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MODELLING OF THE INDIVIDUAL COMPONENTS OF SMART GRID (PV-Cell & Fuel Cell)

Neha Singh[#1], Virendra Kumar Maurya[#2]

[#1]Student, Electrical Engineering, BBD University, Lucknow
[#2]Associate Professor, Electrical Engineering, BBD University, Lucknow

Abstract—*In the development of a smart grid with the help of PV cell & Fuel cell, we generate energy by the individual cells and coupled them on a single grid. With the help of electronics components we convert it as a smart grid. Here in this paper we are going to develop equivalent model of PV cell & Fuel cell with the help of MATLAB. Related modeling of PV & Fuel cells is discussed here.*

Index Terms— *PV cell & Fuel cell, PV array, Diode, Smart grid, Modeling & load.*

[I] INTRODUCTION

Modeling of Hybrid System
(Photovoltaic & Fuel Cell Module):

This is the proposed model of PV-FC Hybrid system. Here we are doing modeling of some components. The important parts of the model are given below.

a) Modeling of Photovoltaic Module
b) Modeling of Fuel Cell Module
c) Modeling of FC Power Control Unit.
d) Modeling of DC to DC converter (Type-Boost)
e) Modeling of Inverter Unit
f) Modeling of Electrical Load
g)

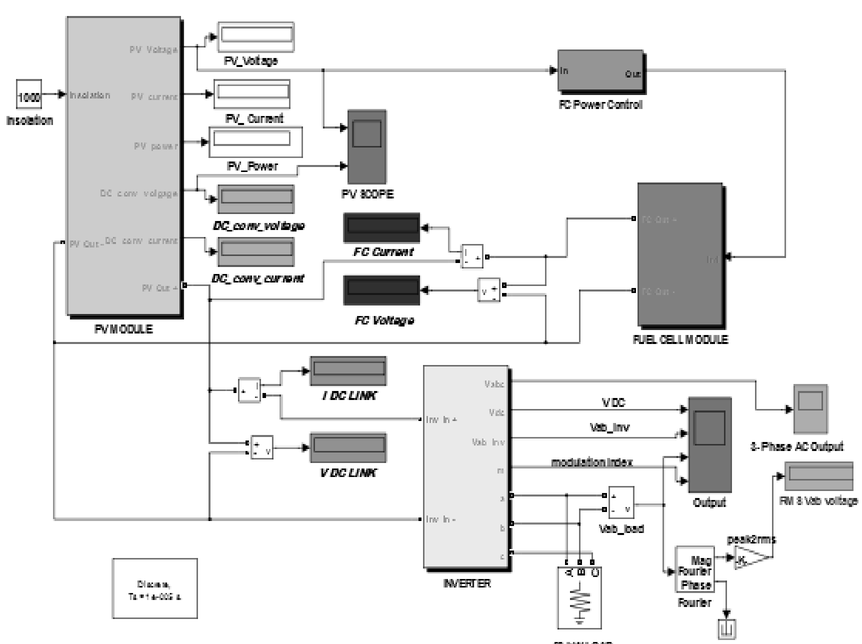


Fig. 1.1 Proposed Model of smart grid

[II] MODELING OF PV CELL

In this paper we are doing the modeling of two cells.

- Modeling of Photovoltaic Module
- Modeling of Fuel Cell Module

2.1 Modeling of Photovoltaic Module: Solar PV module, pictured in Figure 2.1, the module is made of 72 multi-crystalline silicon solar cells in series and provides 50W of nominal maximum power [1]. Table 2.1 shows its electrical specification.

