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POWER MANAGEMENT STRATEGIES FOR GRID CONNECTED PV-FC HYBRID SYSTEM

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ABSTRACT
The objective of this paper is to maintain the reference value of the Hybrid system by changing the output values of the Photovoltaic array and Fuel cell with corresponds to each other. And the logic implemented in this work is, at a given load the total load is driven by the Grid, Photovoltaic and Fuel cell. Here the total load should be supplied by the PV array; if the load demand is not reached by the PV array then the Fuel cell is added to the PV array. Even though, if the load demand is not reached, the Grid will be connected to it to meet the load demand. In all these cases simulated system will maintain voltage and frequency at specified Value.

INTRODUCTION
Electric power generation in small amounts can be achieved by using a technology called distributed energy resource (DER).

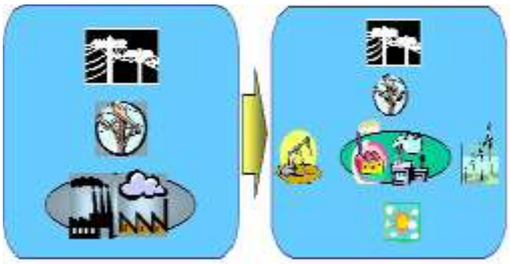

Figure-1: Large central power plant and distributed energy systems

As shown in Figure-1 by using the advanced technologies a relative increase of distribution energy resources throughout the world is achieved.

FUEL CELL
Fuel cell generates electricity by using electrochemical process. The conversion of hydrogen (H_2) and oxygen (O_2) in to water (H_2O) and in process it generate power this process is called electro chemical energy conversion process. In battery the chemical is stored inside it and it converts the chemicals in to electricity too. Where as in battery there is a limit amount of chemical in it if it is over the battery is dead, but in fuel cell the chemical constantly flow in to the cell and it never goes dead.

Most of the fuel cell uses hydrogen and oxygen as their chemicals. These fuel cells generate electricity without combustion, so it is environmental friendly. One fuel cell can generate a minimum 1volt of electric potential. To generate high voltages a set of cells are connected in series [5]. The generic fuel cell system is shown in Figure-2.

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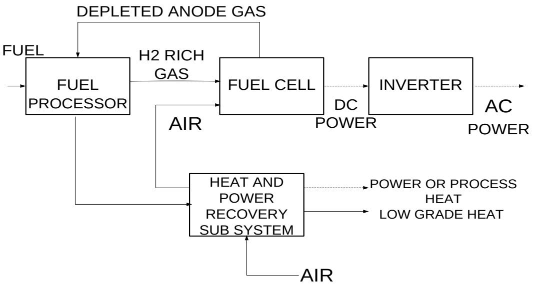

Figure-2: Generic Fuel Cell System.

Many different types of fuel cells are available. But in this paper we are using Proton Exchange Membrane Fuel Cell (PEMFC).

Proton Exchange Membrane Fuel Cells

PEMFC electrolyte made up of solid membrane placed between two electrodes. The operating temperature of PEMFC is about 80-85^{o}c. To get sufficient conductivity the electrolyte needed liquid water. Thus temperatures are bringing down to standard values i.e. about 100^{o}c. The PEMFC steady state requires a low rating of temperature.

Photon Exchange Membrane fuel cells are great power resources to provide required power at steady state but did not work well to electric load transient as fast as required [6]-[7].

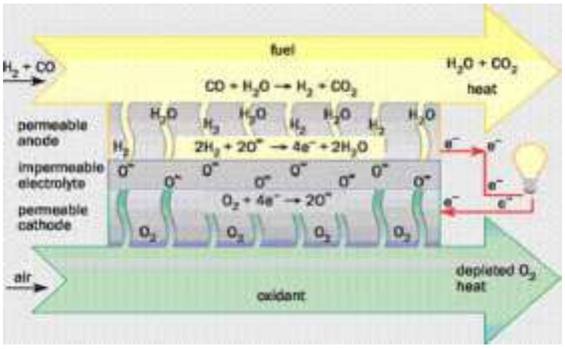

Figure-3: Operating principle of Fuel Cell.

