MATHEMATICAL MODELLING OF GRID INTEGRATION OF 75KW SOLAR POWER WITH UNDER PERFORMING EXISTING 200KW MICON WIND ELECTRIC GENERATOR AT WTRS KAYATHAR

Submitted by

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ABSTRACT

A Novel concept of grid integration of 75 kWp solar power with one of the existing 200 kW under performing 27 years old wind electric generator was executed for increasing overall capacity utilization factor (CUF) of the underperforming wind electric generator using existing infrastructure like land,Transformer, Trainsmission Line etc. The basic idea in this concept is keeping Wind Power as reference since the wind electric generator is stall regulated which cannot be altered. Externally connected 75 KVAR capacity bank is used for reactive power consumption in Wind Electric Generator. By using PLC, cluster controller unit of Inverter, the Solar Power is adjusted for the connected load of 200 KW. The existing system is simulated using MATLAB/Simulink 2016a and resulted are validated with real-time system.

CHAPTER – I
WIND ENERGY CONVERSION SYSTEM

1 INTRODUCTION:

Wind energy is the energy which is extracted from wind and wind mills are used for the extraction. Wind energy is present almost 24 hours of the day and has less emission. Generation of electricity from wind is depend upon the speed of wind velocity.

The wind turbine under study is a 200KW Micon WTG installed 30 years back which is under performing due to the aging. Hence for optimum utilization of existing infra-structure facilities like transformer and power lines, an additional 75KW solar PV panels with power conditioners were installed. This system will try to maintain the constant power injection to the grid with less initial cost which will make system reliable.

1.1 Characteristics and features of wind energy

- Renewable source of energy
- More power is generate with less wind power
- Input source is free
- Wind power systems are non-polluting, so it has no adverse influence on the environment.
- Wind power systems avoid fuel provision and transport
- Generation of electricity is economical.
- Wind energy is easily converted from one form to another form.
- Can be connected easily with grid
- Less time is required to generate power

1.1.1 Components Used in Wind Power Generation System

Wind Turbine: A wind turbine is a device that converts the wind's kinetic energy into electrical power.

Gear Box: This is used to maintain the constant speed in the ratio of 1:37.9**.**

Induction Generator : It is suitable to generate electrical power from these nonconventional energy sources In WECS it is used to operate as a self-excited induction generator.

1.2 Block Diagram:

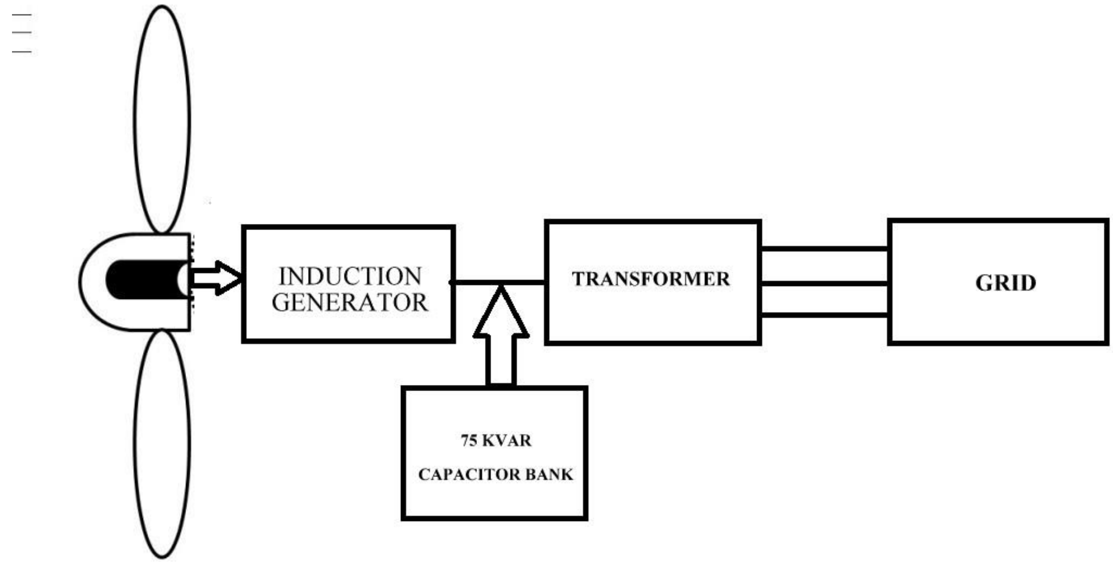

Fig 1.1: Block diagram of Wind Energy Conversion System

1.3 Squirrel Cage Induction Generator (SEIG):

Nowadays the induction generators are replaced by either Permanent Magnet Synchronous Generator (PMSG) or Doubly fed Induction generators (DFIG)

To operate as a self-excited induction generator, an induction machine has to be provided with magnetizing energy. This can be achieved by connecting the capacitor bank across the stator terminals. The major problems with the SEIG are as follows: its terminal voltage and frequency are influenced by the prime mover speed, excitation capacitance, load current, and power factor of the load. With a fixed capacitor bank connected across the stator terminals, it is not possible to keep the terminal voltage of the SEIG as constant under varying loads because of the variable reactive power demand, which is not met by the fixed capacitor bank. Therefore, the major problems associated with SEIG are its poor voltage and frequency regulation. However, due to fast response, improved switching features, and the low cost of the power converters, researchers are attracted to explore their applications for performance improvement of SEIGs.

1.4 Mathematical Modelling of SEIG:

An induction generator offers various advantages over the conventional synchronous generators such as reduced unit cost, easy maintenance, rugged and simple construction, brushless rotor (squirrel cage) and so on. Three-phase induction machine can be made to work as a self-excited induction generator (SEIG) .The SEIG is the induction machine driven by prime mover with capacitor connected in stator terminals. The output power of SEIG depends upon the Wind velocity variations of the horizontal axis wind turbine.

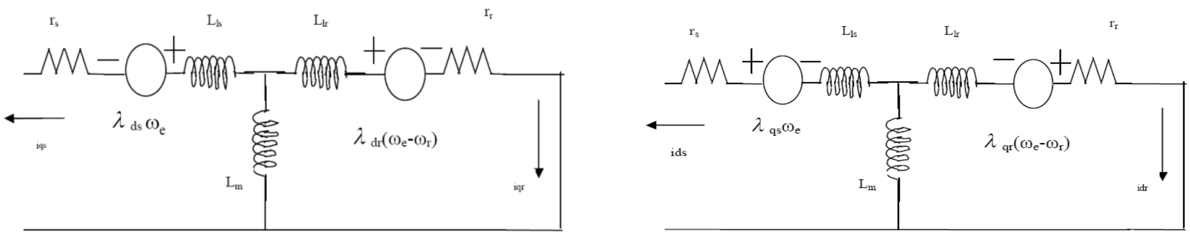

Fig 1.2: Equivalent circuit of SEIG in d-q reference frame

The d-axis and q-axis equation for equivalent circuits are

$$V_s i_{qs} + L_s\left(\frac{d_{iqs}}{dt}\right) + L_m\left(\frac{i_{qr}}{dt}\right) = V_{ds}W_e \quad (1)$$

$$V_s i_{ds} + L_s\left(\frac{d_{ids}}{dt}\right) + L_m\left(\frac{d_{idr}}{dt}\right) = -V_{ds} + V_{as}W_e \quad (2)$$

$$V_r i_{qr} + L_r\left(\frac{d_{iqr}}{dt}\right) + L_m\left(\frac{d_{iqs}}{dt}\right) = V_{dr}(W_e - W_r) \quad (3)$$

$$V_r i_{qr} + L_r\left(\frac{d_{idr}}{dt}\right) + L_m\left(\frac{d_{ids}}{dt}\right) = V_{qr}(W_e - W_r) \quad (4)$$

The following electromechanical equations represent the dynamics of self excited induction generator derived in d reference frame.

$$P_{i_{qs}} = K_l r_s i_{qs}(W_e + K_l L_m W_r) i_{ds} + K_2 r_r i_{qr} K_l L_m w_{rr} \quad (5)$$

$$P_{iqr} = K_2 L_s w_r i_{ds} + K_2 r_s i_{qs} + (K_1 L_s w_r w_e) i_{dr} + [(r_r + K_2 L_m r_r)] i_{qr} \quad (6)$$

Induction generator derived in q reference frame.

$$P_{ids} = K_1 r_s i_{ds}(w_e + K_2 L_m w_r) i_{qs} + K_2 r_r i_{dr} K_1 L_m w_r i_{qr} - K_1 V_{ds} \quad (7)$$

$$P_{idr} = K_2 L_2 w_r i_{qs} + K_2 r_s i_{qs} + (K_1 L_s w_r w_e) i_{qr} + \left[\frac{r_r + K_2 L_m r_r}{L_r}\right] i_{dr} + K_2 V_{ds} \quad (8)$$

Where

$$PV_{ds} = \frac{i_{dc}}{c}; w_e = \frac{i_{qc}}{c v_{ds}}$$

$$K1 = \frac{L_r}{\mathrm{L_s L_r - L_m^2}} \text{ and } K2 = \frac{L_m}{\mathrm{L_s L_r - L}_m^2}$$

The magnitude of the generated air gap voltage in the steady state equation is given by

$$V_g = w_e L_m |i_m| \tag{9}$$

Where

$$|i_m| = \sqrt{[(i_{qs} + i_{qr})^2 + (i_{ds} + i_{dr})^2]}$$

$$L_m = f\ (i_m)$$

Induction generator produced electromagnetic torque $T_g$is expressed as

$$T_g = -1.5\left(\frac{poles}{2}\right) L_m\left(i_{qs} i_{dr} - i_{ds} i_{qr}\right) \tag{10}$$

Dynamic equation of motion is given as

$$P_{W_r} = \frac{\left(\left(\frac{T_t}{G_r}\right) - T_g\right)}{J_g} \tag{11}$$

Developed electromagnetic torque and the torque balance equations are

$$T_e = \left(\frac{3}{2}\right)\left(\frac{P}{2}\right) L_m\left(i_{dr} i_{qs} - i_{qr} i_{ds}\right) \tag{12}$$

$$T_{shaft} = T_e + J\ \left(\frac{P}{2}\right) P_{w_r} \tag{13}$$

Torque balance equation is given by

$$P_{w_r} = \left(\frac{P}{2j}\right)\left(T_e - T_{shaft}\right) \tag{14}$$

1.5 Types of Drive Train

i. One mass drive train
ii. Two mass drive train
iii. Three mass drive train

One Mass drive has the higher oscillations and three mass drive has high complexity in construction. Hence, in real time two mass Drive model is commonly implemented.