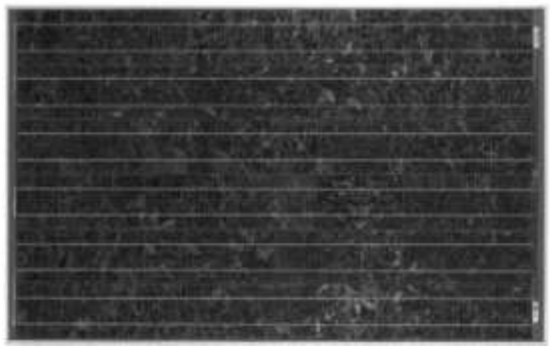


Fig. 2.1 Picture of BPSX 50S PV Module

Following are the characteristics to solve a PV Module

TABLE 2.1

Electrical Characteristics	
Maximum Power (P_{max})	150W
Voltage at P_{max} (V_{mp})	34.5V
Current at P_{max} (I_{mp})	4.35A
Open-circuit voltage (V_{oc})	43.5V
Short-circuit current (I_{sc})	4.75A
Temperature coefficient of I_{sc}	0.065 ± 0.015 %/°C
Temperature coefficient of V_{oc}	-160 ± 20 mV/°C
Temperature coefficient of power	-0.5 ± 0.05 %/°C
NOCT	47 ± 2°C

ELECTRICAL CHARACTERISTICS PV MODULE

a) The strategy of modeling a PV module is no different from modeling a PV cell. It uses the same PV cell model.
b) The parameters are the all same, but only a voltage parameter (such as the open-circuit voltage) is different and must be divided by the number of cells [2].

In the modeling of photovoltaic module, first of all we convert solar cell in to the equivalent circuit. Equivalent circuit of solar cell contains short circuit current (Isc) parallel with diode as shown in figure.

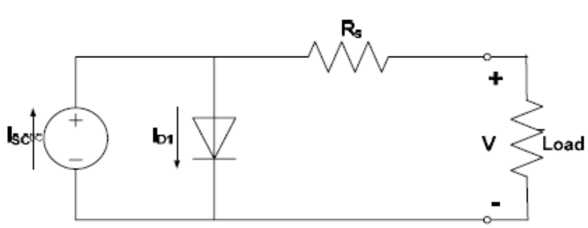


Fig. 2.2 Equivalent circuit model of PV-cell

Equations for the above model are

$$i_D = Io\,(e - ^{VD/VT})$$

A single PV cell produces an output voltage less than 1V, about 0.6V for crystalline silicon (Si) cells, thus a number of PV cells are connected in series to archive a desired output voltage. When series-connected cells are placed in a frame, it is called as a module. Most of commercially available PV modules with crystalline-Si cells have either 36 or 72 series-connected cells. A 36-cell module provides a voltage suitable for charging a 12V battery, and similarly a 72-cell module is appropriate for a 24V battery [3].

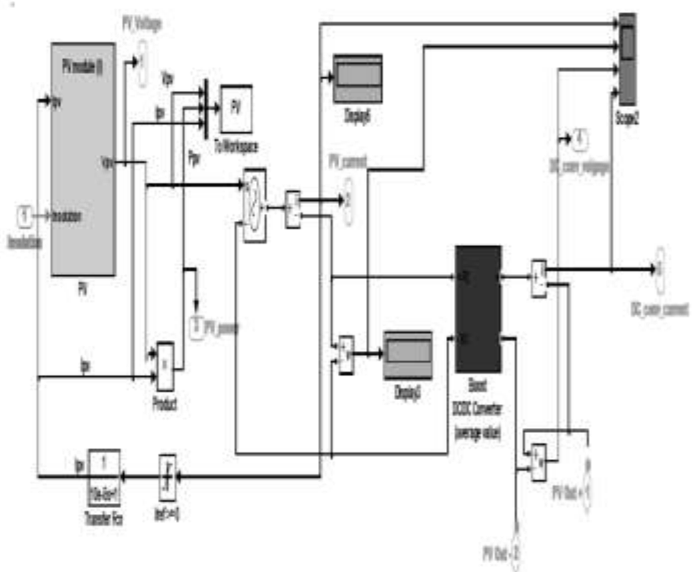


Fig. 2.3 Modeling of Photovoltaic cell

a) This is because most of PV systems used to have backup batteries, however today many PV systems do not use batteries; for example, grid-tied systems with (DC-DC converters)
b) When the PV cells are wired together in series, the current output is the same as the single cell, but the voltage output increases.
c) Also, multiple modules can be wired together in series or parallel to deliver the voltage and current level needed. The group of modules is called an array.