The Figure-3 explains the operation of fuel cell. Anode and cathode are seperated by an thin polymer membrane poly acid, which is permeable to protons but doesnot allow to pass electons. Hydrogen flows in to cell at anode side and spilts in to hydrogen (H+) ions with electrons (e^-). The H+ ions permeate across the membrane towards cathode side. The electron from the anode side passes towards external circuit and generates power. At cathode side oxygen is supplied and the hydrogen ions(H^+) from anode passes through membrane will combine with oxygen(O_2) and electrons(e^-) at cathode side. The reaction at cathode side produces a water(H_2O) and energy.

PHOTOVOLATIC SYSTEM

Solar cell is a p-n junction fabricated semiconductor. The radiation from the sun is directly converted into electrical power (or) energy by using photovoltaic effect. The Solar Cell model is shown in Figure-4 [1].

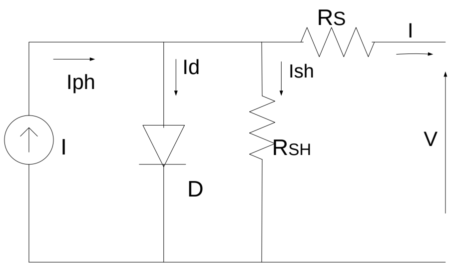

Figure-4: Basic Solar Cell Model.

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By exposing to the solar radiation on the photons the energy greater than the band-gap energy of the semiconductor are absorbed and some electron holes appear which are proportional to the radiation utilized. Under the influence of the internal electric fields, these carriers are move apart and created a photo current which is directly equal to solar isolation.

The V-I equation of solar cell [11] is
$I= [I_{PH} – I_S [_{exp}\ q(v + IR_s) / kT_{CA} – 1] – \qquad [(V+IR_s)/R_{SH}]]$

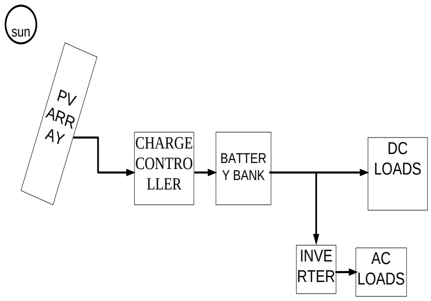

Figure-5: Schematic Diagram for PV System.

Stand alone and grid connected are types of main system configurations. The stand alone PV system operates normally and supplies power to a given load [13]. During the night time and failure of sunlight these system supply power to the load by a storage units like battery banks. These types of systems are also called autonomous systems due to their independent supply.

Maximum Power Point Tracking Technique (MPPT)

The output of PV varies with respect to the weather condition which means solar radiation and temperature. So to make the PV output constant different techniques [2]-[4] are available. In that perturb & observe (P and O) algorithm is mostly used. The P&O algorithm is implemented easily and it is shown in Figure-6.

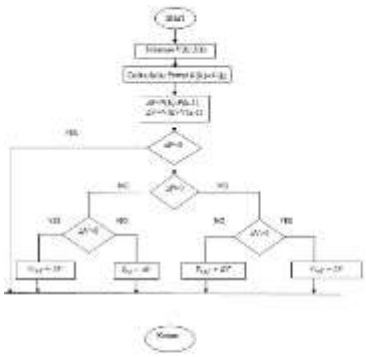

Figure-6: MPPT processing technique.

The P and O algorithm produce a constant power at all period without considering weather conditions and variety of PV array. It calculates periodically by changing the array output voltage and calculating the PV obtained output with that of the previous perturbation (calculated) value. If the value is ascending the perturbation will continue in the next cycle, otherwise the (perturbation) calculation of value will continue in reverse direction. This means that the array terminal voltage is perturbed every MPPT cycle. When P&O is reached it will oscillate around it [10] .

