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Results at grid of Photovoltaic and Fuel Cells MATLAB Model for remote areas

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ABSTRACT: *This paper represents the matlab and simulink results of microgrid made with photovoltaic and fuel cells for the supply of electricity in the remote areas. Sunlight directly into electricity and other form of energy through the use of semiconductors and electricity is also generated by the fuel cell with the help of hydrogen and oxygen gas. This paper also tells about the modeling of system that uses photovoltaic cells and fuel cell for interconnection to grid. Here we are focusing on* ***'Results at grid of Photovoltaic and Fuel Cells MATLAB Model for remote areas'****. This Paper also deals with the various results of 3-phase at grid.*

(I) INTRODUCTION:

The strategy of modeling a PV module is no different from modeling a PV cell. It uses the same PV cell model. 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. In the modeling of photovoltaic module, first of all we convert solar cell in to the equivalent circuit. On the other hand fuel cell can 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. 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, O2), Hydrazine (N_2H_4, O_2), carbon/coal (C, O_2) methane (CH_4, O_2) etc.
Hydrogen oxygen fuel cells 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.

Modeling of hybrid system (photovoltaic & fuel cell module)

Model of PVFC Hybrid system is shown here for modeling. It contains following main parts.

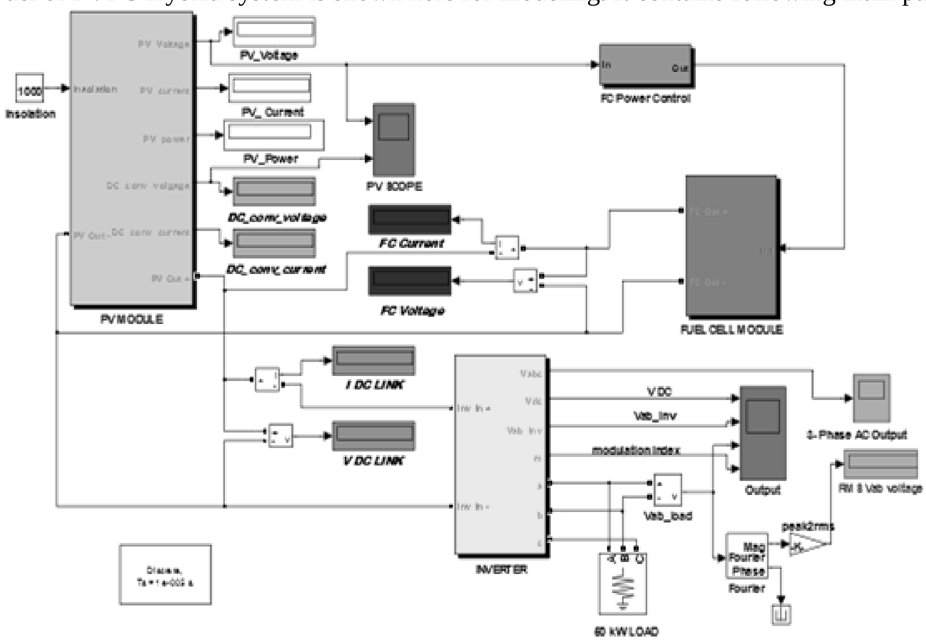


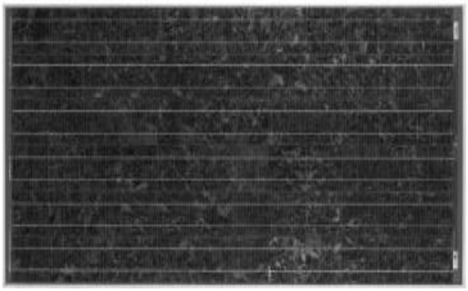
Fig.1. Modeling of Hybrid System

- Modeling of Photovoltaic Module
- Modeling of Fuel Cell Module
- Modeling of FC Power Control Unit
- Modeling of DC to DC converter (Type-Boost)

- Modeling of Inverter Unit
- Modeling of Electrical Load

(II) MODELING OF PHOTOVOLTAIC MODULE:

Solar PV module, pictured in fig.1, the module is made of 72 multi-crystalline silicon solar cells in series and provides 50W of nominal maximum power.



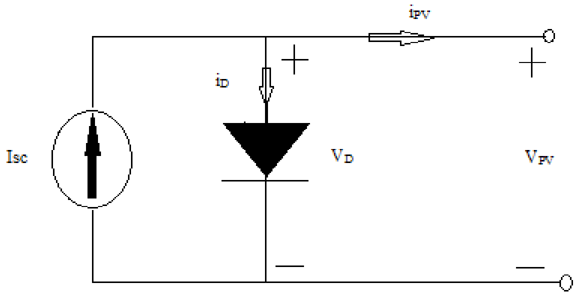


Fig. 2. Picture of BPSX 50S PV Module   Fig.3. Equivalent circuit model of solar cell

Equivalent circuit of solar cell contains short circuit current (Isc) parallel with diode as shown in fig.3. Equations for the above model are:

$i_D = Io.(e^{VD/VT}-1)$ (1)

Input equation: $V_D = V_{PV}$ (2)

Output equation: $i_{PV} = I_{SC} - i_D$ (3)

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.