1.5.1 Two mass drive train.

This Model shows the combination of wind turbine and shaft side. The differential equations are representing its mechanical dynamics which are given below

$$2H_t \frac{dWt}{dt} = T_m - T_{sh} \tag{15}$$

$$\frac{1}{W_{elb}} * \frac{dWt}{dt} = W_t - W_r \tag{16}$$

$$2H_{g\frac{dWt}{dt}} = T_{sh} - T_g \tag{17}$$

Where,

H_g=Inertia constant of the turbine = 0.125,

H_t=Inertia constant of the SEIG = 4,

W_t = angular speed of the turbine in P.U = 1,

W_r=rotor speed of the SEIG in P.U=1,

W_{elb} = Electrical base speed=153.9 rad/sec

The Shaft torque T_{sh} is

$$T_{sh} = K_{sh} * \theta_{tw} + D_{t\frac{d\theta wt}{dt}} \tag{18}$$

Where,

K_{sh} = Shaft Stiffness =0.3,

1.6 Matlab Simulink for Wind Energy Conversion System:

Parameters for Modelling of SEIG:

S.no	Parameter	Values
1	Nominal Power	275KW
2	Rotor	Squirrel Cage
3	Line Voltage V	440V
4	Frequency	50HZ
5	Stator Resistance (R_s)	0.016P.U
6	Stator Inductance (L_s)	0.06P.U
7	Rotor Resistance (R_r)	0.015P.U
8	Rotor Inductance (L_r)	0.06P.U
9	Mutual Inductance (L_m)	3.5P.U
10	Magnetising Inductance & Resistance	500
11	Inertia Constant	2
12	Pole Pair	2
13	Capacitor Bank	162.5KVAR

Table:1.1 Parameters of wind generator

The wind driven self –excited induction generator fed WECS is simulated using MAT LAB/SIMULINK and the results are analysed.Fig 1.3 shows the wind velocity and it is observed that, the wind velocity is maintained at 12m/s till 1 sec and after 1 sec, it is reduced to 6m/s. Fig 1.4 shows the torque output from the wind turbine. The negative torque indicates that, the induction machine act as generator. The variation torque reflects the variation in the wind velocity. Fig 1.5 shows the angular speed of the WT in PU. The angular speed reduces due to the reduction in the wind velocity and it is given to the drive train to maintain the constant speed in Induction generator. Fig 1.7 shows the output speed of the drive train which is maintained as constant. Fig 1.6 shows the output torque of the drive train and it is function of the wind velocity.

