MODELING OF PHOTOVOLTAIC CELL- FUEL CELL HYBRID SYSTEM: FOR UNINTERRUPTED POWER MANAGEMENT

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Abstract - *This paper deals with the details of a hybrid model of a solar and fuel cell. The load supplied is based on the photovoltaic panel, while the fuel cells are back-up for compensating possible power load shortage. The simulation includes all realistic components of the system, in this thesis power delivered by the combine system component is compared with each other and various conclusions are drawn. This paper describe of solar-fuel hybrid system for supplying electricity to power grid. In this thesis solar power module and its modeling is also simulated through MATLAB.*
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Key Words: *Solar power, fuel cell, hybrid generation energy,* grid *etc…*

1. INTRODUCTION

Hybrid systems, as the name implies, combine two or more renewable or non-renewable modes of electricity generation together, usually using renewable technologies such as solar photovoltaic (PV) and fuel cell. Non - Renewable energy sources are fast depleting source and are not sustainable in nature. Apart from that present topographical India doesn't have grid connectivity in every place. This thesis deals with the introduction of Hybrid power sustainable system comprising of solar power system and fuel cell system connected to feeder. Although photovoltaic panels are used as popular renewable energy sources, major problems they encounter depending on power production are with solar irradiation. Hence this problem can be solved by using fuel cell in this thesis.

2. SOLAR POWER SYSTEM

The solar system is developed and designed with the series and parallel connection of solar cell or photovoltaic cell. A Solar cell is a device that converts the energy of sunlight into electricity or flow of electron. The effect by which energy of sunlight is converted into flow of electron is called photoelectric effect. A single solar cell produces only about 0.5V however 12 V panel about 25inches by 54 inches will contain 36 cells wired in series to produce about 17 volts peak output.

Nomenclature

Vph is the output of photovoltaic cell
I is current output of PV cell,current source
Iph represents the cell photocurrent.
Rsh and Rs are the intrinsic shunt and series resistance of the cell
A = B is an ideality factor = 1.6
k is Boltzman constant = 1.3805 × 10-23 J/K
Isc is the cell short circuit current at 250C and 1kW/m2
Ki is cell short circuit current temperature coefficient,
Tr is the cell reference temperature,
λ is the solar isolation in kW/m2
Irs is the reverse saturation current at a reference temperature,
Eg is the band-gap energy 1.1eV
Voc is the PV open circuit voltage at the reference temperature

2.1 PV cell model

General model:

A general mathematical description of the I-V output characteristics of a PV cell has been studied. As shown in figure 1, the equivalent circuit of the general model is composed of photo current source, diode, parallel resistor expressing the leakage current and series resistor describing the internal resistance to the current flow

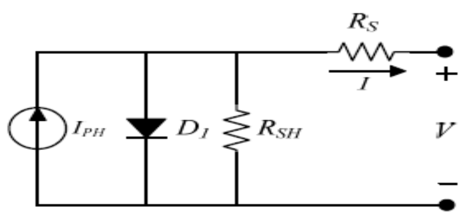

Fig 1**The equivalent circuit of photo voltaic cell**

Characteristic equation for the pv cell is given by

$$I=I_{ph}-I_s(\exp[\frac{q(v+IRs}{kTA}]-1)-(\frac{v+IRs}{Rsh}) \quad (1)$$

The photo current mainly depends on solar isolation and cell working temperature is given as:

$$I_{ph}=\lambda(I_{SC}+K_i(T-T_r)) \quad (2)$$

The cell saturation current varies with the cell temperature, which is described as:

$$I_s=I_{rs}\left(\frac{T}{Tr}\right)^3 \exp\left[qEg\,\frac{\left(\frac{1}{Tr}-\frac{1}{T}\right)}{KA}\right] \quad (3)$$

The reverse saturation current at reference temperature can be approximately obtained as:

$$I_{RS}=\frac{I_{sc}}{\exp\left[\frac{qV_{oc}}{N_s KTA}\right]-1} \quad (4)$$

The following program is written in MATLAB for achieving PV characteristics and IV characteristics:

Matlab code for PV cell

```
% gaurav 08 April 2015

clc;close all;clear all;

k=1.38065e-23;

q=1.602e-19;

Iscn=4.02;

Vocn=16.9;

Kv=-.123;

Ki=0.0032;

Ns=36;

T=32+273;

Tn=25+273

Gn=1000;

a=1.3;

Eq=1.12;

G=1000;

Rs=0.221

Rp=415.405;

Vtn=Ns*(k*Tn)/q;

Ion=Iscn/(exp(Vocn/(a*Vtn))-1);

Io=Ion*( ((Tn/T)^3)* exp( ((q*Eq)/(a*k))*((1/Tn)-(1/T)) )) ;

Ipvn=Iscn;

Ipv=(Ipvn+Ki*(T-Tn))*G/Gn;

I=zeros(170,1);

i=1;


for V=0:0.1:16.9

  I_part=Io*(exp(( V+(I(i,1)*Rs))/(Vtn*a) )-1);

  + ((V+(Rs*I(i,1)))/Rp);


    I(i+1)=Ipv-I_part

    if I(i+1)<0,

      I(i+1)=0;

    end

    V1(i)=V;


    P(i)=V*I(i);


    i=i+1;

end

    V1(i)=V1(i-1);

    P(i)=P(i-1);


    %subplot(3,1,1)

    plot(V1,I);

    %subplot(3,1,2)

    %plot(V1,P);

    %subplot(3,1,3)

    %plot(V,I_part)
```

2.3 Photovoltaic module

The power produced by a single pv cell is not enough for general use so by connecting many single pv cell in series and in parallel we can get the desired power output. Generally a series connection of pv cells as used . As per the commercial availability one module consist of 36or 72 cells. The overall efficiency of a pv module is less than a pv cell.

2.4 Photovoltaic array

A photovoltaic array is a interconnection of modules the power produced by a single module is seldom enough for commercial use so modules are connected to form array to connected in series to get an increased voltage or in parallel to get an increased current generally the photovoltaic arrays are on a roof.

2.5 Charge controller

The charge controller is required to prevent overcharging of batteries. Proper charging will prevent damage and increase the life and performance of batteries.

2.6 Power inverter

Inverters are the most important part of the system. It converts DC generated power into AC power. Whereas generated power can also be stored in the batteries.

3. FUEL CELL

A fuel cell is a device that converts the chemical energy from a fuel into electricity through a chemical reaction of positively charged hydrogen ions with oxygen or another oxidizing agent.

3.1 Design:

The main components of a fuel cell are

1) A fuel electrode (anode)
2) An oxidant or air electrode (cathode)
3) An electrolyte

3.2 Principle

There are many types of fuel cells, but they all consist of an anode, a cathode and an electrolyte that allow positively charged hydrogen ions (or protons) to move between the two sides of the fuel cell. The anode and cathode contain catalysts that cause the fuel to undergo oxidation reactions that generate positive hydrogen ions and electrons. The hydrogen ions are drawn through the electrolyte after the reaction. At the same time, electrons are drawn from the anode to the cathode through an external circuit, producing direct current electricity. At the cathode, hydrogen ions, electrons, and oxygen react to form water.

3.3 Operation:

The electro chemical reactions occurring at the electrodes of the hydrox cell are as follows At the negative electrode H2 gas is converted into hydrogen ions .

$$H_2 \rightarrow 2H^+ + 2e^-$$

At this electrode, hydrogen is diffused the catalyst enables the hydrogen molecules H2 are to be absorbed on the electrode surface as hydrogen atoms which react with the hydroxyl ions (OH_) in the electrolyte to form water. The electrons flow from the negative electrode to the external load to the positive electrode. These electrons interact with O2and H2O from the electrolyte to form negatively charged hydroxyl ions.

$$\tfrac{1}{2}O_2 + H_2O + 2e^- \rightarrow 2OH$$

The hydrogen and hydroxyl ions then combine in the electrolyte to produce water

$$H^+ + OH^- \rightarrow H2O$$

When the cell is operating the overall process is the chemical combination of hydrogen and oxygen to form water.

$$H_2 + \tfrac{1}{2}O_2 \rightarrow H2\ O$$

Thus water is the waste product of the cell.

