer than a stand-alone system. If proper controls for different energy source are develop than hybrid system can be implemented for production of large electrical power from infinites source of clean energy. In this paper multi source Fuel Cell and Solar Cell are used to form a hybrid micro grid which produces power towards connected load within micro grid and utility grid. A micro grid is a group of interconnected loads and distributed energy resources within clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid. A micro grid can connect and disconnect from the grid to enable it to operate in both grid-connected and island mode.

2. HYBRID ELECTRICAL ENERGY SOURCE.

Hybrid system means interconnection of two different generation system where one system is compliment to the other system. In this paper Hybrid system is connected to Utility grid through inverter. Fig.1 shows hybrid system connected with utility grid

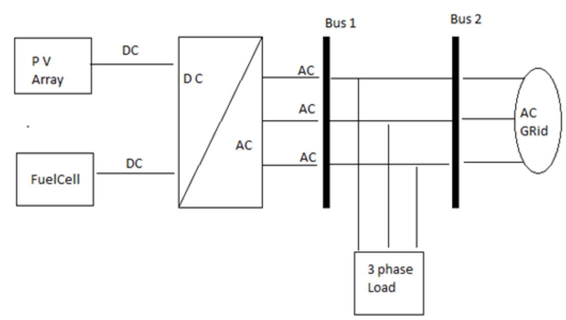

Fig. 1: Hybrid PV/Fuel cell system

2.1 PV CELL

Photovoltaic cell converts directly sunlight to electricity by photovoltaic effect, with no pollutant emission. It can generate direct electricity without any environmental impact and contamination when exposed to solar radiation. They are made up of PN junction. When sunlight hits the cell, photons are absorbed by semiconductor atoms, freeing electrons of negative layer. These electrons of negative layer find its path through an external circuit toward positive layer which results of flow of an electric current from the positive layer to the negative layer. Depending upon semiconductors and build up technology, a PV cell generate a voltage of around 0.5 to 0.8 volts. This voltage is low enough to be use. So to get more benefit from this technology, tens of PV cells (involving 36 to 72 cells) are connected in series to form a module. These modules are interconnected to form PV panel. The voltages are added with same current if modules are connected in series. When they are connected in parallel, their current is added while the voltage is same.

The three major families of PV cells are:

Môn crystalline technology: This technology is based on microelectronic manufacturing technology and its efficiency is in general between 10% and 15%.

Polycrystalline technology: This technology is also based on microelectronic manufacturing technology and its efficiency is in between 9% and 12%.

Thin film technology: for thin film cells, the efficiency is 10% for a-Si, 12% for CuInSe2 and 9% for CdTe.

2.2 Fuel Cell

Fuel Cell is a device that converts chemical energy into electricity from a fuel by direct combustion. This device uses hydrogen as a fuel to produce electrons, protons, heat and water. It consists of two electrodes, on positive called anode and one negative called cathode. They are separated by an electrolyte that allows the moving of positively charged hydrogen ions between two sides of fuel cell. Hydrogen fuel is supplied to anode of fuel cell and oxygen is supplied to the cathode of fuel cell. In chemical reaction, hydrogen is split into an electron and a proton. The proton passes through the electrolyte while the electrons are drawn from anode to the cathode through an external circuit, producing direct current electricity. Both are reunited at the cathode. The electron, proton, and oxygen combine to form by product of water.

According to electrolyte used fuel cell can be of following type.

Proton exchange membrane fuel cell (PEMFCS) type of fuel cell use a polymer electrolyte in form of thin, permeable sheets. This type of polymer will not leak or crack so that these cells operate at very low temperature around 80℃ which is used for commercial purposes. Efficiency is about 40% to 50%.

Phosphoric acid fuel cell (PAFC) type of fuel cell, the electrolyte is a liquid phosphoric acid which is bonded in silicon carbide matrix. These type of fuel cell work in temperature of around 200 degree Celsius. By using the heat the overall efficiency can be enhance from (37%-42%) to 80%.they cannot be easily poisoned by carbon monoxide. This fuel cell can be used in power stations.

Alkaline fuel cell type fuel cell, the electrolyte used is alkaline solution such as potassium hydroxide in water. This is used in many space programmes on NASA shuttles. They operate the temperature between 100 ℃-250 ℃.it is easily poisoned by carbon dioxide. Only pure hydrogen can be used as fuel. Efficiency is about 70%.