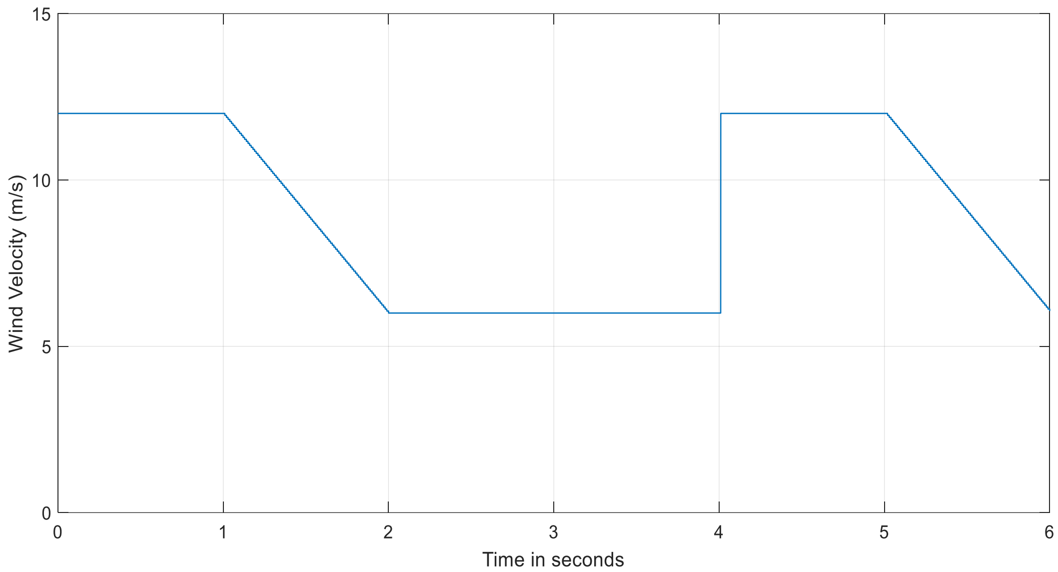

Fig 1.3 Wind Velocity

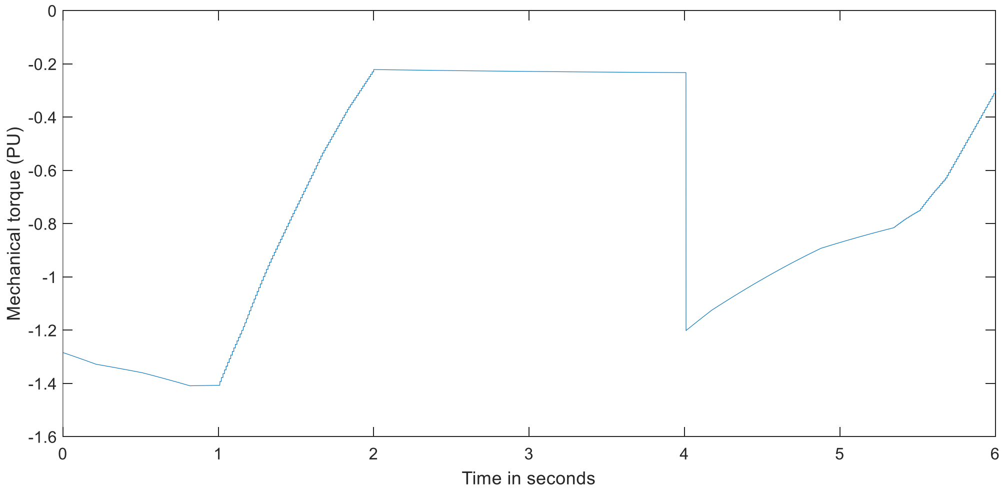

Fig 1.4 Mechanical Torque

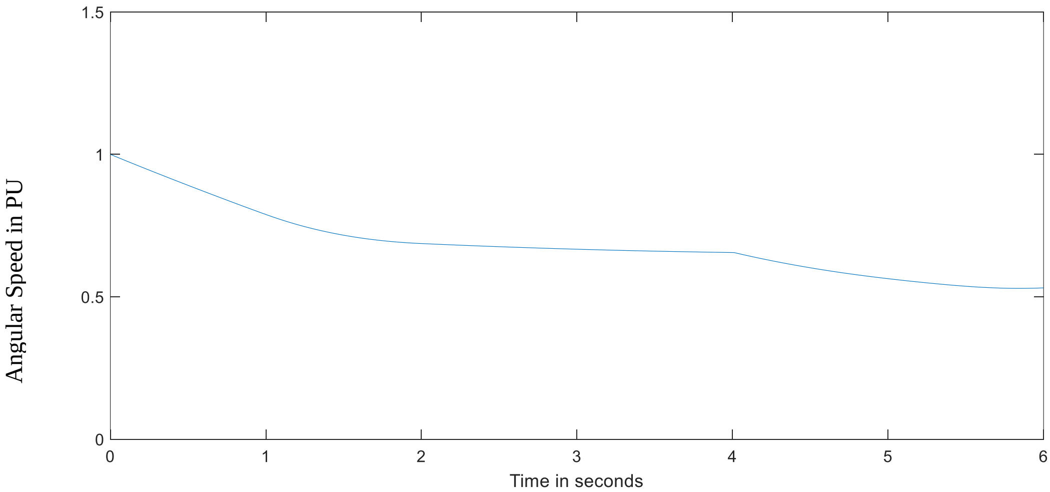

Fig 1.5 Angular speed of Wind turbine

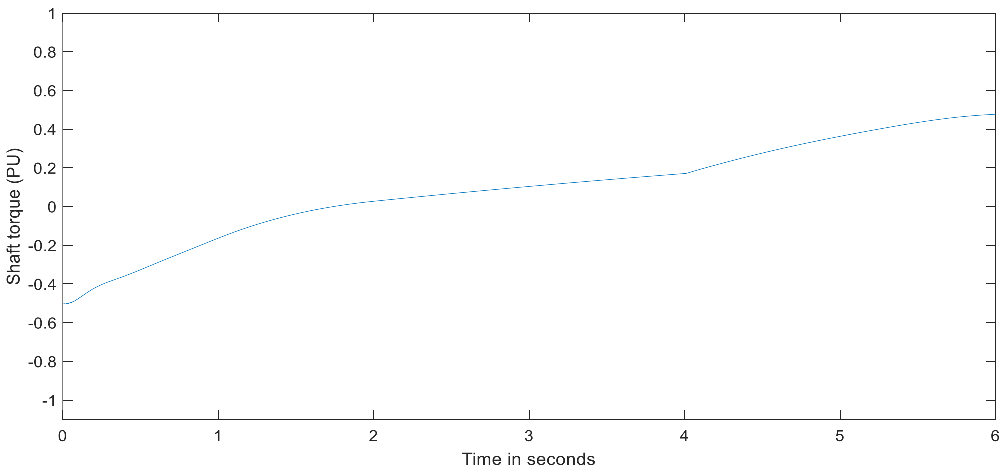

Fig 1.6 Shaft torque

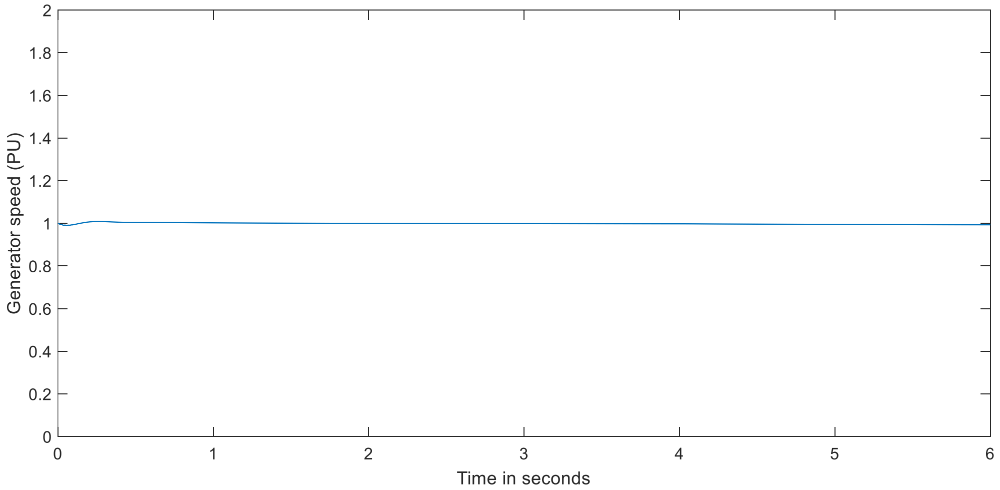

Fig 1.7 Generator speed

Fig 1.8 shows the generator instantaneous output voltage of 440V RMS with the frequency of 50Hz. Fig 1.9 shows the output current of 200A RMS which gives the output power of 152KVA with UPF ($\sqrt{3}V_L I_L$) and it is shown in Fig 1.10. A load of 350KW is connected at the PCC. The WTG supplies 130KW power to the load and the remaining demand of approximated 230KW is supplied from the grid. These powers are compared in Fig 1.12. Fig 1.11 shows the power delivered to the load by the grid.