3.4 Type Of Fuel Cell

1 Proton exchange membrane fuel cells (PEMFCs)
2 Phosphoric acid fuel cell (PAFC)

High-temperature fuel cells

3 Solid oxide fuel cell (SOFCs)
4 Molten carbonate fuel cell (MCFCs)

4. OPERATING STRATEGY FOR HYBRID SYSTEM

1 The unit power control (UPC) mode

2 The feeder flow control (FFC) mode

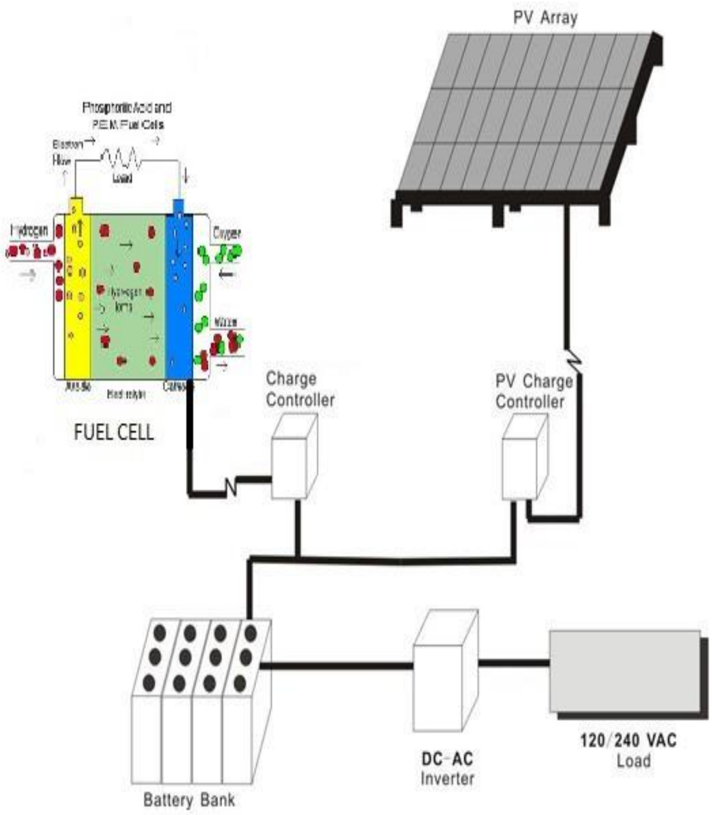

Fig 2 Hybrid system

Matlab code for operating strategy for hybrid system:

```
up=30;
low=10;
Fcmax=40;
pfeedmax=35;
ppv{1}=up-low;
pmsref{1}=up;
ppv{2}=input('entrer pv value');
dpms=ppv{2}-ppv{1};
pmsref{2}=pmsref{1}+dpms;
for i=3:9,
    pv=input('enter load power');
    ppv(i)=pv;
    if pv>ppv{1}
      if (ppv{i-2}<=pv&pv<=ppv{i-1})
          pmsnet(i)=ppv{i}+low;
else
dpms=ppv{i}-ppv{i-1};
pmref{i}=pmsref{i-1}+dpms;
end
else
pmref{i}=up;
end
pload1=pfeedmax+pmsref{i};
ploadm2=up+pfeedmax+ppv{i};
ploadx2=fcmax+pfeedmax+pmsref{i};
loadpw=120;
disp('output of the hybrid source is');
if loadpw>pload1
if (pload1<loadpw & loadpw<ploadm2)
disp('ffc pewc source');
disp(loadpw)
end
if(ploadm2<loadpw & loadpw<ploadx2)
 disp('load shedding');
end
end
if (loadpw<pload1)
disp('upc mode');
disp('loadpw');
end
```

end

5. PERFORMANCE ESTIAMTION AND OUTPUT

With the developed model, PV module characteristics and Hybrid system load characteristics are estimated as follow:
I-V and P-V characteristics for PV module are shown as follow