DESCIPTION OF SYSTEM

A. Hybrid Power System Structure:

The hybrid system combined with PV FC systems connected at PCC with the main grid as shown in Figure-7.The PV and PEMFC are taken as non linear resources. These resources are connected to the DC-DC converter (i.e. buck –boost converter) [9], [12].

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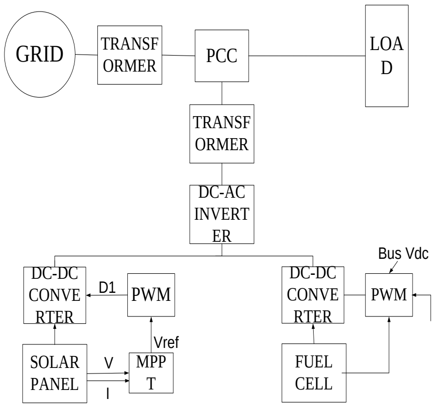

Figure-7: Block Diagram for Grid Connected System.

The power from solar array is maximized by using an MPPT's P&O technique. Voltage from the MPPT was given to the PWM to generate the pulses. And these pulses will control the dc-dc converter i.e. buck boost converter. The fuel cell power is controlled by generating pulses with usage of reference bus voltage to the reference voltage. And the change in voltage will generate pulses from PWM to the DC-DC converter. The DC ends was connected to inverter DC side to produce ac supply.

For remote applications a large amount of power is required and the usage of standalone and autonomous PV systems require a high cost. To reduce that cost effect different types of electrical sources are connected in parallel. PV has been connected to any other power resources such as wind, hydral power plant, thermoelectric, etc. There are many factors to be considering a site to install a hybrid systems are avaliability of energy, cost of implementation, cost of energy storage, total site requirements.,

B. PQ Inverter Control

The control of PQ by a inverter can be done by using a technique called current control technique by using qd reference frame [17], [19]. In this technique the 'I' in inverter is adjusted in amplitude and in phase to obtain the desired output values of P and Q. Two PI regulators are used in current controller to minimize the steady state error to zero as shown in Figure-8. By using this control scheme the inverter is controlled in such away the injected reference values of P_{ref} and Q_{ref}.

To regulate the voltage the PV control scheme is used which is same as the P-Q mode with the feedback of voltage is used to regulate Q_{ref}.

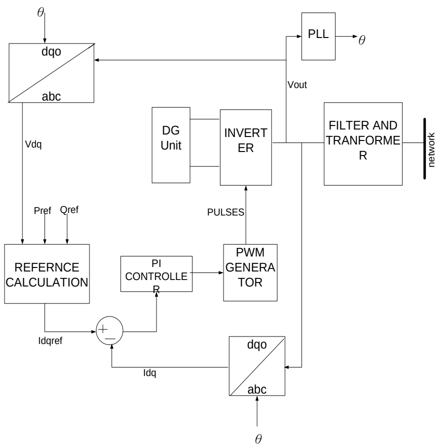

Figure-8: Block Diagram of PQ Control for Inverter.

C. Power Management Strategy

There are two control modes for the system. They are unit power control mode (UPC) and feeder flow control mode (FFC).

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In UPC mode the PV-FC resources of the system can manage the magnitude of voltage at the point of common coupling and the power that the source is injecting. If there is any power change in system that extra power will come from the grid. In FFC mode the hybrid system manage the magnitude of voltage at the point of common coupling and the power that is in feeder point. In this the maximum power delivered by the grid and change in power supplied by hybrid system. The operating technique of the PV-FC system is described in [5], [13].