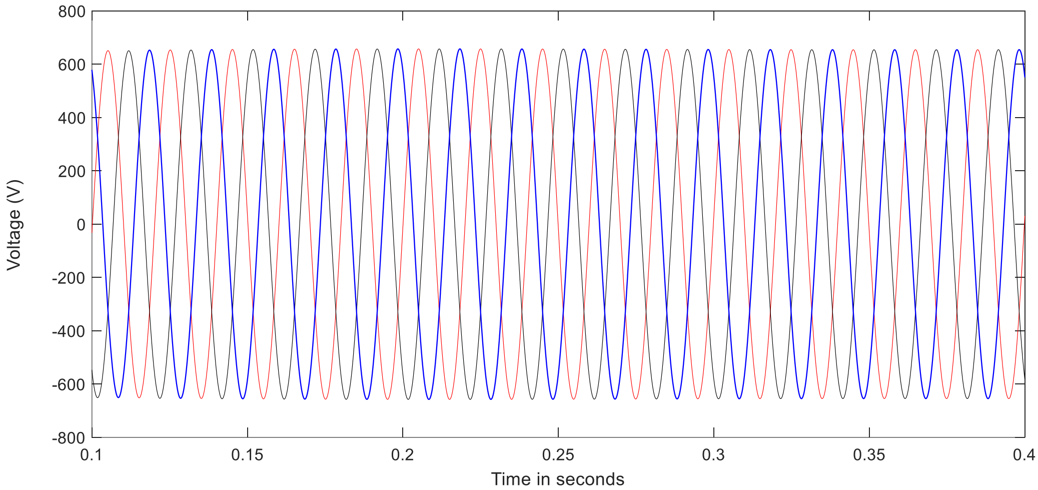

Fig 1.8 Generator output voltage

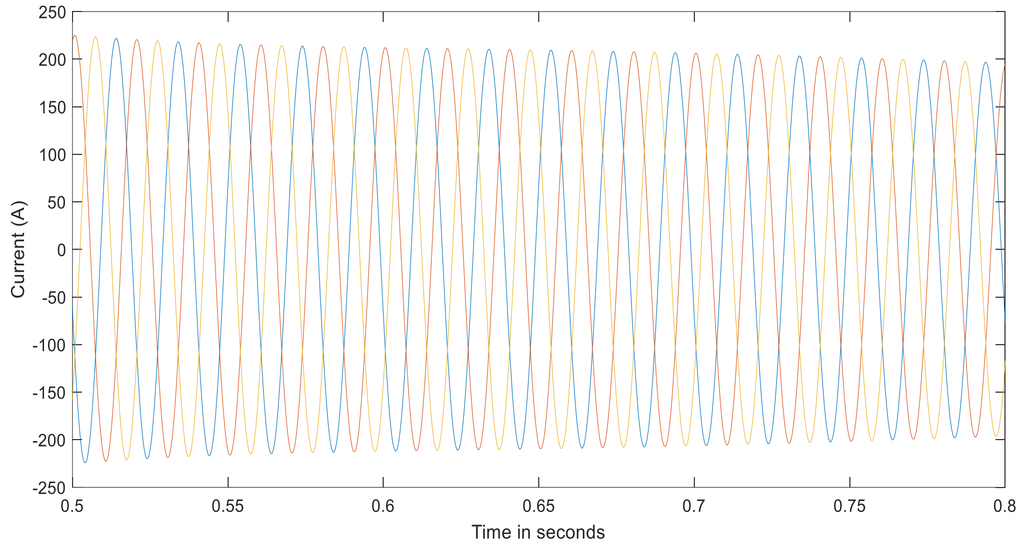

Fig 1.9 Generator output current

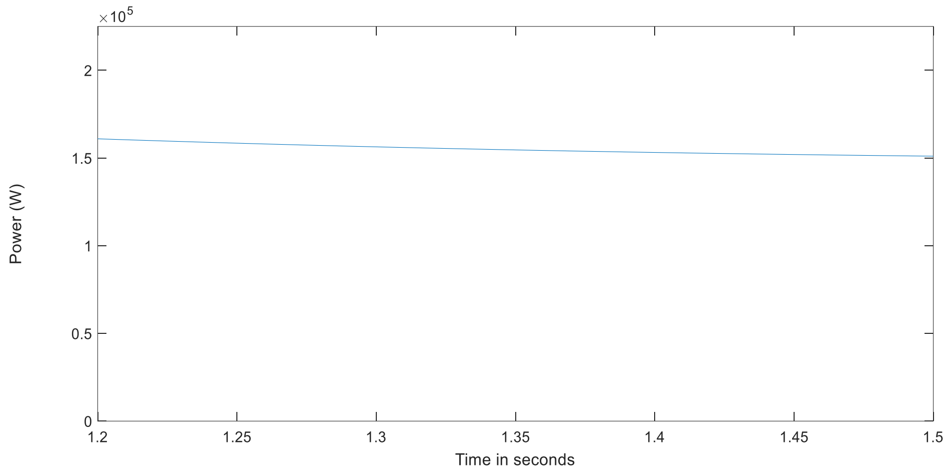

Fig 1.10: Output Power of WTG

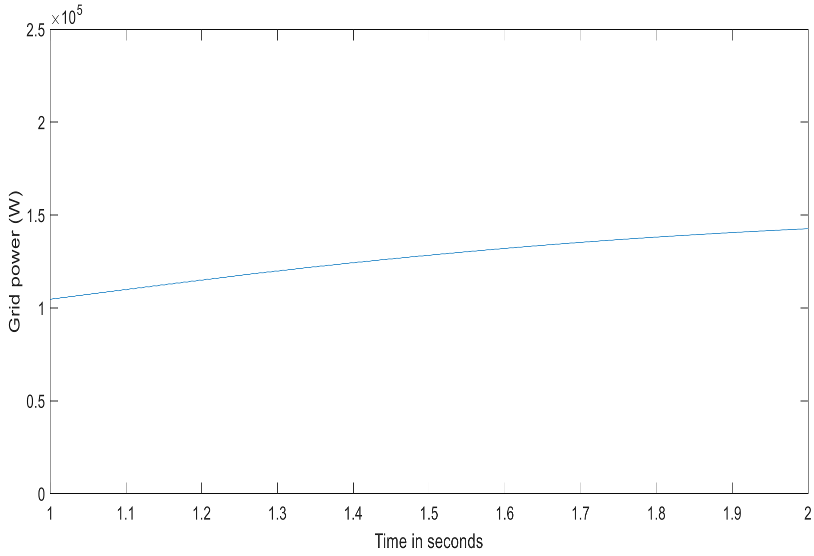

Fig 1.11. Grid Power at 350KW load

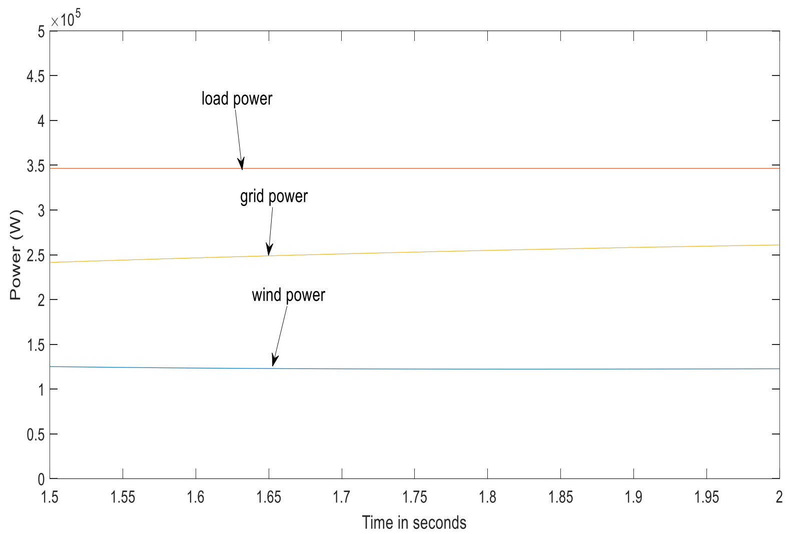

Fig 1.12 Comparison of Powers at 350KW load

CHAPTER – II

SOLAR ENERGY

INTRODUCTION

The sun is the largest energy source and the ultimate source of all energy. The sun is a star with surface temperature is about 5800 Kelvin. This temperature derives from reactions which were based on the transformation of hydrogen to helium, the process called Nuclear Fusion, which produce high temperature of the sun and the continuous emission of large amount of energy. Solar energy is emitted to the universe mainly by electromagnetic radiation and approximately one-third of energy radiated from sun is reflected back. The rest is absorbed and retransmitted to the space while the earth reradiates just as much energy as it receives and creates a stable energy balance at a temperature suitable for life. Solar radiation provides a huge amount of energy to the earth. The total amount of energy which is irradiated from the sun to the earth surface equals approximately 10,000 times the annual global energy consumption. There are normally two ways to generate electricity from sunlight, through photovoltaic (PV) and solar thermal systems. In this thesis is used photovoltaic power system. The light of the sun, which reaches the surface of the earth, consists mainly of two components, direct sunlight and indirect or diffuse sunlight, which is the light that has been scattered by dust and water particles in the atmosphere. Photovoltaic cells not only use the direct component of the light, but also produce electricity when the sky is overcast. To determine the PV electricity generation potential for a particular site it is important to assess the average total solar radiation received over the year.

2.1 PV Cell

PV Cell are made up of Semiconductor materials which absorb light and coverts part of the energy of the absorbed photons to carriers of electricity – electrons and holes. Solar cell or PV cell is the basic unit of a PV source, which is a simple P-N junction diode, formed by semiconductor material. The incidental sunlight comes perpendicularly on the solar cell. Electrical contacts are formed by metallic grid of the diode and allows light to fall on the semiconductor between the grid lines and thus it is absorbed and converted into electrical energy. An antireflective layer between the grid lines enhances the amount of light transmitted to the semiconductor. This is achieved through diffusion or implantation of dopants with specific impurities. The diode's other side electrical contact is done by a metallic layer on the back of the solar cell plate. Electromagnetic radiation from sunlight constitutes of photons particles which carry specific amounts of energy. By means of photovoltaic effect the electricity can be generated from the available photon energy.

The three particular points of interest for any PV cell are:

- The short-circuit (SC) condition is characterized by a zero voltage at the PV module terminals and by short-circuit current ISC.
- The open-circuit (OC) condition is characterized by a zero current in the PV panel terminals and by an open-circuit voltage VOC.
- The MPP, at which the current value is IMPP, the voltage value is VMPP and the power PMPP = VMPP x IMPP is the maximum the PV panel is able to deliver in the temporary operating conditions.

2.1.1 I-V and P-V Curves

The electrical characteristic of the PV cell is generally represented by the current Vs. voltage (IV) curve. The fig 1 depicts the I-V curve of PV cell which is for simulation and in real time system. This curve shows the variation of current and voltage when cell resistance varies from zero to infinity. In this curve the point at which the voltage is zero is called the short-circuit current. This is the current which is measured with output terminal shorted. On the other hand the point at which current is zero is known as open-circuit voltage. This is the voltage which is measured with output terminal open. Somewhere in the middle of the two regions, the curve has a knee point.

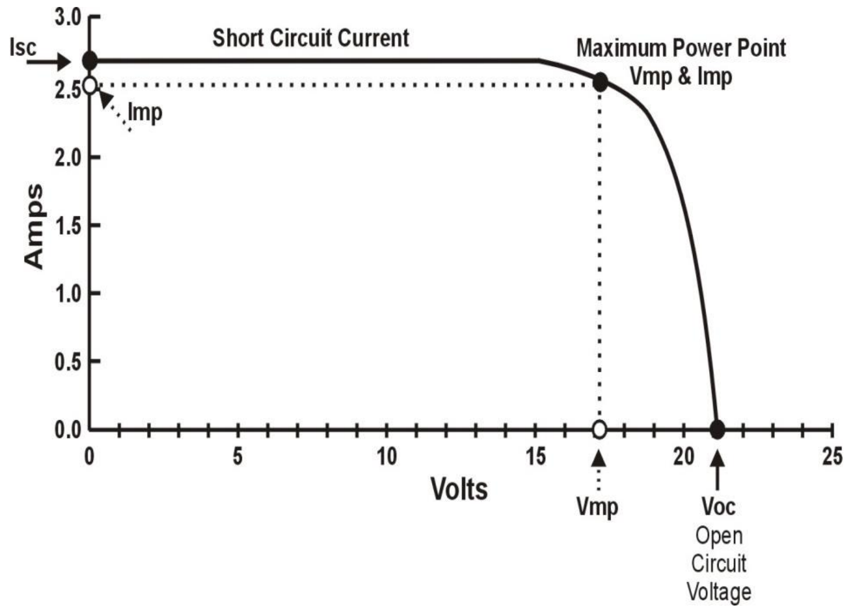

Fig 2.1. VI Curve of Solar PV

The power output of the panel is the product of the voltage and current outputs. The power is plotted against the voltage which is P-V curve of the PV cell.

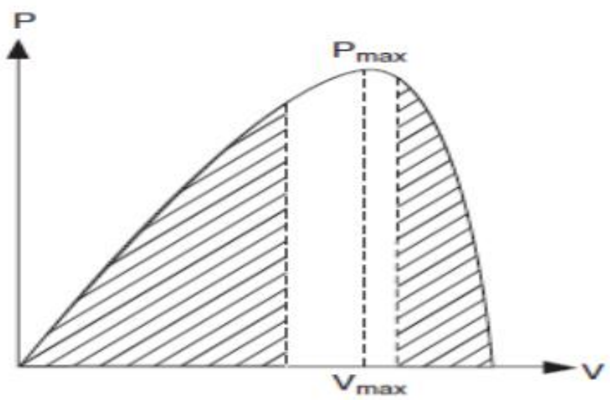

Fig 2.2 P-V Curve of the PV Cell

Note that the cell produces no power at zero voltage or zero current, and produces the maximum power at the voltage corresponding to the knee point of the I-V curve. This is why the PV power circuit is always designed to operate close to the knee point with a slight slant on the left-hand side. The PV circuit is modelled approximately as a constant current source in the electrical analysis of the system.

Finally in order to measure the photovoltaic cells output power the following standard test conditions are established internationally. The irradiance level is 1000 W/m², with the reference air mass 1.5 solar spectral irradiance distributions and cell or module junction temperature of 25°C.

2.1.2 PV System Components

- **Panels:** PV panels are the single biggest expense of a PV system. Their placement and mounting affect the system performance more than any other facet of the job.
- **Mounting equipment:** Mounting PV panels is of critical importance. First, it is needed to mount the panels where they'll get maximum sunshine over the course of a year. But the more difficult problem is to mount them with enough integrity that they'll stay put for 25 years or more.
- **DC-to-AC inverters:** Inverters take the low-voltage, high-current signals from the PV panels and convert them into 120VAC (or 240 VAC), which is directly compatible with grid power. From a reliability standpoint, they are generally the weak link in any PV system, so quality is a must.

2.2 BUCK-BOOST CONVERTER:

The **buck–boost converter** is a type of DC-to-DC converter that has an output voltage magnitude that is either greater than or less than the input voltage magnitude. It is equivalent to a flyback converter using a single inductor instead of a transformer. Two different topologies are called *buck–boost converter*. Both of them can produce a range of output voltages, ranging from much larger (in absolute magnitude) than the input voltage, down to almost zero.

The inverting topology, the output voltage is of the opposite polarity than the input. This is a switched-mode power supply with a similar circuit topology to the boost converter and the buck converter. The output voltage is adjustable based on the duty cycle of the switching transistor. One possible drawback of this converter is that the switch does not have a terminal at ground; this complicates the driving circuitry. However, this drawback is of no consequence if the power supply is isolated from the load circuit (if, for example, the supply is a battery) because the supply and diode polarity can simply be reversed. When they can be reversed, the switch can be on either the ground side or the supply side.