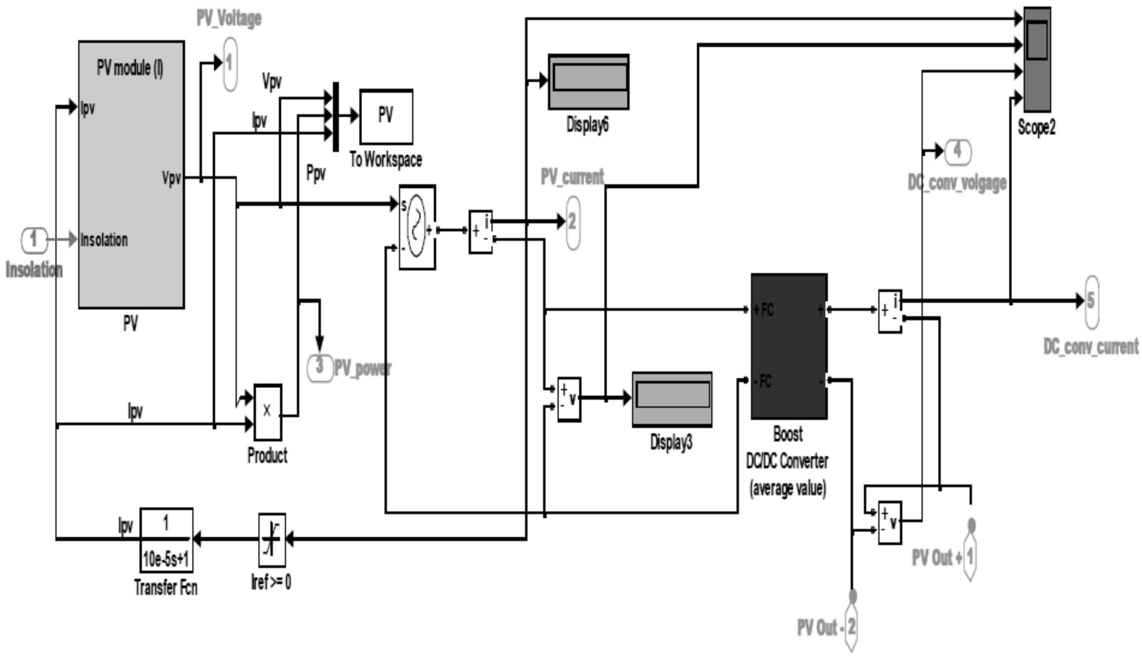


Fig. 4. Modeling of Photovoltaic Module.

.Fig 4. 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 $I_{pv.}$ Now modeling the circuit and we get the characteristics of solar cell. When the radiation is high, more current draw in the circuit. The radiation is change with the atmosphere. Condition at the early morning the radiation 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.

Now, fig 5. Shows the modeling block diagram of PV array.

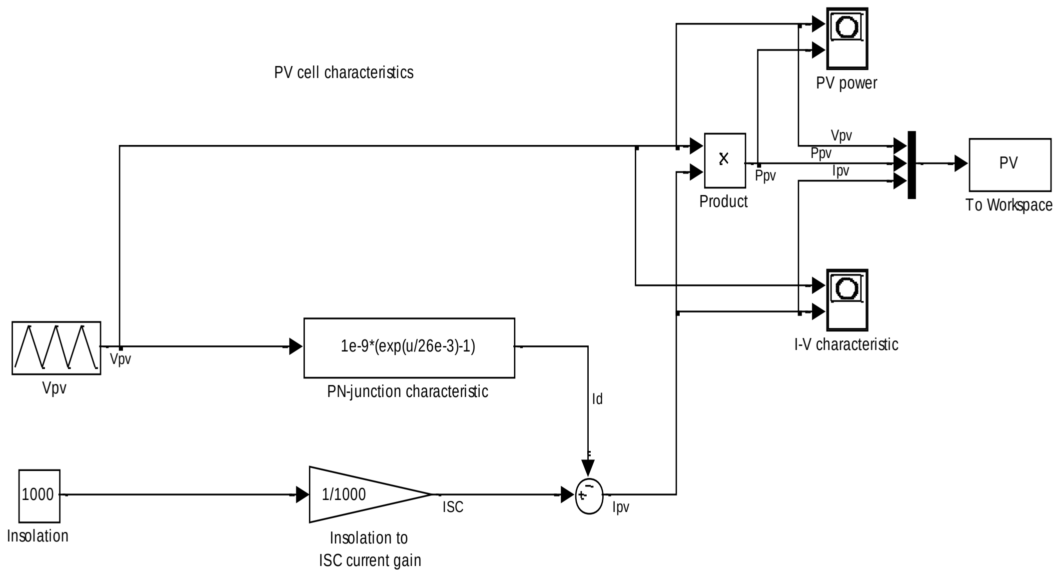


Fig. 5 Modeling of PV array

(III) MODELING OF FUEL CELL MODULE:

Main components of a cell are:

- A fuel electrode,
- An oxidant or air electrode,
- An electrolyte.