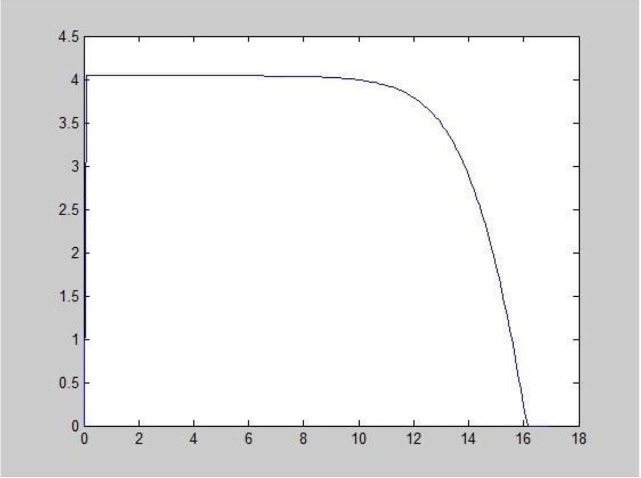

Fig3: I-V Characteristics for PV module

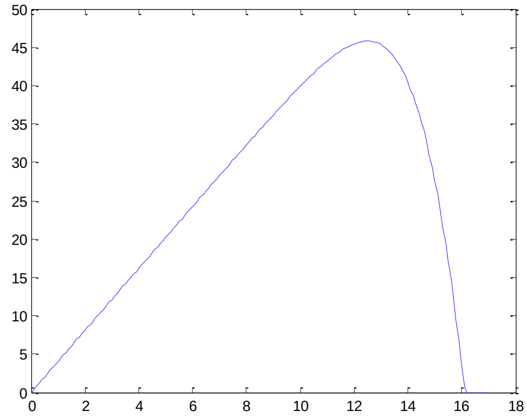

Fig4: V-P Characteristics for PV module

As shown in fig4, power output decreases as the temperature increases at constant irradiation. Whereas with the increase in operating temperature the following observations are made:

- The current output is increased marginally.
- The voltage output in decreased drastically.
- Results in net reduction in power output with rise in temperature.