A buck (step-down) converter combined with a converter, the output voltage is typically of the same polarity of the input, and can be lower or higher than the input. Such a non-inverting buck-boost converter may use a single inductor which is used for both the buck inductor mode and the boost inductor mode, using switches instead of diodes,[2][3][4] sometimes called a **"four-switch buck-boost converter"**,[5] it may use multiple inductors but only a single switch as in the SEPIC and Ćuk topologies.

2.3 MPPT ALGORITHM

Incremental Conductance Technique (ICT):

Incremental conductance (INC) method is a type of MPPT algorithm. This method utilizes the incremental conductance (dI/dV) of the photovoltaic array to compute the sign of the change in power with respect to voltage (dP/dV). INC method provides rapid MPP tracking even in rapidly changing irradiation conditions with higher accuracy than the Perturb and observe method.

Algorithm:

The power-voltage curve's slope is null at the MPP, negative to the right of the MPP and positive to the left of the MPP. INC computes the maximum power point by comparison of the incremental conductance ($\Delta I/\Delta V$) to the instantaneous conductance (I/V). When the incremental conductance is zero, the output voltage is ascertained to be the MPP voltage and fixed at this voltage until the MPP encounters a change due to the change in irradiation conditions. Then the process above is repeated until a new maximum power point is reached.

Advantage:

- This technique has an advantage over the perturb and observe method because it can stop and determine when the Maximum Power Point is reached without having to oscillate around this value.
- It can perform Maximum Power Point Tracking under rapidly varying irradiation conditions with higher accuracy than the perturb and observe method.

Drawback:

- It can produce oscillations and can perform erratically under rapidly changing atmospheric conditions.

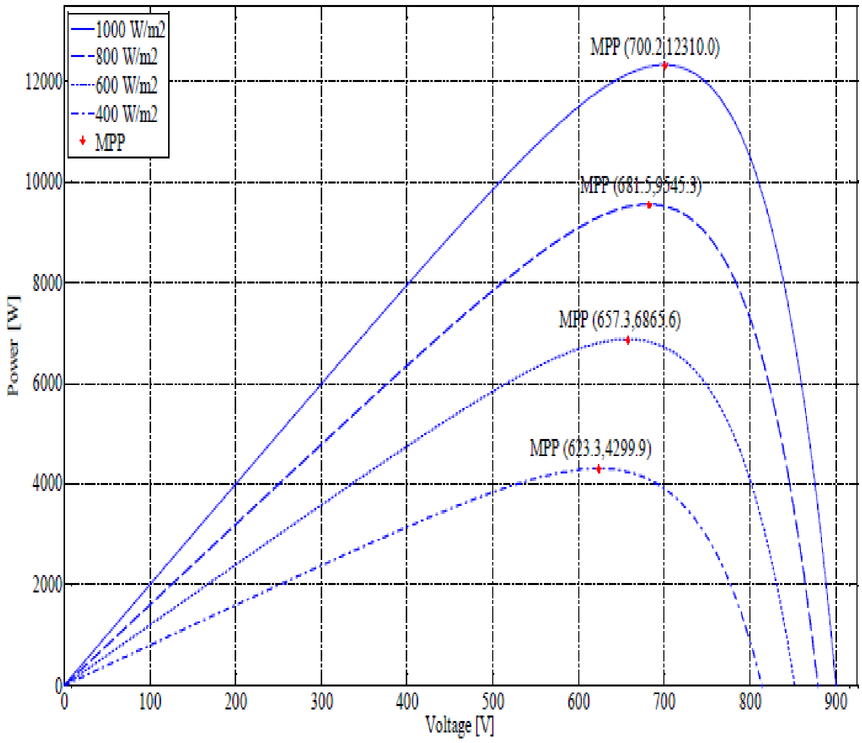

Fig 2.3: Incremental Conductance Method

- ➢ The computational time is increased due to slowing down of the sampling frequency resulting from the higher complexity of the algorithm compared to the P&O method.

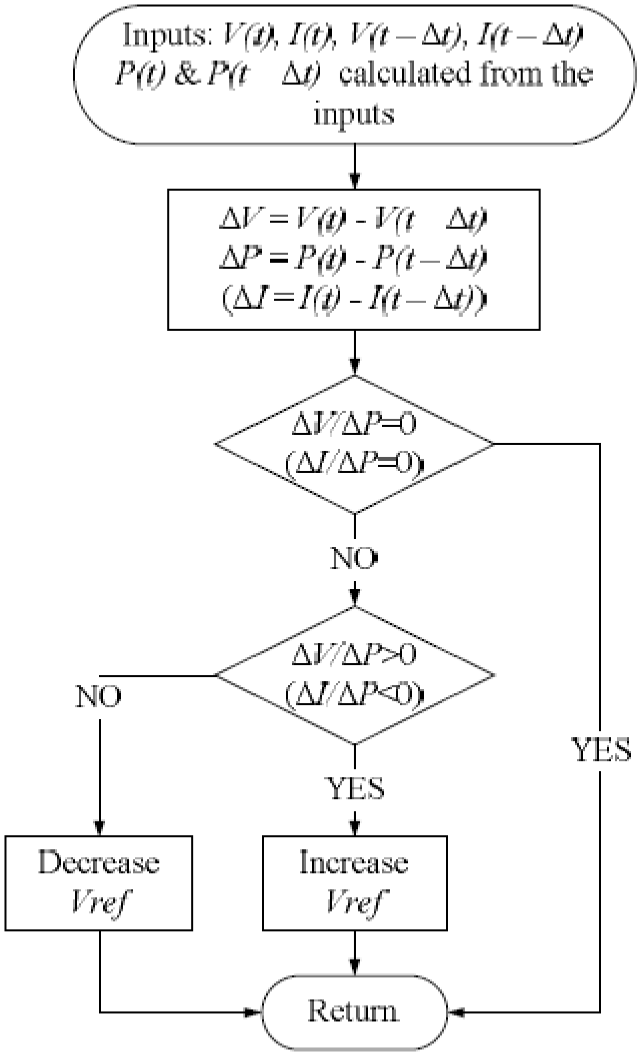

Fig 2.4: Flow chart of ICT Algorithm

2.4 Inverter

An inverter converts the direct current (dc) electricity from PV modules to alternative current (ac) electricity. The normal output ac waveform of inverters is a sine wave with a frequency of 50Hz.

Inverters are available in three different categories based on where they are applied: grid-tied battery less, grid tied with battery back-up and stand-alone. The grid tied battery less are the most popular inverters today. These inverters connect directly to the public utility, using the utility power as a storage battery. The grid-tied with battery backup are more complex than battery less grid-tied inverters because they need to sell power to the grid, supply power to backed-up loads during outages, and charge batteries from the grid, PV or wind turbine after an outage. The stand alone inverters are designed for independent utility-free power system and are appropriated for remote hybrid system installation.

In the other hand, based on their output waveforms there are three kinds of inverters; square wave, modified sine-wave, and pure sine wave inverters. Of the three, the square wave type is the simplest and least expensive, but with the poorest quality output signal. The modified sine wave type is suitable for many load types and is the most popular low-cost inverter. Pure sine wave inverters produce the highest quality signal and are used for sensitive devices such as medical equipment, laser printers, stereos, etc. The efficiency of converting the direct current to alternative current of most inverters today is 90% or more [Rivera, 2008].

2.5 Block Diagram

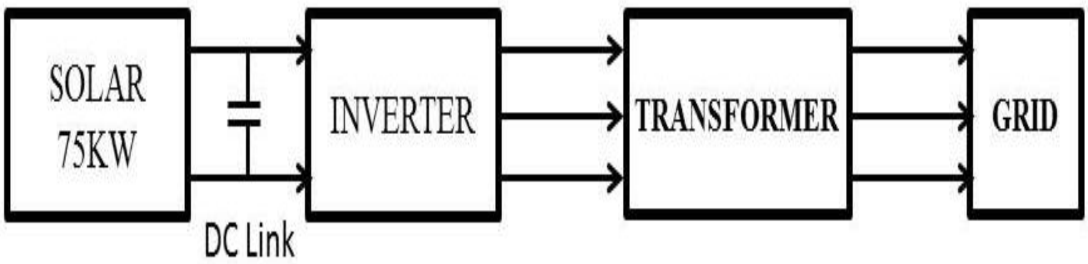

Fig 2.5: Block diagram of solar power Generation unit

The basic element of solar PV system is solar cell. These basic cells are connected to form solar PV nodules. Further expansion of solar PV is done by connecting solar PV modules to form solar PV array.Cells connected in series increases the voltage output while cells connected in parallel increase the current. The solar array or panel is a group of several modules electrically connected in series-parallel combination to generate required current and voltage and hence the power. In this proposed work PV array is designed to generate 75KW power. Totally 100 solar panels for each phase with 25 panels in series and 4 panel in parallel are used. Hence totally 300 solar panels of 250Wp are used to generate 75KW power.

2.6 Modelling the Solar Cell

Thus the simplest equivalent circuit of a solar cell which shown in fig 2.6 is current source in parallel with a diode. The output of the current source is directly proportional to the light falling on the cell (photocurrent Iph). During darkness, the solar cell is not an active device; it works as a diode, i.e. a p-n junction. It produces neither a current nor a voltage. However, if it is connected to an external supply (large voltage) it generates current ID, called diode (D) current or dark current. The diode determines the I-V characteristics of the cell.