H_2 is fed to one electrode and is absorbed gives free electrons and also reacts with hydroxyl ions of the electrolyte to form water. 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. These 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 1 kW to nearly 100 MW.

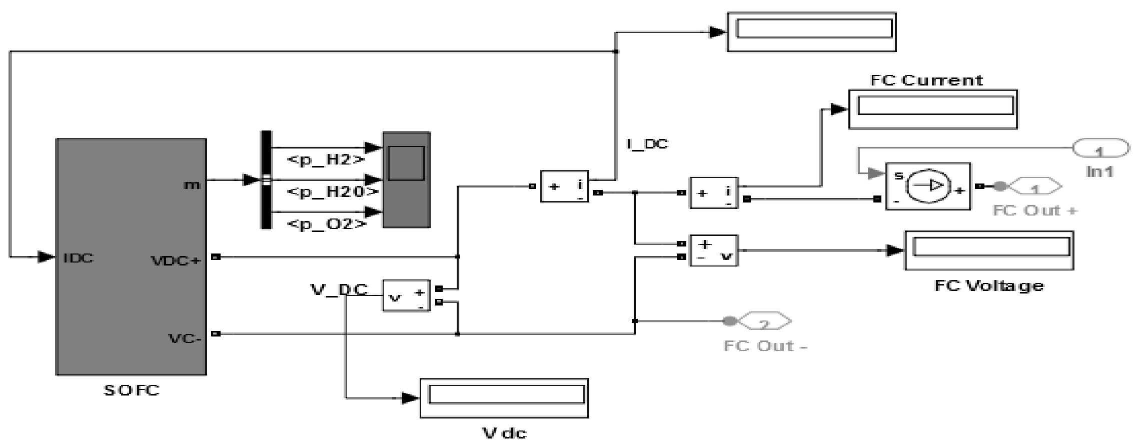


Fig. 6. Modeling of Fuel Cell Module

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

(IV) MODELING OF FC POWER CONTROL UNIT:

Monitoring is the main work of this unit. This is known as FC power control unit, It run on the basis of LOOK-UP DATA. LOOK-UP DATA is a table, which decides the operation of FC power control unit. Fuel cell unit come in action according to the low values of radiation of photovoltaic array. Scope-1 is used for the Output wave form of FC power control unit.

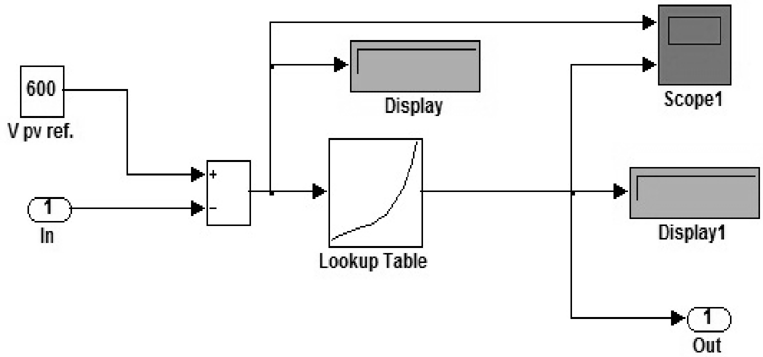


Fig. 7. Modeling of FC Power Control Unit

(V) MODELING OF DC TO DC CONVERTER (TYPE-BOOST):

Electronic switch-mode DC to DC converters convert one DC voltage level to another, by storing the input energy temporarily and then releasing that energy to the output at a different voltage. The storage may be in either magnetic field storage components (inductors, transformers) or electric field storage components (capacitors). This conversion method is more power efficient (often 75% to 98%) than linear voltage regulation (which dissipates unwanted power as heat).

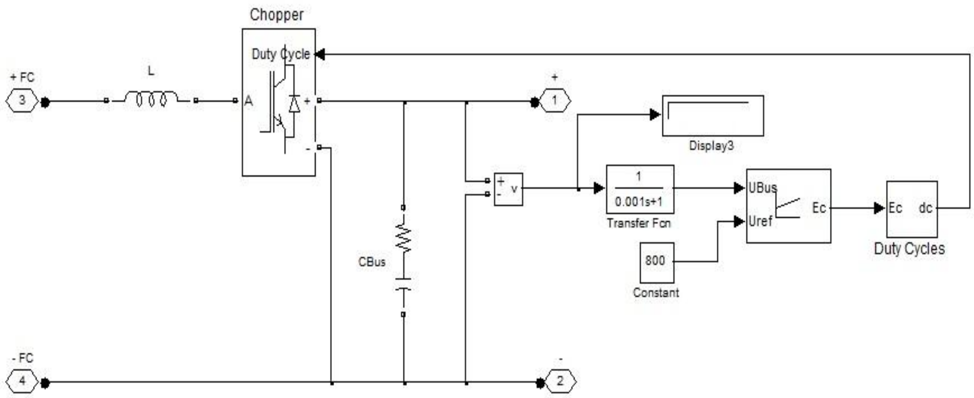


Fig. 8. Modeling of DC to DC Boost converter

Most AC-to-DC converters are designed to move power in only one direction, from the input to the output. However, all switching regulator topologies can be made bi-directional by replacing all diodes with independently controlled active rectification. A bi-directional converter can move power in either direction, which is useful in applications requiring regenerative braking. Drawbacks of switching converters include complexity, electronic noise (EMI / RFI) and to some extent cost, although this has come down with advances in chip design.