MODELLING OF CASE STUDY

At the PCC the main grid connecting to loads with PV-FC hybrid source is shown in fig-7. The PV [16]-[18] and the PEMFC [8] are modelled as nonlinear resources, which is connected to DC converter which is coupled at the dc side of inverter. PV array which is connected to the MPPT controller with the usage of MPPT algorithms [14]-[15] makes a simple feedback structure and fewer measured parameters and it is shown in Figure 6. Then it is connected to buck boost converter and in same way the PEMFC is also connected.

A. Modelling of Hybrid System with Linear Load

The PV array [11] and fuel cell are connected in parallel with each other to the dc bus. With the combination of both PV and fuel cell the voltage delivers (According to our need). That dc power is converted in to ac power by using an inverter and it is feed to linear R-load and the Simulink diagram shown in Figure-9

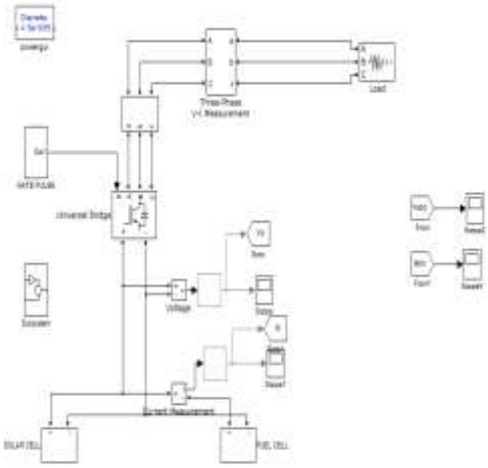
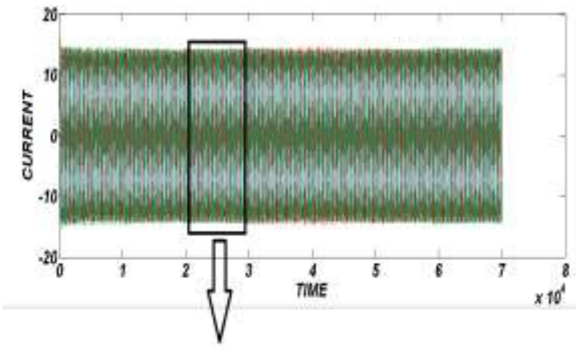


Figure-9: Hybrid system connected to R load.

The voltage and current waveforms for a linear R load is shown below.



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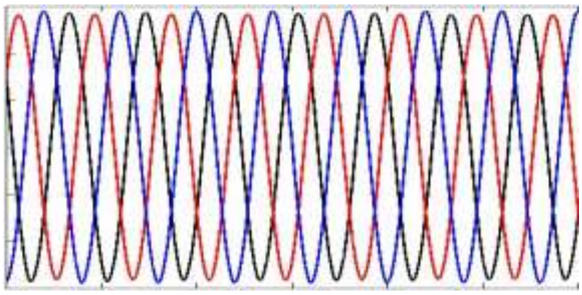
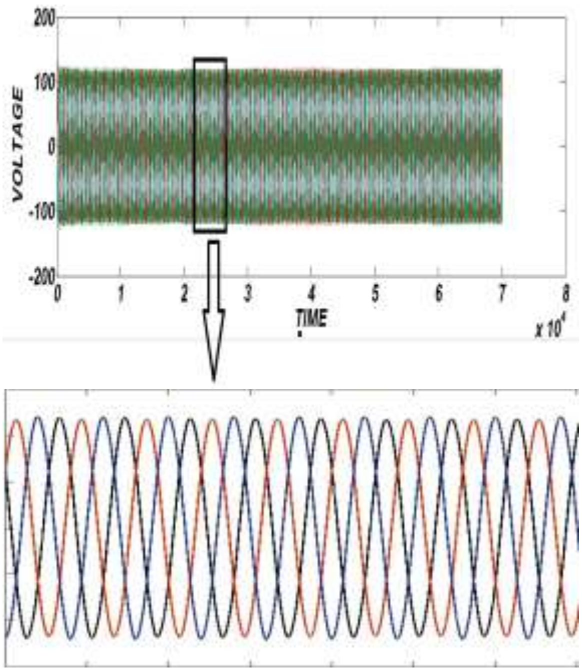


(a)



(b)

Figure-10: a) Current and b) Voltage Waveform of Hybrid System.