Fig shows the circuit model of photovoltaic cell. In the equation at the input side is voltage which is V_{pv} and the o/p is the current which is I_{pv} [4]. Now modeling the circuit and we get the characteristics of solar cell. When the insolation is high, more current draw in the ckt. The insolation is change with the atmosphere. E.g. at the early morning the insolation is about 600W/m^2, then nearer to noon its 800W/m^2 and at the noon it is max about 1000 W/m^2.

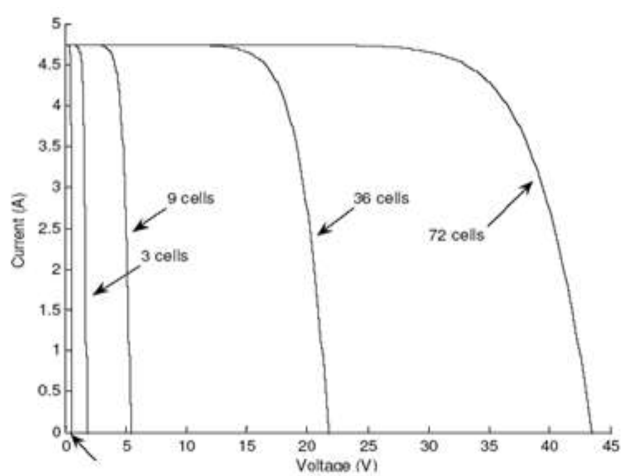


Fig. 2.4 PV Cell Connected In Series to Make Up A PV Module

Now modeling the block diagram of the single PV cell.

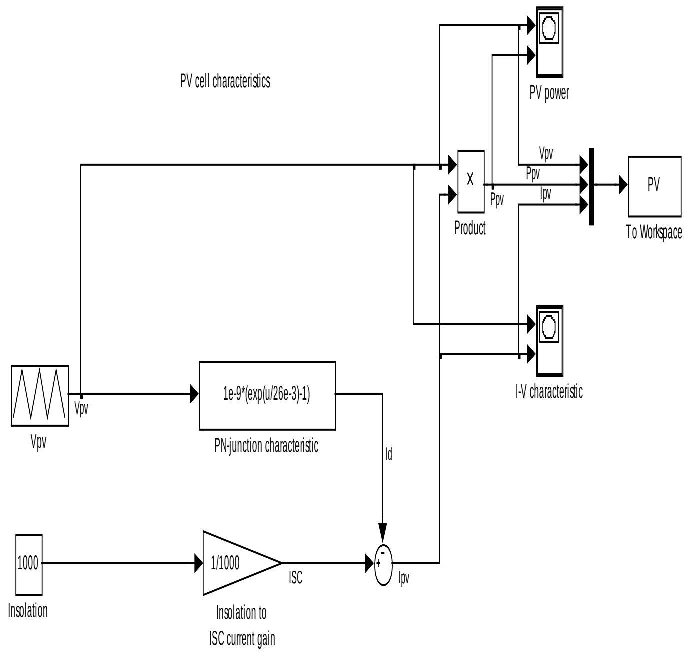


Fig. 2.5. Modeling of PV array

Different characteristics I-V and p-v at the different insolation level. (As 1000W/m^2, 800W/m^2, 600W/m^2)[5]:

1000W/m^2

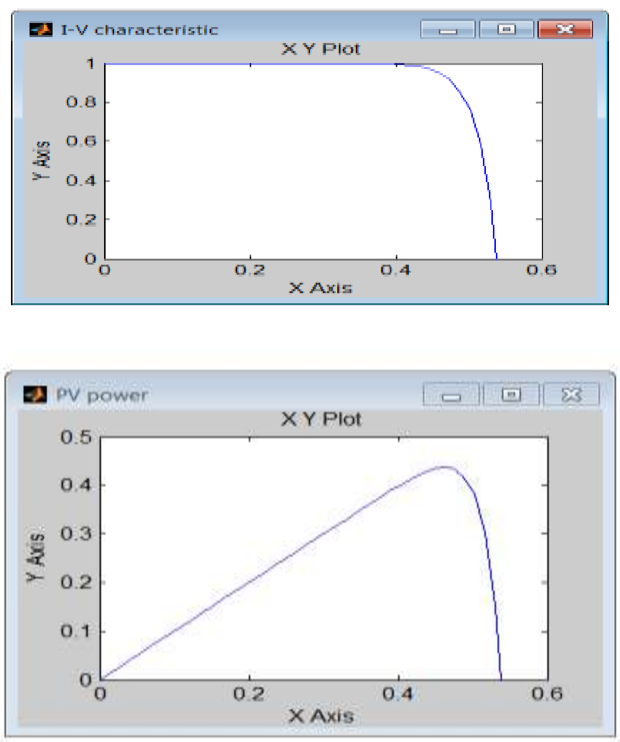


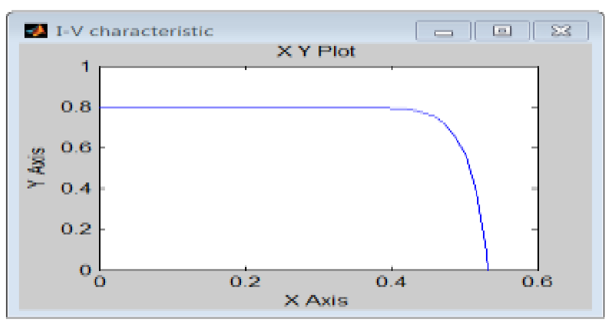
Fig. 2.6. I-V and P-V characteristics

TABLE 2.2 (V, P, & C OUTPUT)

Voltage	Power	Current
0.012	0.012	1
0.026	0.026	1
0.04	0.04	1
0.054	0.054	1
0.068	0.068	1
0.18	0.18	0.999999
0.194	0.194	0.999998
0.208	0.207999	0.999997
0.222	0.221999	0.999995
0.236	0.235998	0.999991
0.474	0.434799	0.917297
0.488	0.41885	0.858299
0.502	0.380121	0.757214
0.516	0.301353	0.584017
0.53	0.152252	0.287268

Solar Radiation 1000W/m^2		
MPP Power	**MPP Voltage**	**MPP Current**
0.2550	0.4460	0.5718

800W/m^2



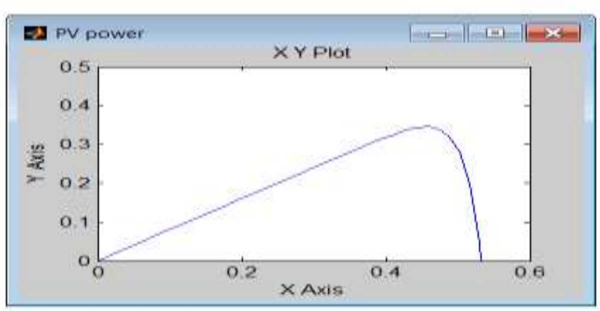


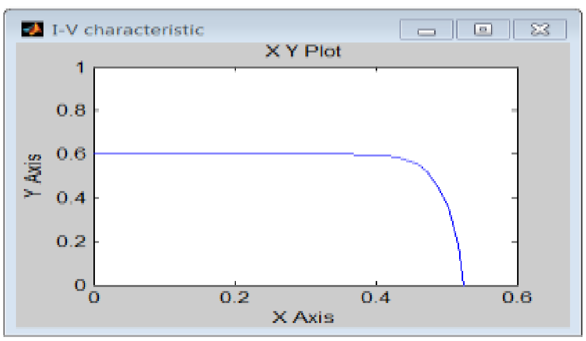
Fig. 2.7. I-V and P-V characteristics

TABLE 2.3 (V, P, & C OUTPUT)