(VI) MODELING OF INVERTER UNIT:

This is the unit which is run by diode and switchs. Three phase inverter may be considered as three single –phase inverters and the output of each single phase inverter is shifted by 120^0. The voltage control techniquies is applied in three phase inverter.

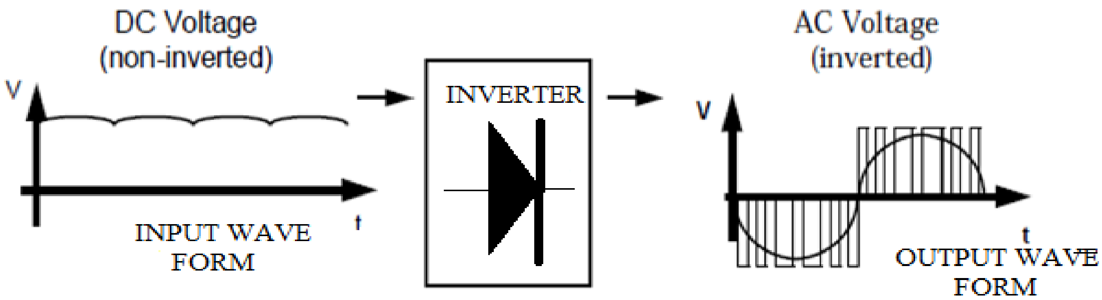


Fig.9. Inverter

There are three-sinusoidal reference waves, each shifted by 120^0. Acarrier wave is compared with the reference signal corresponding to a phase to generate the gating signals for that phase. The output voltage, as shown in fig.11. It is generated by eliminating the condition that two switching devices in the same arm can not conduct at the same time