Solid oxide fuel cell (SOFC) generally used solid electrode yttrium stabilized zirconia which in non porous ceramic compound. It operates in high temperature which is around 1,000℃. Cell output is 100 KW. Hydrogen and higher hydrocarbons can oxygen ions travels from the cathode to the anode. These fuel cell's efficiencies could be 85%. It is used for large scale stationary power generators.

3. MODELING OF HYBRID SYSTEM COMPONENT

3.1 Modeling of PV system

The PV cell equivalent circuit consist a current source , a diode , a series resistance and a shunt resistance.

$$I=I_{ph}-I_D[\exp\frac{q\,[v+RsI]}{NKT}-1]-\frac{[V+RsI]}{Rsh} \text{...........3.1}$$

I_{ph} = Photocurrent

I_D = Reverse saturation of the diode

q = Electron charge

V = Voltage across the diode

K = Boltzmann's constant

T = Junction temperature

N = Ideality factor of the diode

R_s = Series resistor of cell

R_{sh} = Shunt resistor of cell

Eq 3.1 shows that output of pv cell is directly proportional to the light falling on it.

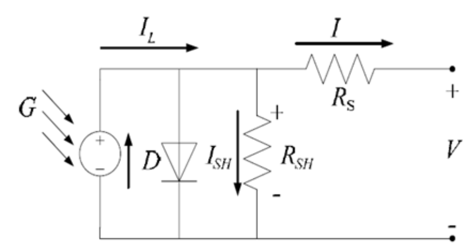

Fig. 2: Modeling of PV cell

Maximum Power Tracking Point

Maximum power point is the method which helps in increasing the efficiency of solar cell. Generally solar cell has low efficiency. To increase its efficiency, maximum power point tracking method has to be taken to enhance its functions. This technique is generally used to obtain maximum power from a varying source. As we know that the I-V curve in photovoltaic system is non linear, so this is difficult to be used to power a certain load. So, this done by utilizing a boost converter whose duty cycle is varied by using a mppt algorithm. A solar panel is used to power this boost converter. There are many methods which is used for maximum power point tracking but only incremental conductance method is used in this paper.

Incremental conductance method

When $\frac{dI}{dv}$ is equal and opposite to the value of I/V (where $\frac{dp}{dv} = 0$) then this method uses the PV array's incremental conductance $\frac{dI}{dV}$ to compute the sign of $\frac{dp}{dv}$ the algorithm knows that the maximum power point is reached and thus terminates and returns the corresponding value of operating voltage for MPP. This method is economically less effective as it requires many sensors to operate.

P = V*I

Differentiating w.r.t voltage yields;

$\frac{dp}{dv}=\frac{d(v*i)}{dv}$ ………………3.2

$\frac{dp}{dv}=I*(\frac{dV}{dV})+V*(\frac{dV}{dV})$ …...3.3

$\frac{dP}{dV} = I + V * (\frac{dI}{dV})$ …….3.4

When the maximum power point is reached the slope $\frac{dp}{dv}$=0. Thus the conditionwould be $\frac{dp}{dv} = 0$

$$\frac{dp}{dv} = 0$$

$I+V*(\frac{dI}{dV}) = 0$ ………..3.5

$\frac{dI}{dV} = -\frac{I}{V}$ ………..3.6

3.2 Modelling of fuel cell

In this paper, solid oxide fuel cell is used as fuel cell. The voltage of fuel cell, is define as the sum of three terms: the thermodynamic potential, the activation over voltage and ohmic over voltage. The voltage equation describe as follows:

E=V–Losses ……….. 3.7

The overall reaction in fuel cell

$H_2+5O_2= H_2O$………..3.8

The thermodynamic potential E is defined via a Nernst equation in expand form as

$E = 1.299 – 0.85\times 10^{-3} (T – 298.15) + 4.3085 \times 10^{-5} T(InP_{H2} + .51InP_{O2})$.... 3.9

Where P is the effective pressure in atm and T is temperature in Kelvin. The concentration of dissolved oxygen at the gas/liquid interface can be defined by Henry's law expression of the form

$CO_2=Po_2(5.08\times10^6)exp(-498/T)$………..3.10

The parametric equation for the over voltage due to activation and internal resistance developed from the empirical analysis are given as

$H_{act} = 0.9514 + 0.00312T – 0.000187T [In(I) + 7.4\ 10^5T\ In (co_2)$.................3.11