Voltage	Power	Current
0.012	0.0096	0.8
0.026	0.0208	0.8
0.04	0.032	0.8
0.054	0.0432	0.8
0.068	0.0544	0.8
0.082	0.0656	0.8
0.18	0.144	0.799999
0.194	0.1552	0.799998
0.208	0.166399	0.799997
0.222	0.177599	0.799995
0.236	0.188798	0.799991
0.46	0.345796	0.751731
0.474	0.339999	0.717297
0.488	0.32125	0.658299
0.502	0.279721	0.557214

Solar Radiation		**800W/m^2**
MPP Power	**MPP Voltage**	**MPP Current**
0.3458	0.4400	0.7517

600W/m^2



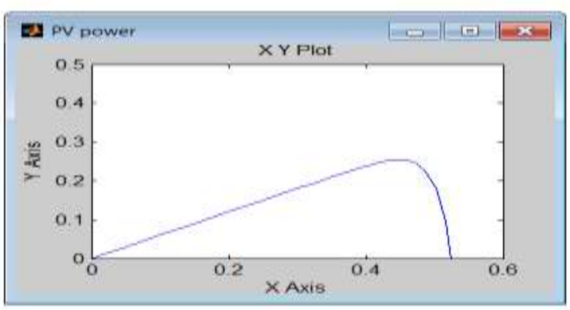


Fig. 2.8 I-V and p-v characteristics

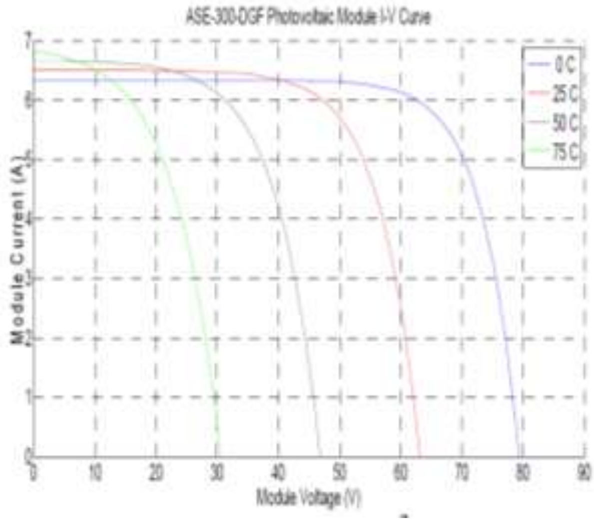
TABLE 2.4 (V, P, & C OUTPUT)

Voltage	Power	Current
0.012	0.0072	0.6
0.026	0.0156	0.6
0.04	0.024	0.6
0.054	0.0324	0.6
0.068	0.0408	0.6
0.082	0.0492	0.6
0.18	0.108	0.599999
0.194	0.1164	0.599998
0.208	0.124799	0.599997
0.222	0.133199	0.599995
0.236	0.141598	0.599991
0.46	0.253796	0.551731
0.474	0.245199	0.517297
0.488	0.22365	0.458299
0.502	0.179321	0.357214

Solar Radiation 600W/m^2		
MPP Power	**MPP Voltage**	**MPP Current**
0.4600	0.2537	0.5517

TABLE 2.5 (OUTPUT)

1000W/m^2	**pv array 50 kW**		
Resistant	**Voltage**	**Power**	**Current**
10	737.7	54.49	73.77
800W/m^2	**pv array 50 kW**		
Resistant	**Voltage**	**Power**	**Current**
10	655.7	43.08	65.57
600W/m^2	**pv array 50 kW**		
Resistant	**Voltage**	**Power**	**Current**
10	500.6	24.99	50.06



2.2 The More Accurate Model: There are a few things that have not been taken into account in the simple model and that will affect the performance of a PV cell in practice.

a) Series Resistance

In a practical PV cell, there is a series of resistance in a current path through the semiconductor material, the metal grid, contacts, and current collecting bus [6].