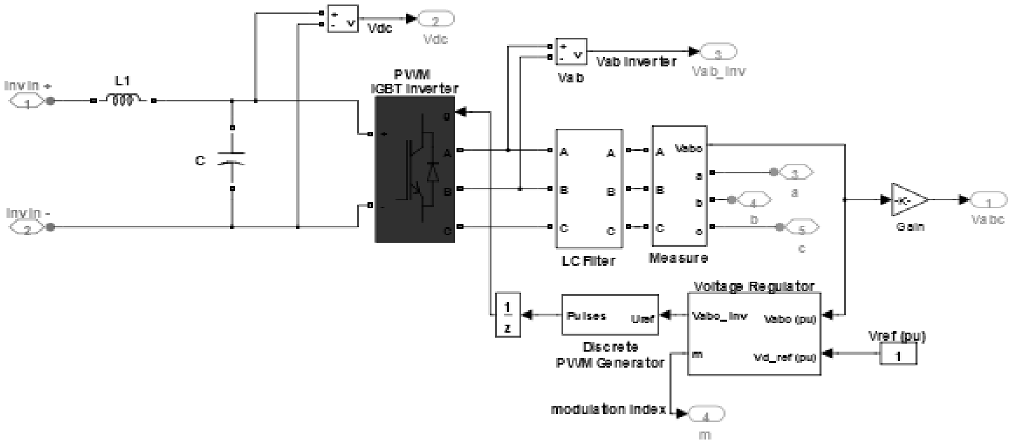


Fig.10**.** Modeling of Inverter Unit

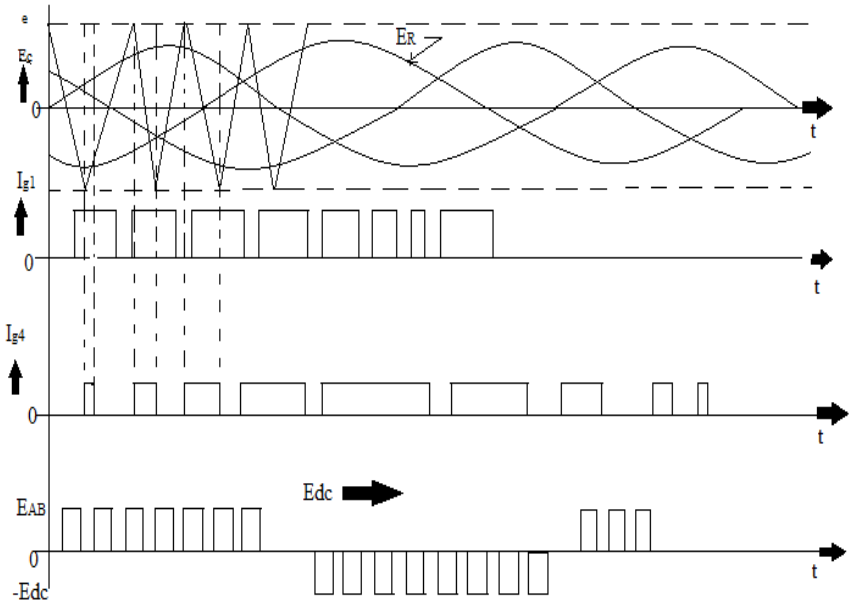


Fig.11. Sinusoidal pulse-with modulation for three-phase inverter

Gate-commutated power devices, like BJT, MOSFET, IGBTs etc., are used for low-and medium-power applications. For high power applications, it is necessory to connect them in series and / or parrel combinations, which increase the circuit complexxity. Therefore, for high power applications, fast-switching thyristers (inverter-grade) which are available in high voltage and current ratings are more suitable.

(VII) MODELING OF ELECTRICAL LOAD:

Output voltage may varry only by two reasons, one is change in radiation (Radiation) level of solar and other one is change in load. The output load may varry from microwatts up to mega watts by connecting more and more arrays of units in series. Here modeling is done for the three phase AC load of value 50kW. A constant voltage of 415 volts is made at the output(rms value). While there is change in the output load stil we get a constant output voltage, it is obtained by the simultanious operation of PV and FC hybrid system.

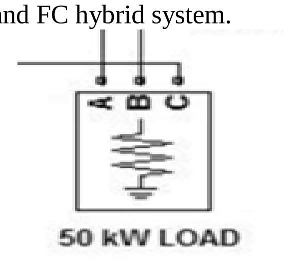


Fig.12. 50kW Load

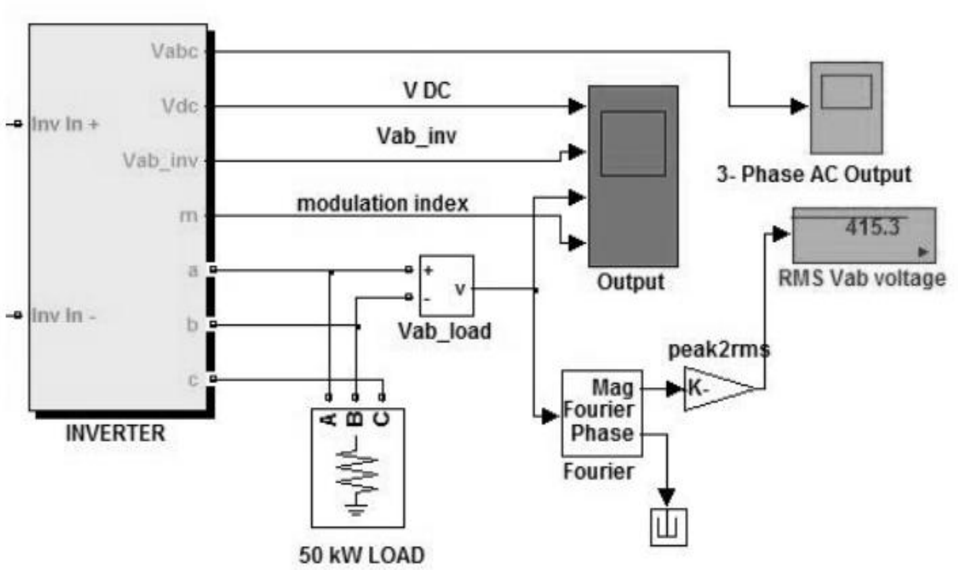


Fig.13. Modeling of Electrical Load

(VIII) RESULTS

Radiation 1000W/m² and 50 kW load:

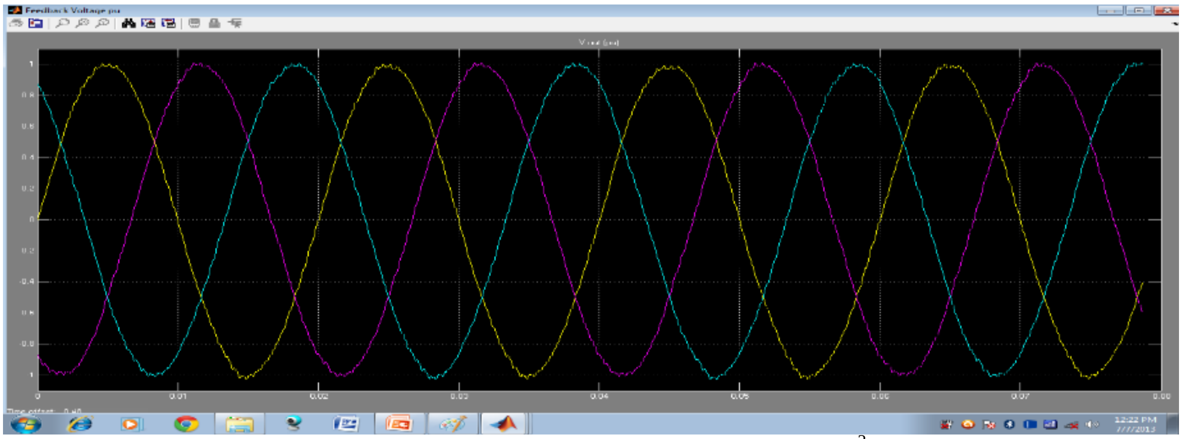


Fig. 14 Three phase output of Inverter at (1000W/m²)