B. Modelling of whole System with Linear Load

The whole system is a combination of grid and hybrid system. Both the sources generate the power and supply to the load to meet the demand. And the Simulink diagram shown in Figure-11

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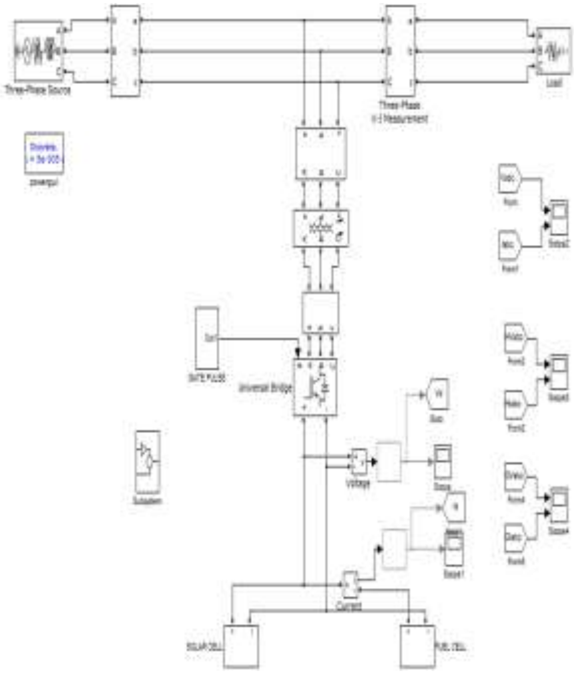
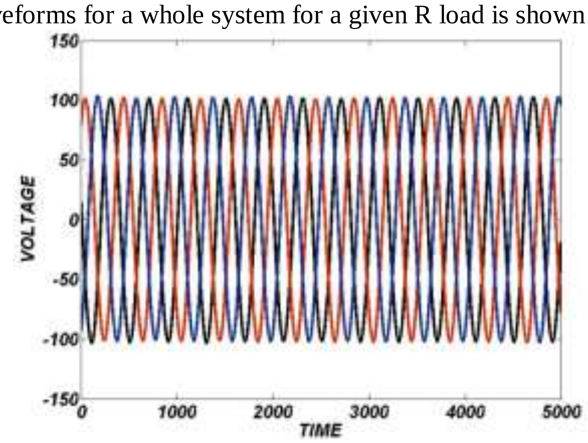


Figure-11: Grid and Hybrid System Connected To R Load

The voltage and current waveforms for a whole system for a given R load is shown below.



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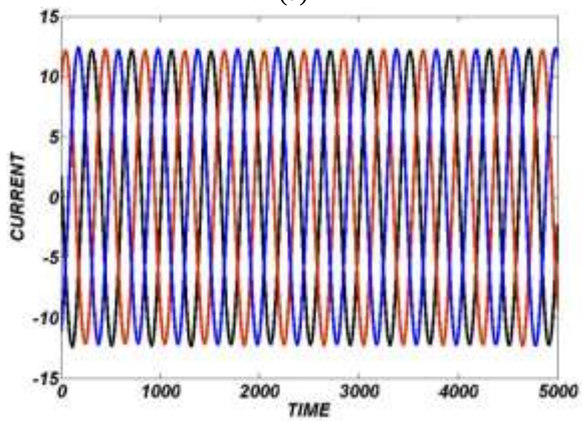

(b)

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C. Modelling of whole System with Non- Linear Load

In this phase a linear load is replaced by a non-linear load. In the non linear load the P and Q values are given externally by using a timer circuit and the Simulink diagram is shown in Figure-13