These resistive losses are lumped together as a series resister (*Rs*). Its effect becomes very conspicuous in a PV module that consists of many series-connected cells, and the value of resistance is multiplied by the number of cells.

b) Parallel Resistance

This is also called shunt resistance. It is a loss associated with a small leakage of current through a resistive path in parallel with the intrinsic device [6]. This can be represented by a parallel resister (*Rp*). Its effect is much less conspicuous in a PV module compared to the series resistance, and it will only become noticeable when a number of PV modules are connected in parallel for a larger system.

c) Recombination

Recombination in the depletion region of PV cells provides non-ohmic current paths in parallel with the intrinsic PV cell . As shown in Figure 2-5, this can be represented by the second diode (*D2*) in the equivalent circuit.

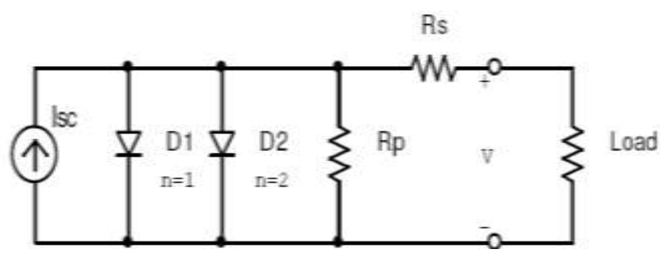


Fig. 2.9 More Accurate Equivalent Circuit Of PV Cell

Summarizing these effects, the current-voltage relationship of PV cell is written as:

$$I = I_{sc} - I_{01}[e^{q\left(\frac{V+I.R_S}{kT}\right)} - 1] - I_{02}[e^{q\left(\frac{V+I.R_S}{kT}\right)} - 1] - \left(\frac{V + R_s}{R_p}\right)$$

It is possible to combine the first diode (*D1*) and the second diode (*D2*) and rewrite the equation (2.8) in the following form.

$$I = I_{sc} - I_0[e^{q\left(\frac{V+I.R_S}{kT}\right)} - 1] - \left(\frac{V + R_s}{R_p}\right)$$

where: *n* is known as the "ideality factor" ("*n*" is sometimes denoted as "*A*") and takes the value between one and two. Here we use the electric model with moderate complexity, shown in Figure, and provides fairly accurate results. The model consists of a current source (Isc), a diode (D), and a series resistance.

[III] MODELING OF FUEL CELL

3.1 Modeling of Fuel Cell Module:

Fuel cell may be defined as an *electro chemical device* for the continuous conversion of the portion of the free energy change in a chemical reaction to electrical energy. It is distinguished from a battery in that it operates with continuous replenishment of the fuel and the oxidant at active electrode area and does not require recharging.

Main components of a cell are:

a) A fuel electrode,

b) An oxidant or air electrode,

c) An electrolyte.

Hydrogen as a fuel has so far given the most promising results, though cells consuming coal, oil or natural gas would be economically much more useful for large scale application. Some of the fuel cells are hydrogen, oxygen (H_2,O_2), Hydrazine (N_2H_4, O_2)[7], carbon/coal (C, O_2) methane (CH_4, O_2) etc.