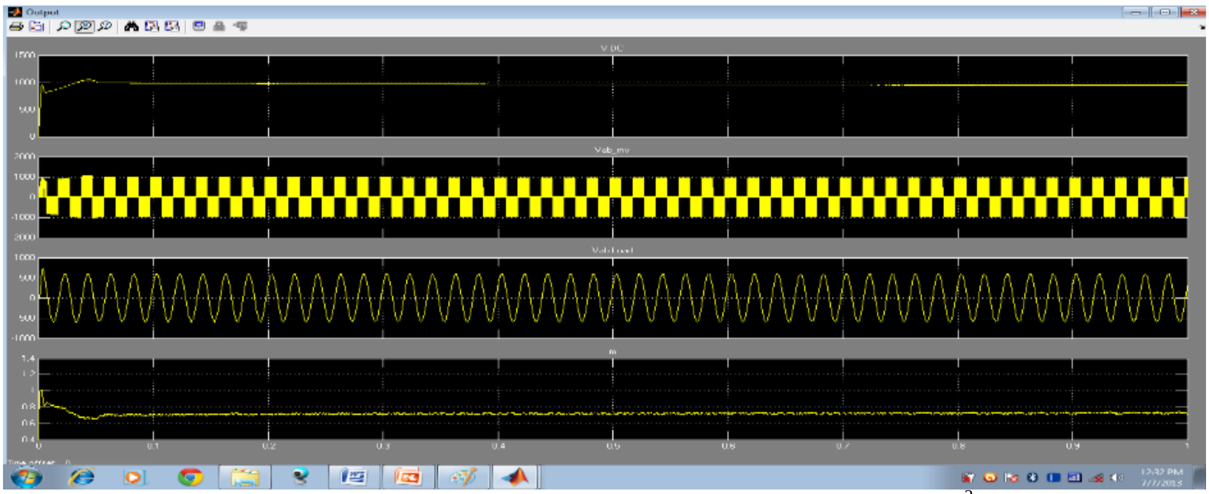


Fig. 15 Output waveform of V_{dc}, V_{ab_inv}, V_{ab_load} and m at (1000W/m²)

Radiation 750W/m^2 and 50 kW load:

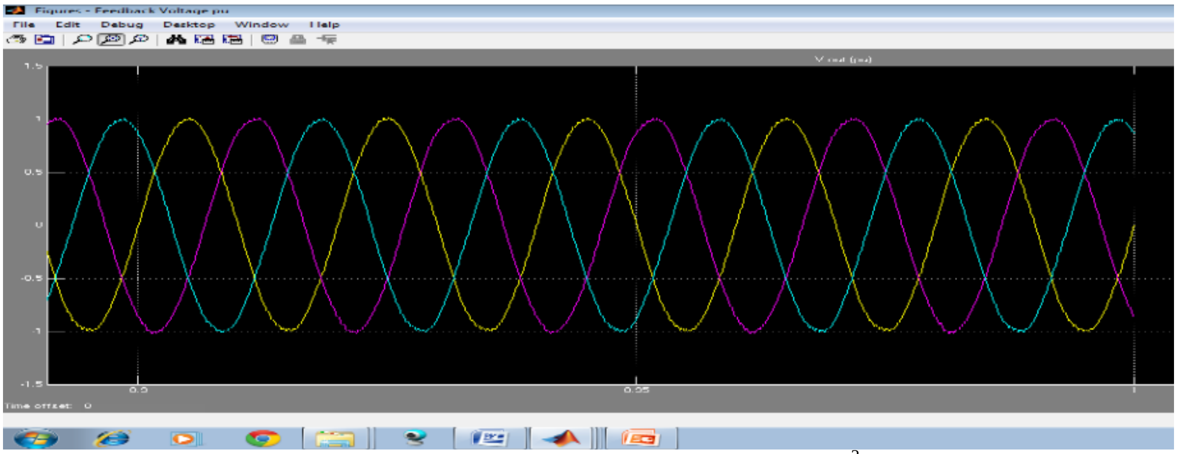


Fig. 16. Three phase output of Inverter at (750W/m^2)