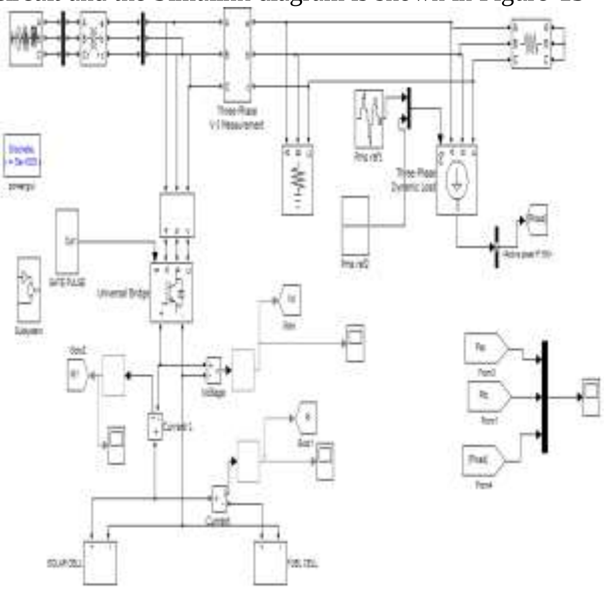

Figure-13: Whole System Connected to the Non-Linear Load

The power waveforms when connected to the non-linear load are shown below.

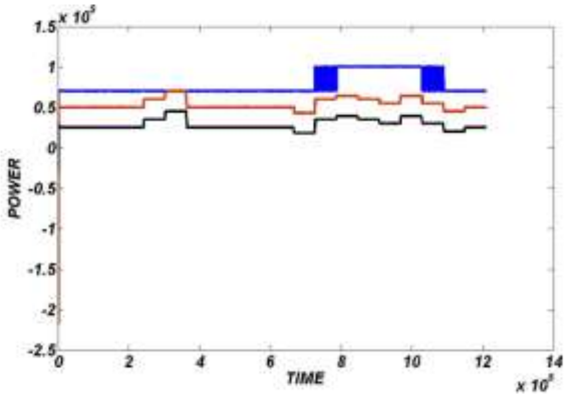

Figure-14: Power Waveforms of PV, FUEL Cell and Hybrid System Resources.

D. Modelling of Whole System when failure of either one Source in Hybrid System

In this phase if any one of the sources in hybrid system fails to respond then the power delivered by that source is zero. That undelivered power is switched or supplied by the grid. And the Simulink diagram is shown in Figure-15

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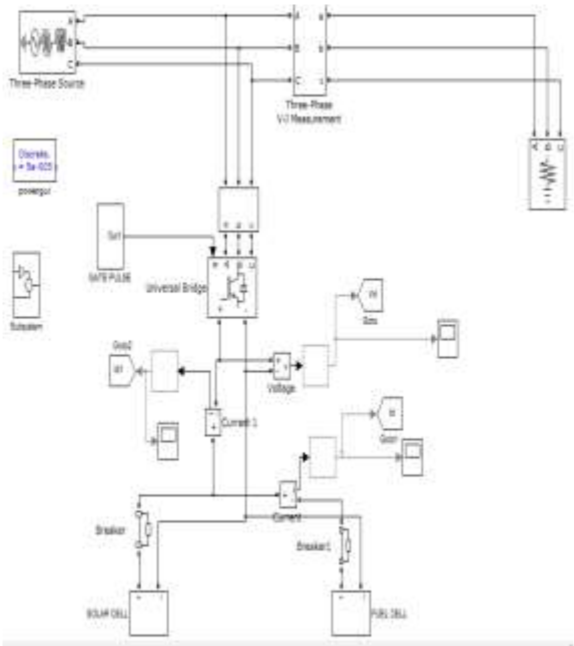


Figure-15: Disconnecting the One of the Sources Alternatively Using Circuit Breakers.

The voltage and current waveform for a failure of one source and waveforms for a connection of grid to the system is shown below.