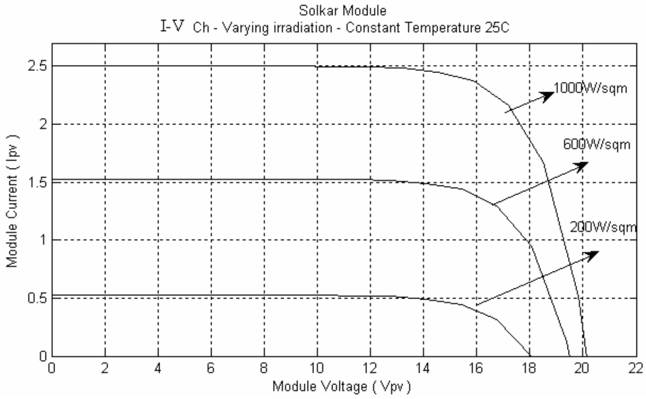

Fig5: I-V Characteristics for PV module at varying insolation

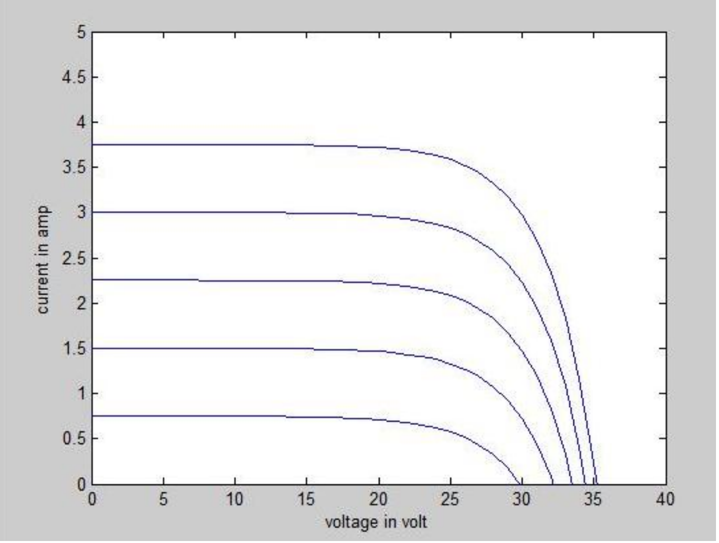

Fig6:I-V Characteristics for PV module at varying temp

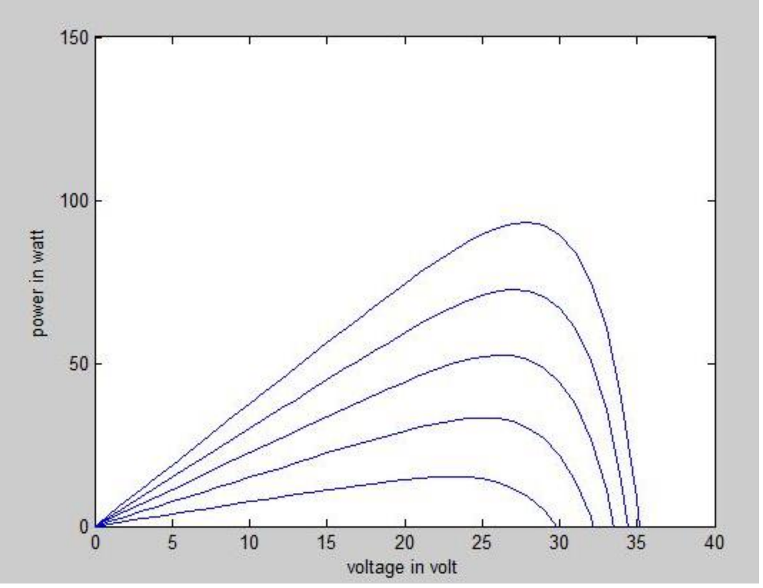

Fig7: P-V Characteristics for PV module at varying Temperature

Hybrid system laod sharing during peak load are as follows:

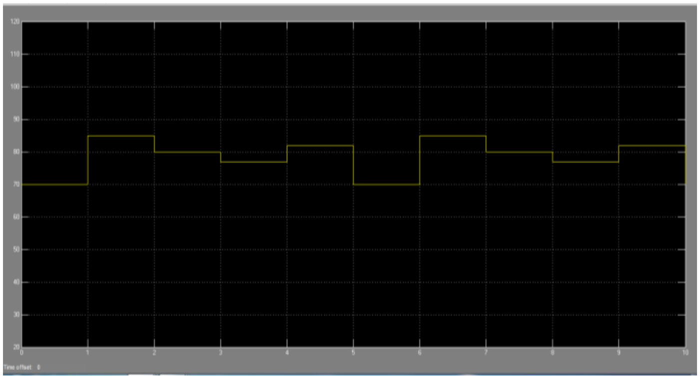

Fig 8: Load curve for solar power system

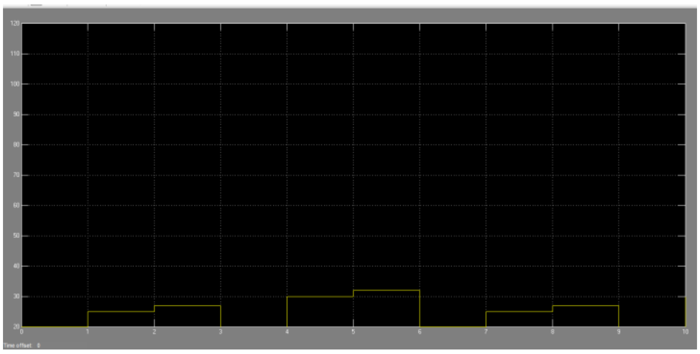

Fig 9: Load curve for fuel cell

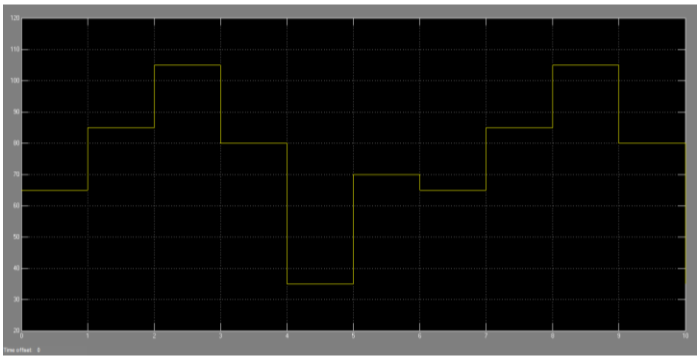

Fig 10: Load curve for Hybrid system

5. CONCLUSIONS

The step-by step procedure for modeling of PV module is presented. As well as hybrid system load sharing is presented. In a light load condition the hybrid source works in the UPC mode and the hybrid source regulates the output power to the reference value PMSref. The PMSref is determined by the algorithm shown in figure.In heavy load conditions the control mode changes to FFC and the variation of load will be matched by the hybrid source.

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