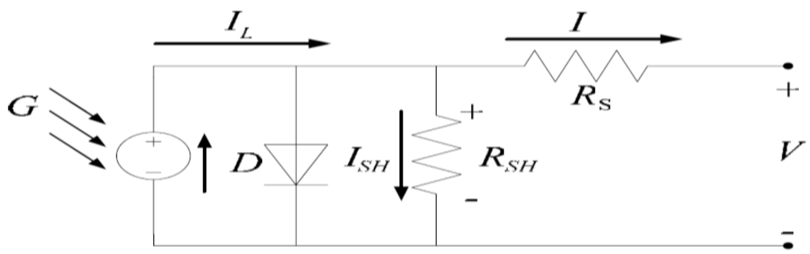

Fig 2.6 Equivalent Circuit of Solar cell

Increasing sophistication, accuracy and complexity can be introduced to the model by adding in turn:

- Temperature dependence of the diode saturation current I_0.
- Temperature dependence of the photo current I_L.
- Series resistance R_s, which gives a more accurate shape between the maximum power point and the open circuit voltage. This represents the internal losses due to the current flow.
- Shunt resistance R_{sh}, in parallel with the diode, this corresponds to the leakage current to the ground and it is commonly neglected
- Either allowing the diode quality factor *n* to become a variable parameter (instead of being fixed at either 1 or 2) or introducing two parallel diodes with independently set saturation currents.
  - The voltage–current characteristic equation of a solar cell is provided as Module photo-current I_{ph}.

$$I_{ph} = [I_{sc} + K_i(T - 298)] \times \frac{I_r}{1000} \quad (19)$$

Where,

I_{ph}: photo-current (A);

I_{sc}: short circuit current (A) ;

K_i: short-circuit current of cell at 25 °C and 1000 W/m2;

T: operating temperature (K);

I_r: solar irradiation (W/m2).

Module reverse saturation current I_{rs}:

$$I_{rs} = I_{sc}/\left[\exp\left(\frac{qV_{oc}}{N_s knT} - 1\right)\right] \quad (20)$$

Voc: open circuit voltage (V);

N_s: number of cells connected in series;

n: the ideality factor of the diode;

k: Boltzmann’s constant = 1.3805 × 10−23 J/K.

The module saturation current I0 varies with the cell temperature, which is given by:

$$I_0 = I_{rs}\left[\frac{T}{T_r}\right]3\exp\left[q \times \frac{E_{g0}}{nk\left(\frac{1}{T}-\frac{1}{Tr}\right)}\right] \tag{21}$$

Here,

Tr: nominal temperature = 298.15 K;

E_{g0}: band gapenergy of the semiconductor, = 1.1 eV;

The current output of PV module is:

$$I = N_P \times I_{ph} - N_P \times I_0 \times [\exp((\frac{V}{N_S} + I \times \frac{R_s}{N_P}) / (n \times V_t)) - 1] - I_{sh} \tag{22}$$

2.7 Real and Reactive Power Control

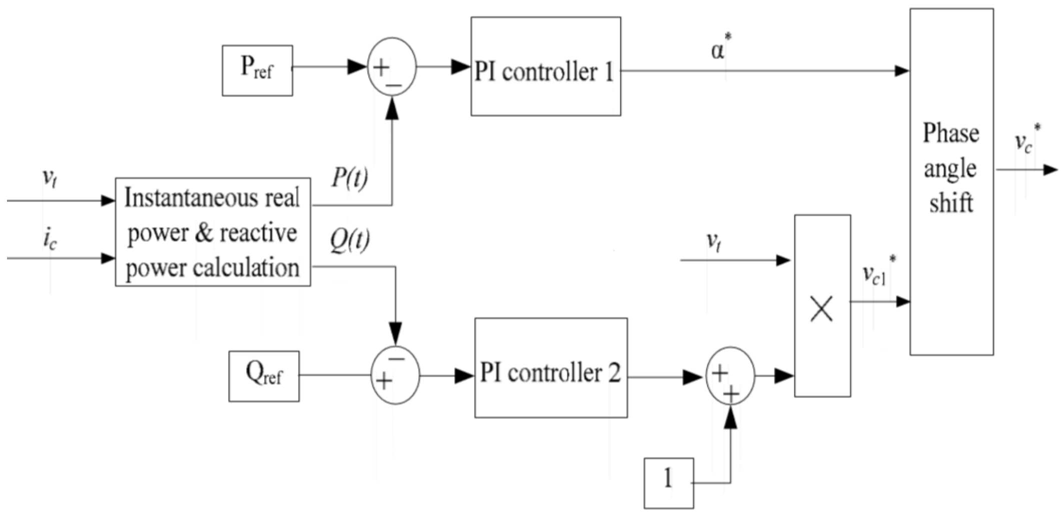

Fig 2.7 Fixed real power and voltage/var control of the PV system.

Here real and reactive power control algorithm for a three-phase single-stage PV inverter is implemented. The real power can be a MPPT or a fixed power control, and the reactive power control can be a local voltage regulation control or a fixed amount of reactive power control. The MPPT control algorithm is based on a dP/dV feedback control. The PV inverter control can be extended for automatic switching between fixed real power mode and MPPT control mode according to an operational command and/or atmospheric condition.

Since the output voltage of the PV panel is 750V, a DC-DC boost converter is not necessary and hence single stage PV inverter is used. A DC link capacitor is located in between PV array and the inverter. Both the phase angle and magnitude of the inverter output voltage are controlled to regulate the PV inverter real power and the reactive power supplied to the grid. The real power and reactive power of the PV inverter can be controlled simultaneously and independently. Depending on the control objectives, the MPP of the PV arrays or a fixed amount of real power could be the control goal for the real power control. For the reactive power, the control goal could be maintaining the local PCC voltage at some reference setting or providing a fixed amount of reactive power.

The PI1 controller is used to control the real power while the PI2 controller is used to control the reactive power. The instantaneous real power and reactive power are calculated from instantaneous inverter voltage and current and compared with a real power reference, P_{ref}, and reactive power reference, Q_{ref}, respectively. The errors in the power output are fed into their respective PI controllers to minimize the error between the actual and reference values. The signal generated by the real power PI controller regulates the phase angle of the inverter output voltage while the signal from the reactive power PI controller adjusts the amplitude of inverter output voltage. The local PCC voltage control is implemented by replacing the reactive power reference signal, Q_{ref} , of the control logic in Fig.2.7 with the PCC voltage reference signal, V_{ref}. The control logic for the fixed real power and voltage control is shown Fig.

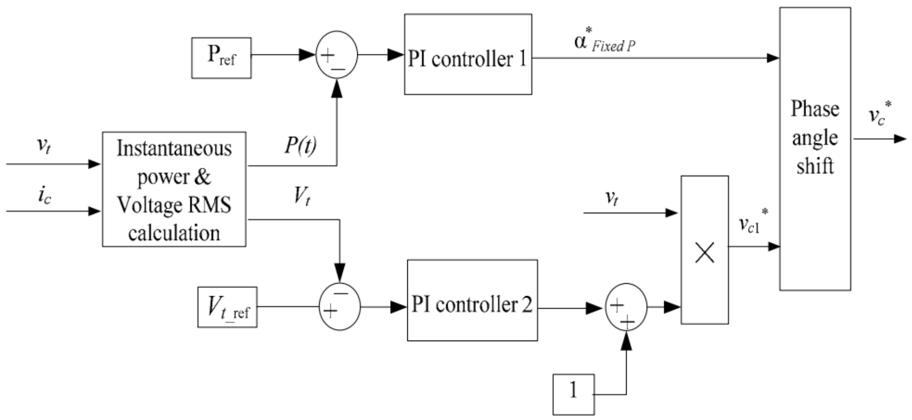

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Fig.2.8 Fixed real power and voltage control of PV array

For instance, when the summation of wind power and maximum power from solar is greater than 200KVA, PV system should be operated in the fixed real power control mode. But when the total power generation from hybrid system is less than 200KVA, PV system should be shifted from fixed real power control mode to MPPT. Generally, seamless switching between fixed real power and MPPT control is necessary for PV systems to operate smoothly during dynamic atmospheric and power grid conditions.

The MPPT control logic implemented with a PI controller, in which dppv/dvpv is approximated with $\Delta_{Ppv}/\Delta_{Vpv}$. The PI controller generates the phase shift reference of the inverter output voltage to keep $\Delta_{Ppv}/\Delta_{Vpv}$ close 0. MPPT can be achieved simultaneously with either the reactive power control or voltage control. As indicated earlier, the reactive power control or voltage control is achieved by regulating the magnitude of inverter output voltage. Fig shows the MPPT control in PV system.

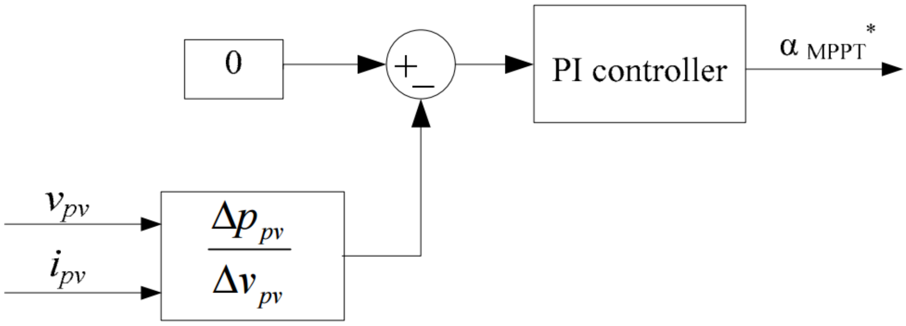


Fig 2.9 MPPT Control

When $d_{Ppv}/d_{Vpv} < 0$ ∗increases, causing PV inverter to increase real power output and the capacitor of the DC link will discharge. As a result, the DC voltage will decrease and the PV array operating point moves to the MPP. If the PV array moves beyond the MPP, $d_{Ppv}/d_{Vpv} > 0$ and †∗decreases, causing PV inverter to decrease real power output. When the PV inverter real power output is less than the PV array output power, the capacitor will be charged. As a result, the DC voltage will increase and the PV array operating point will move toward the MPP.