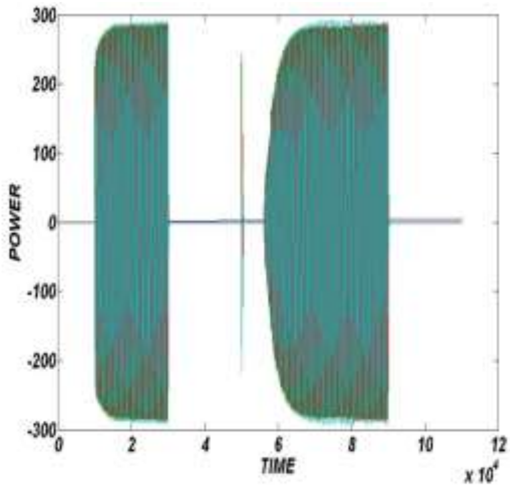
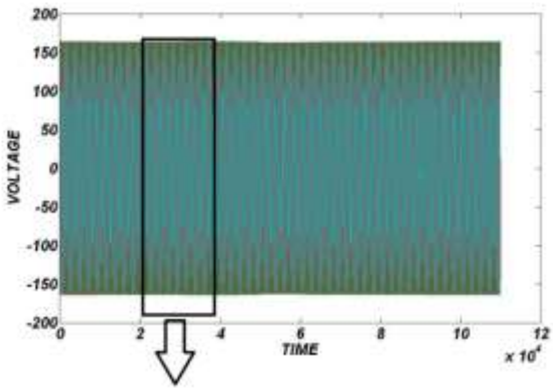
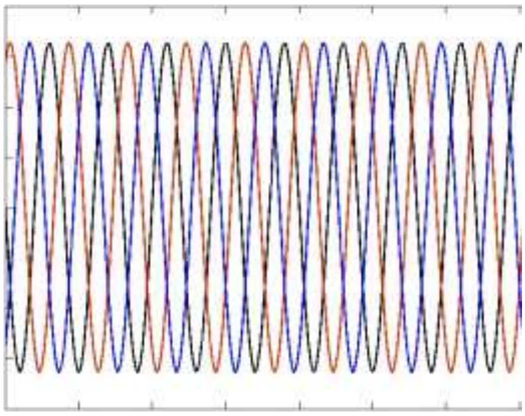
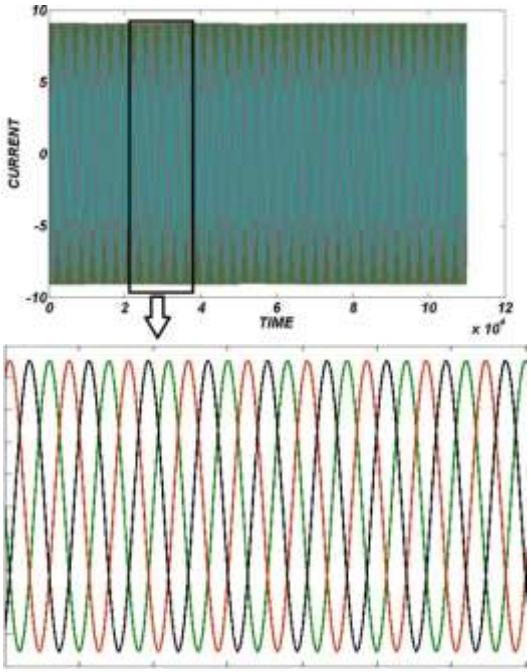


Figure-16: Power Waveforms When one the Sources are disconnecting alternately.





(a)



(b)

Figure-17: (a) Voltage and (b) Current Waveforms When Connected to Grid.

CONCLUSION

This paper presents a working of a grid connected hybrid system at different modes. In this hybrid system the PV array and PEMFC are consider. The different operating strategies make the system work more stably and both the resources to work at its maximum capacity.

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