$R_{int}=0.01605-3.5x10^5T+8x10^{-5}i$ …….3.12

Where i is the fuel cell current and the activation resistance is determined as

$R_a= - h_{act}/i$……………………………3.13

The combined effect of thermodynamics, mass transport, kinetics, and ohmic resistance determines the output voltage of the cell as defined by

$V = E – V_{act} + h_{ohmic}$ …………………3.15

This model describes that the current drawn, cell temperature, hydrogen pressure and o_2 presssure will affect the fuel cell voltage. By an increase in fuel pressure, a drop in fuel cell voltage can be compensated. Dynamics of fuel cell voltage can be modelled by an addition of a capacitor C, to the steady state model. The effect of double charge layer is modelled by a capacitor C connected in parallel with activation resistance as shown in following figure

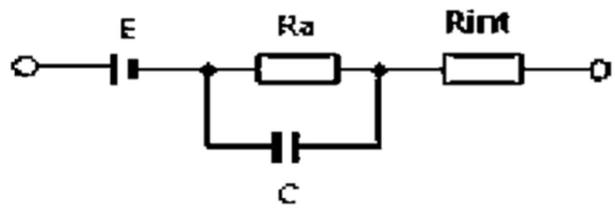

Fig. 3 Equivalent diagram of fuel cell

3.3 Inverter

It is a device that converts DC power into AC power at desired output voltage and frequency. In this thesis DC power input is obtained from fuel cell and photovoltaic array. Inverters can be broadly classified into two types-: one is voltage source inverter other is current source inverter.

Current source inverter: It is fed with adjustable current from DC source of high impedance.

Voltage source inverter: In this thesis we used voltage source inverter.VSI use transistor like MOSFET, GTO, IGBT and IGCT. As a switching devices to convert DC power into AC power by highly sophisticated converter design with these transistor.

3.4 Modeling of Battery

In this, battery is used to store electrical energy for back up in absence of supply from PV or Fuel cell. In this, battery is connected to both PV and Fuel at DC level by bi-directional converter. Battery is modeled with charging and discharging circuit in which two SCR switch are employed one switch is for charging of battery and another is for discharging of battery. The main purpose of battery is to maintain constant voltage at common point of coupling.

4. SIMULATION OF TEST SYSTEM.

In this paper 100Kw PV cell is integrated with 50 Kw Fuel cell with battery at DC level and this whole system is further integrated with utility grid at AC level through inverter. Different loads are connected at common point and results are analysis using scope in MATLAB Simulink. Scope at grid side show that if load is 50 kw than 100 kw is transferred towards grid (shown in positive value). If load is 150 kw then all power generated by hybrid system is absorbed by load therefore zero power is transferred towards grid. If load is 250 kw(i.e more than generating power by PV/Fuel) then load took extra supply of 100 kw from grid and rest of 150 kw from PV/Fuel cell.