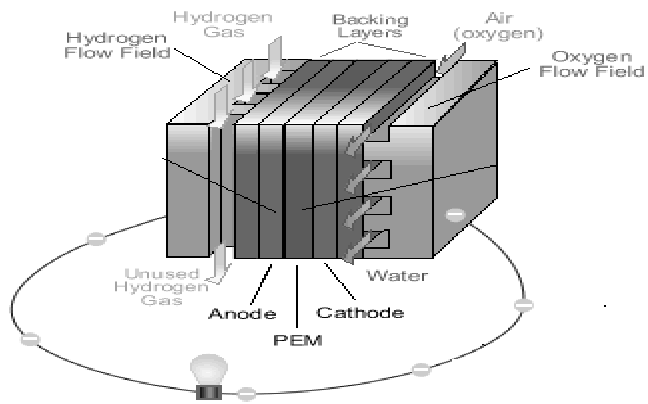


Fig. 3.1 Fuel Cell

Hydrogen oxygen fuel cells (Hydrox), are efficient and the most highly developed cell. A low pressure Hydrogen oxygen cell is illustrated in the diagram. Two porous carbon or nickel electrodes are immersed in an electrolyte. Catalyst is embedded in nickel electrodes. The electrolyte is typically 30% KOH because of its high electrical conductivity and it is less corrosive than acids.

H2 is fed to one electrode and is absorved gives free electrons and also reacts with hydroxyl ions of the electrolyte to form water[8]. The free electrons travel towards oxygen electrode through the external circuit. The two electrons arriving by the external circuit and one molecule of water to form 2 OH^- ions. These OH^- ions migrate towards to H_2 electrode and are consumed there. The electrolyte remains in variant. It is prime requirement that the composition of electrolyte should not change as the cell operates. The cell operates at or slightly above atmospheric pressure and at a temperature about 90^0C. This type of cell are called low temperature cells in high pressure cells pressure is up to about 45 atmospheric and temperature up to 300^0C. A single hydrogen oxygen cell can produce an emf of 1.23 volts at atmospheric pressure and 25^0C. By connecting a no. of cells, it is possible to create useful potential of 100 to 1000 volts and power levels of 1kW to nearly 100MW.

Here we use it for the generation of power for 50kW load along simultaneous operation with photovoltaic array.

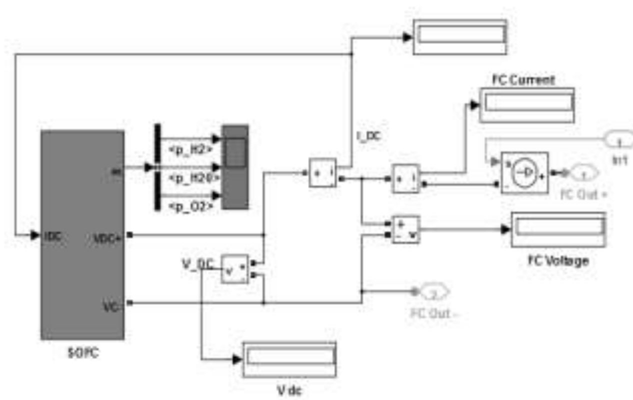


Fig. 3.2. Modeling of Fuel Cell Module

In the modeling of fuel cell the levels of H_2 and O_2.

[IV] CONCLUSION AND SCOPE FOR FUTURE WORK

4.1 Conclusion:

Various results of the dissertation in the form of voltage, current, power, and waveforms are discussed with the old work and following conclusions have been made from the comparative study of tables.

- **It has been seen that unlike the Micro-grid PV Based System, here in the PVFC Hybrid System the Fuel Cell Unit is operated in parallel with the Photo Voltaic Unit and hence the voltage remains constant at output.**
- **Also it has been observed from the comparative study from the table that the R.M.S. value of output voltage is 415 V (Aprrox.) and it remains constant in spite of the fluctuation in load and radiation.**

[V] FUTURE SCOPE

5.1 Scope for future work:

a) Operates PV array at max power point.
b) Connect battery to DC Bus and store surplus solar power in it. In case of less radiation first uses battery power then FC power.
c) Connect grid to this Hybrid Generation model & set logic for optimum use of solar.
d) Hybrid Generation can be extended for wind/solar/fuel cell

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