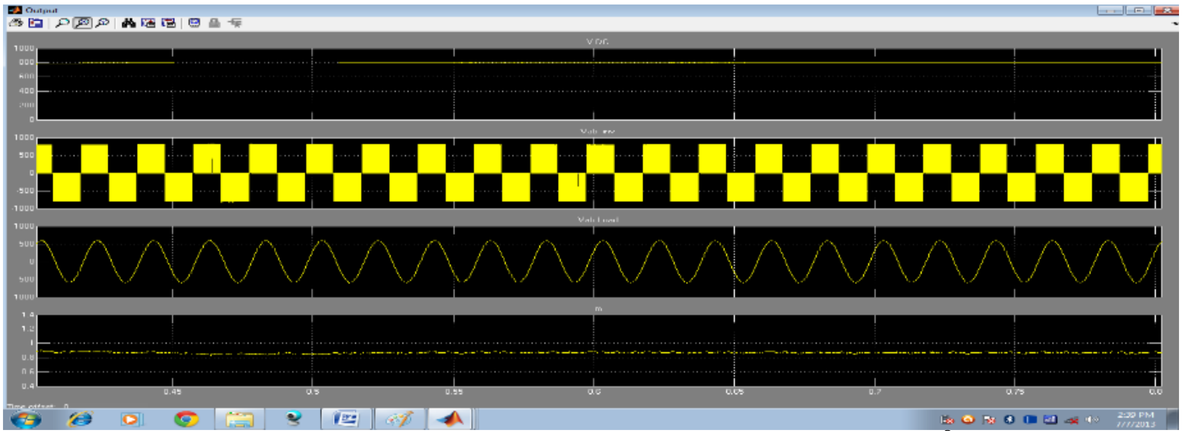


Fig.17. Output waveform of V_{dc}, V_{ab_inv}, V_{ab_load} and m at (750W/m^2)

Radiation 500W/m^2 and 50 kW load:

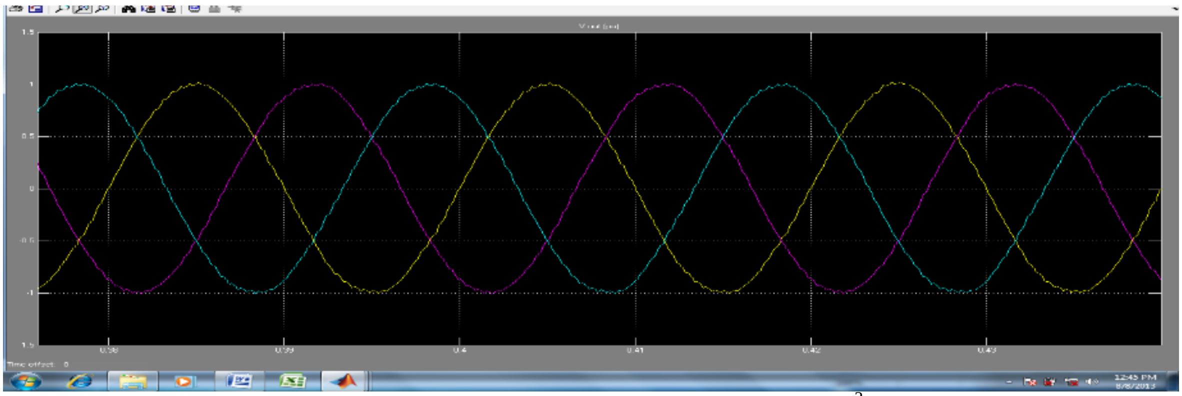


Fig. 18. Three phase output of Inverter at (500W/m^2)

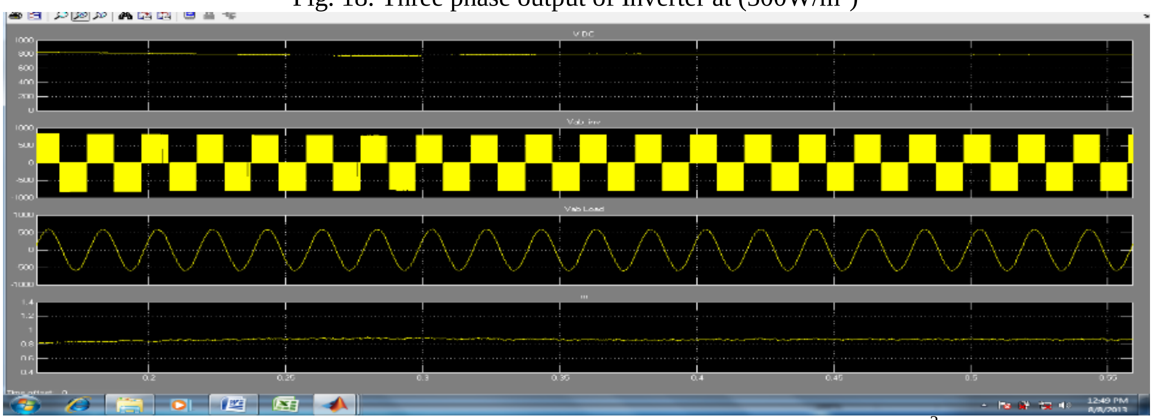


Fig.19. Output waveform of V_{dc}, V_{ab_inv}, V_{ab_load} and m at (500W/m^2)

Radiation 250W/m^2 and 50 kW load :