2.7.1 Parameters for Modelling of solar PV using Matlab Simulink:

Cell Parameters:

S.no	Parameter	values
1	No of Cells in a Module	60(10*6)
2	Maximum Power P_{max}	250Wp
3	Rated Voltage V_{rated}	30.2 V
4	Rated Current I_{rated}	8.42A
5	Open Circuit Voltage V_{oc}	37.4 V
6	Short Circuit Current I_{sc}	8.86 A
7	No of Modules/Array	100(25*4)
8	No of Arrays	3
9	Voltage of Solar Array	750 V
10	Current from Solar Array	33A
11	Current from Solar Panel	100A

Table 2.1 Parameters of Solar PV

Rating of Inverter:

INPUT		OUTPUT	
Power	25550W	Prated	25KW
Vmax	1000V	AC Voltage	160-280V
Vrated	392 to 800V/ 600V	Frequency	50Hz
Imax	33A	Imax	36.2A

Table 2.2 Rating of Inverter

2.7.2 Simulation Results and Discussion:

Based on the above mentioned parameters in table the solar PV module is simulated. Fig 2.10 shows the PV voltage and PV current. With the irradiation of 1000w/m^2 and temperature of 25° C, the PV voltage of 750V (30V * 25 panels in series) and current of 100A (8.4A * 12 panels in Parallel) is obtained. The maximum power of 74KW is extracted from the PV array using MPPT algorithm and it is shown in fig 2.9.

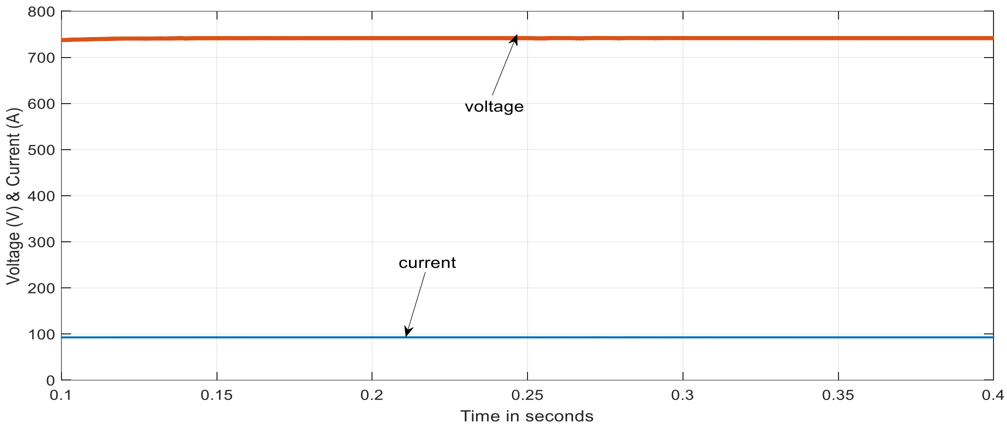


Fig 2.10 Solar output voltage and current

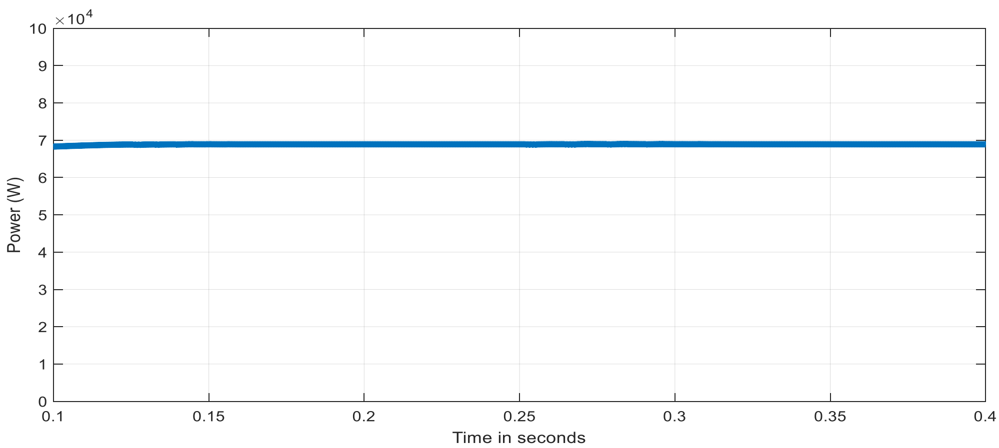


Fig 2.11 PV output power

Fig 2.12 shows the output voltage of buck/boost converter which is given as input to the inverter. Fig 2.13 & 2.14 shows the output voltage and current of the inverter with filter. The 41KW of output power with the output voltage of 440V RMS, output current of 62A RMS and PF of 0.86 is obtained from inverter. Fig 2.15 & 2.16 shows the voltage and current at PCC and the capacity of the grid is taken as 100KVA.