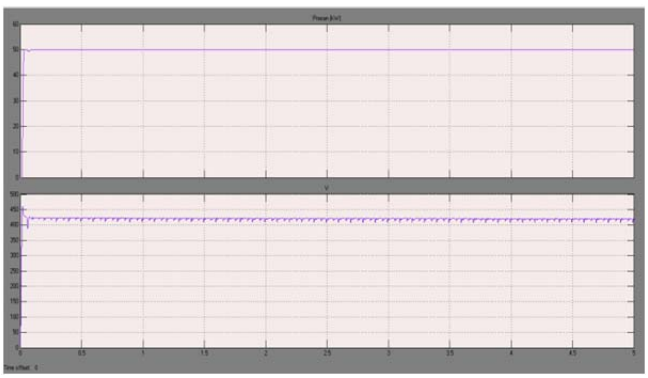

Fig.4 Output of solid oxide fuel cell

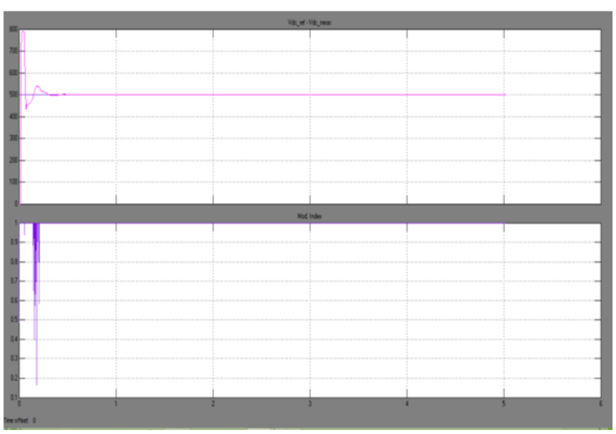

Fig.5 Output at Inverter

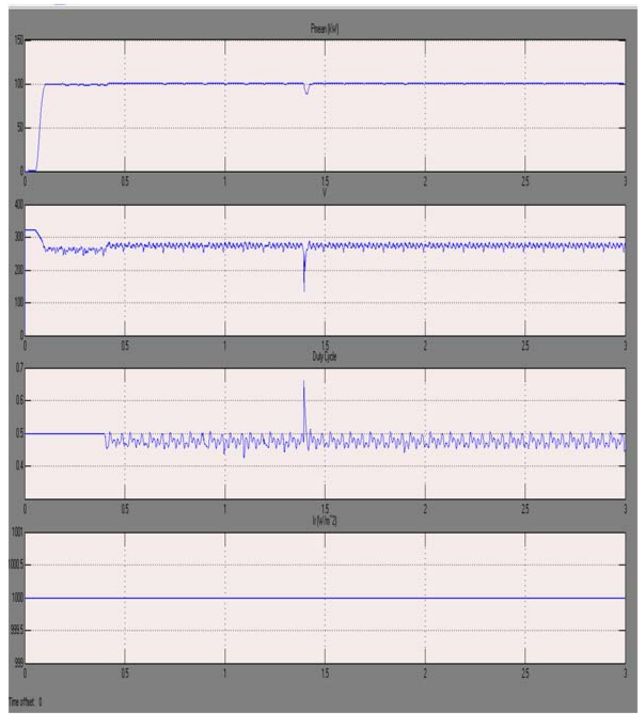

Fig.6 Output of PV cell

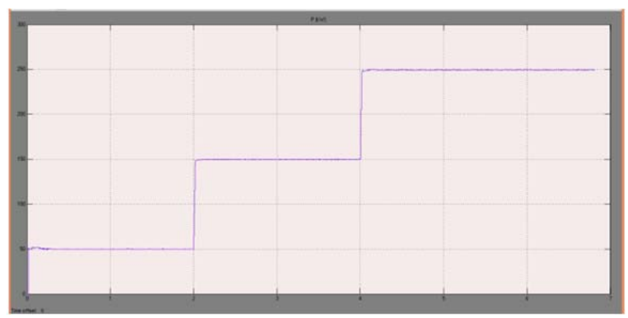

Fig.7 power output at load bus.

Fig.8 voltage and current output at load bus.

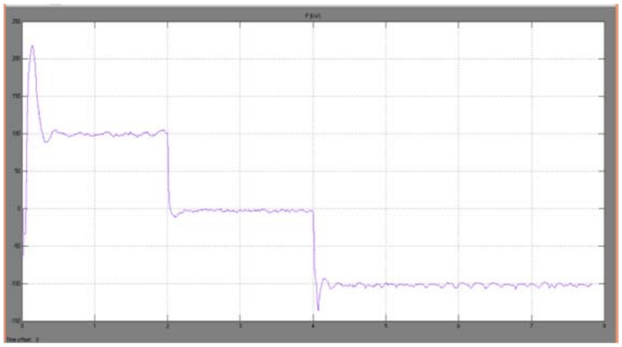

Fig.9 Power at Grid side

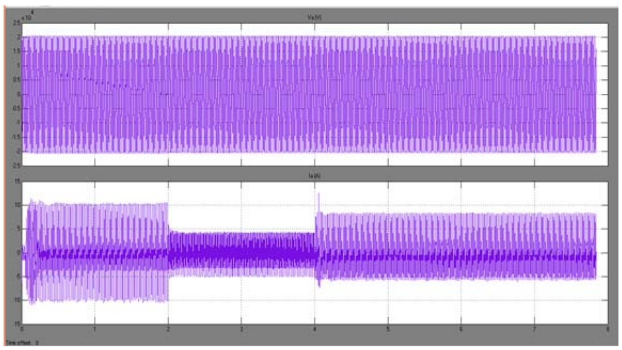

Fig. 10 Voltage and Current at Grid side

5. CONCLUSION

In this paper load prefer primary source of power from hybrid system and secondary from grid, by this way burden on grid is decrease and also customer can sell power to utility grid if excess power is generated. Hybrid system with grid at different load has been successfully demonstrated using MATLAB/SIMLINK.

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