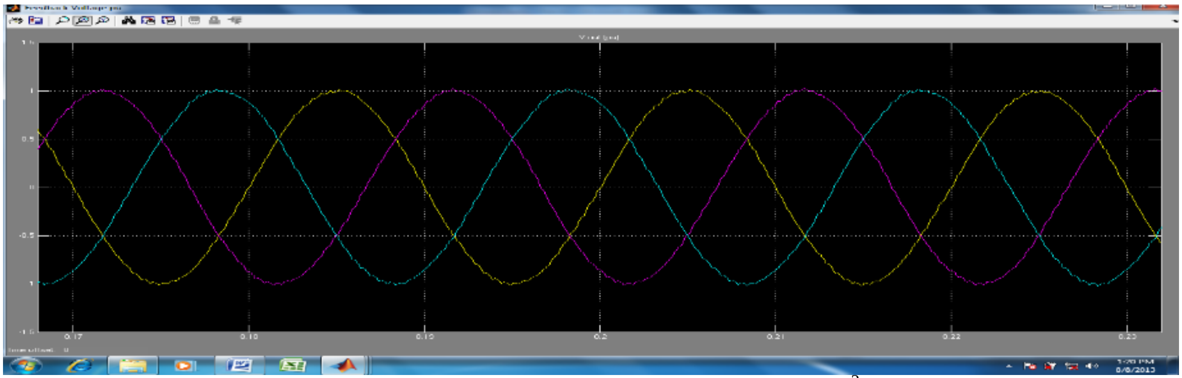


Fig.20. Three phase output of Inverter at (250W/m^2)

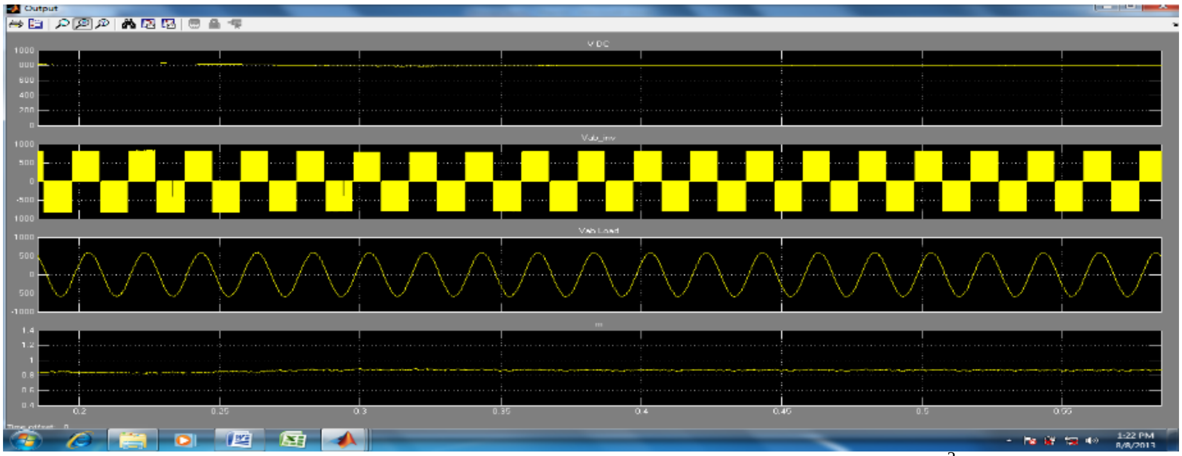


Fig. 21. Output waveform of V_{dc}, V_{ab_inv}, V_{ab_load} and m at (250W/m^2)

(IX) CONCLUSION AND SCOPE FOR FUTURE WORK

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 table no. 5.1, 5.2 and 5.3:
'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 (Approx.) and it remains constant in spite of the fluctuation in load and radiation.'

Advantages:
Some of the advantages of PVFC Hybrid system are:

- System is a direct conversion process and does not involve a thermal process, so it has high operating efficiency is 38% and it is expected to reach 60%.
- The unit is lighter, smaller and needs less maintenance.
- Fuel power plant may further cut generation costs by reducing transmission losses.
- Little noise, so that it can be readily acceptable in residential areas.
- Direct room temperature conversion of light to electricity through a single solid state device.
- Absence of moving parts.
- Ability to function unattended for long periods as evidence in space programme.
- Modular nature in which desired currents, voltages and power levels can be achieved by mere integration.
- They are easy to operate.
- They do not create pollution.
- They have a long effective life.
- They are highly reliable.
- They have rapid response in output to input radiation changes; No long time constant is involved, as on thermal system, before steady state is reached.
- Output ranges vary from microwatts up to MW. (Modules are combined in to large area arrays)
- They are easy to fabricate.
- They have high power to weight ratio.

- Amenable to onsite installation i.e. decentralized or dispersed power; thus the problem of power distribution by wires could be eliminated by the use of solar cells at the site where the power is required.
- They can be used with or without sun tracking, making possible are wide range of application possibilities.

6.3 Disadvantages:
- High in cost
- Extra devices are required to storage the generated energy. (No radiation at night)

(*Efforts are being made worldwide to reduce cost through various technological innovations*.)

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

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