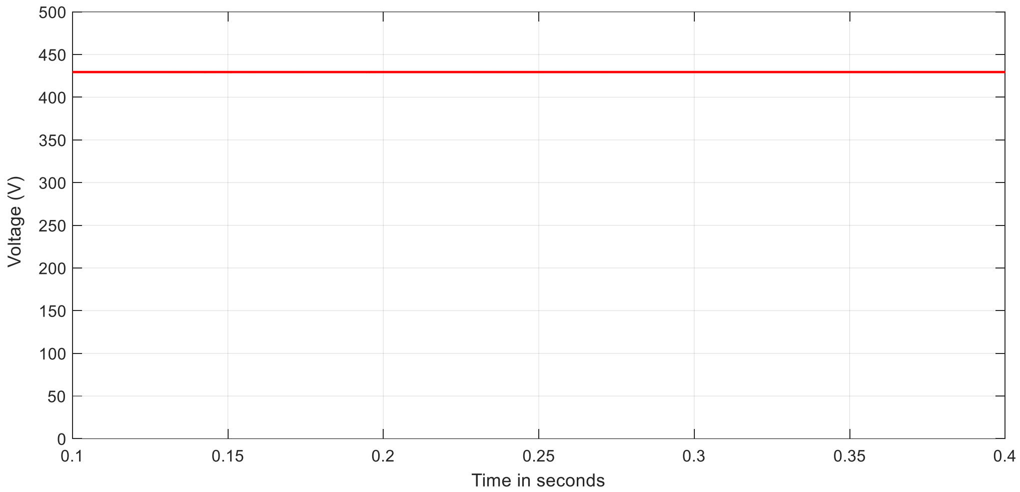


Fig 2.12 Input voltage of Inverter

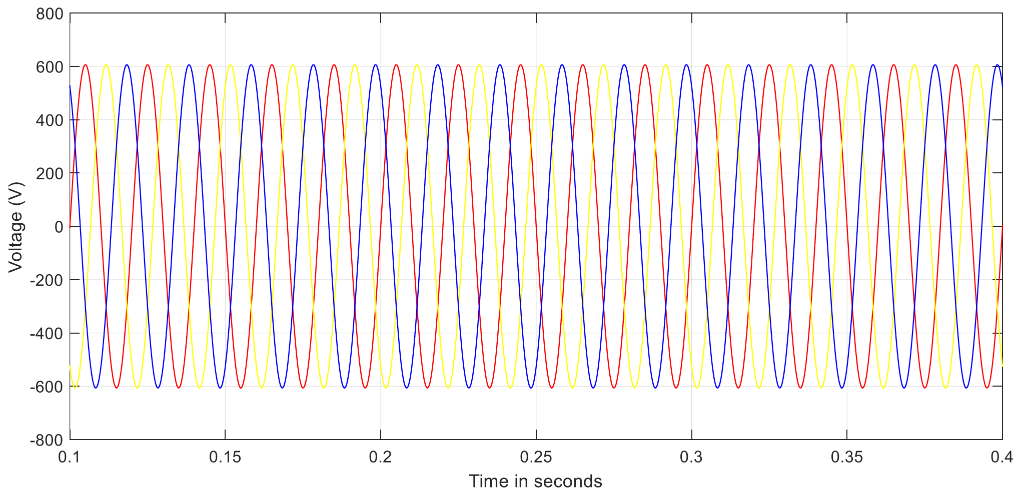


Fig 2.13 Inverter output voltage

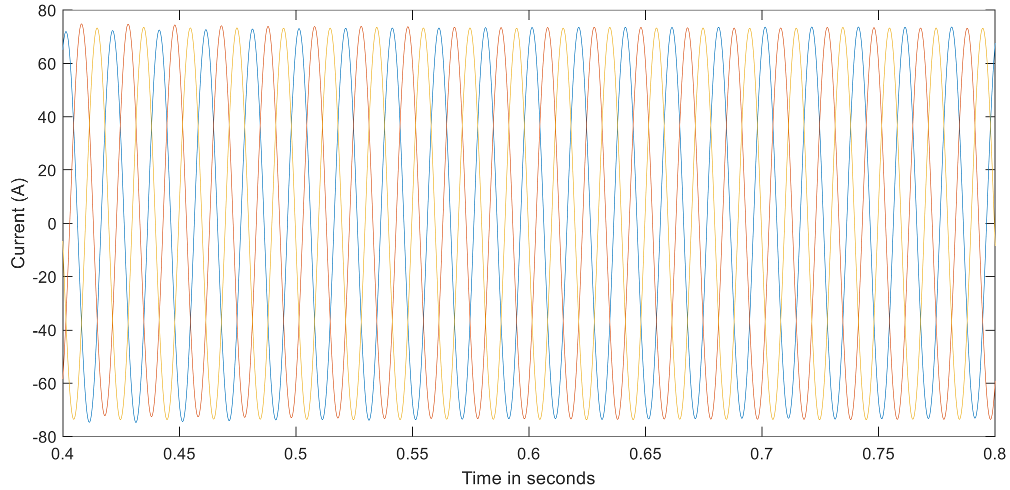


Fig 2.14 inverter output current

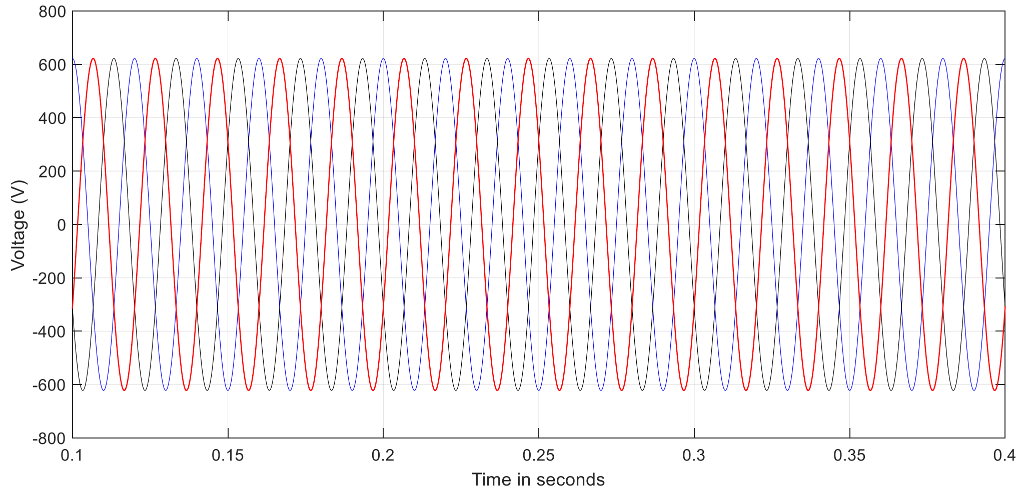


Fig 2.15 Voltage at pcc

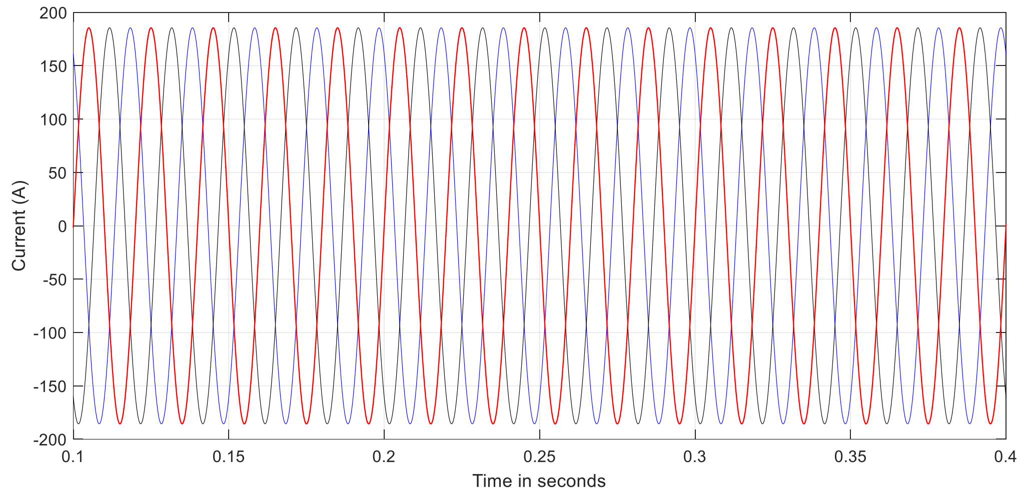


Fig 2.16 Current at PCC

The reference real power is given as 30KW and a load of 40KW is connected to the system. Here the load power is higher than the power generated by the solar panels. Hence the remaining power is delivered by the grid. The comparison of powers for a load of 40KW is shown in fig 2.18. The reactive power at PCC is 30KW and is shown in fig 2.17.

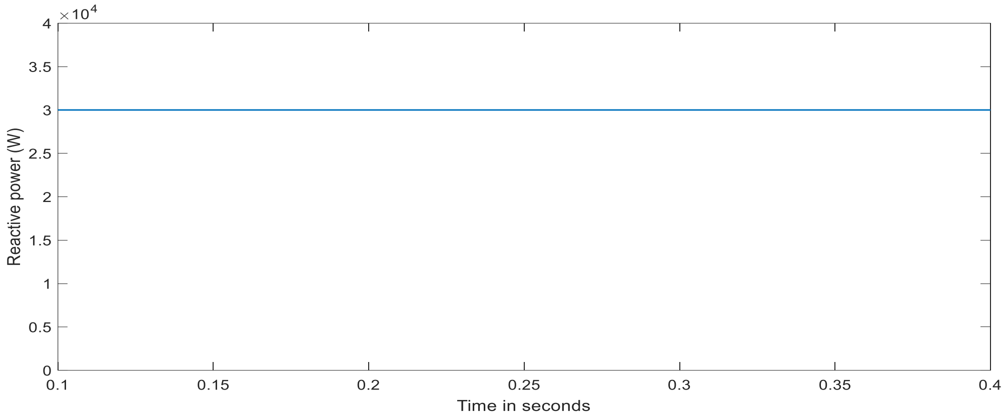


Fig 2.17 Reactive power at grid

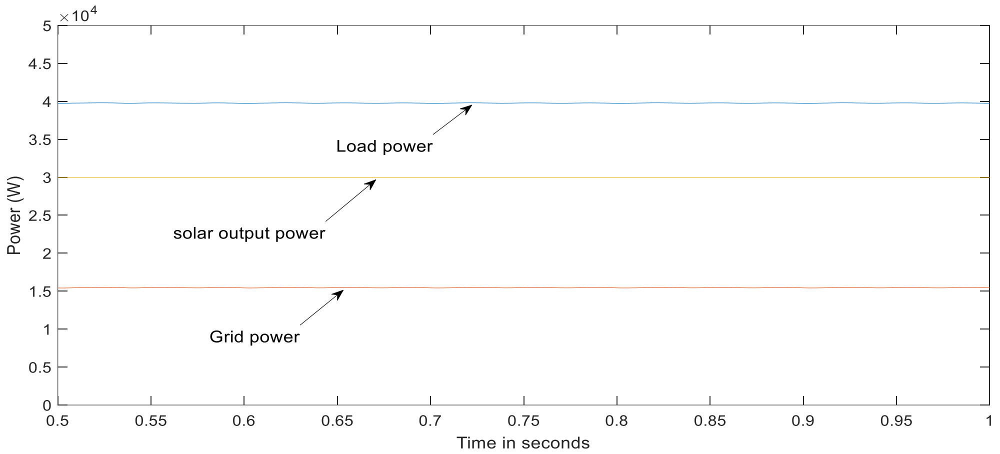


Fig 2.18 Powers at 40KW load

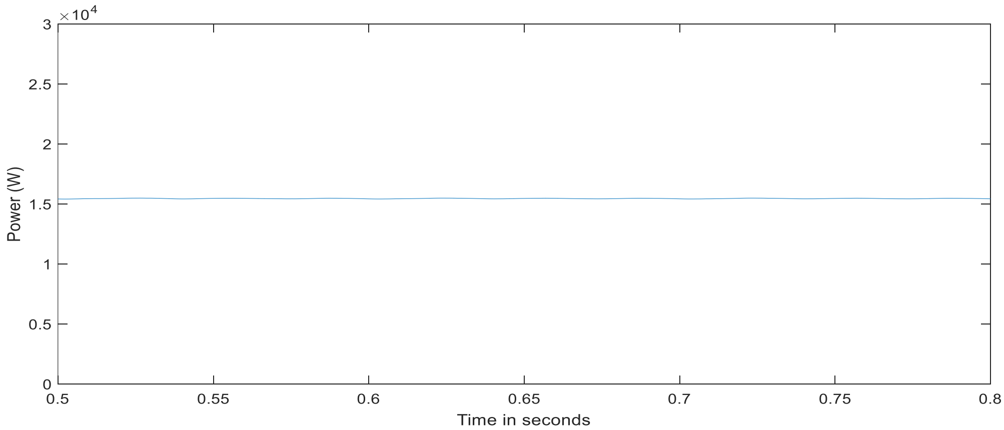


Fig 2.19 Grid power

2.8 REAL POWER CONTROL:

The reference real power is reduced from 3.1KW to 2.5KW at 1sec, with the constant load of 2 KW. Hence the output power of inverter also reduces with the reference real power. Since the power delivered by the inverter reduces, the power injected into the grid also reduces form 2.5 KW to 1.8 KW and it is shown in fig 2.20.

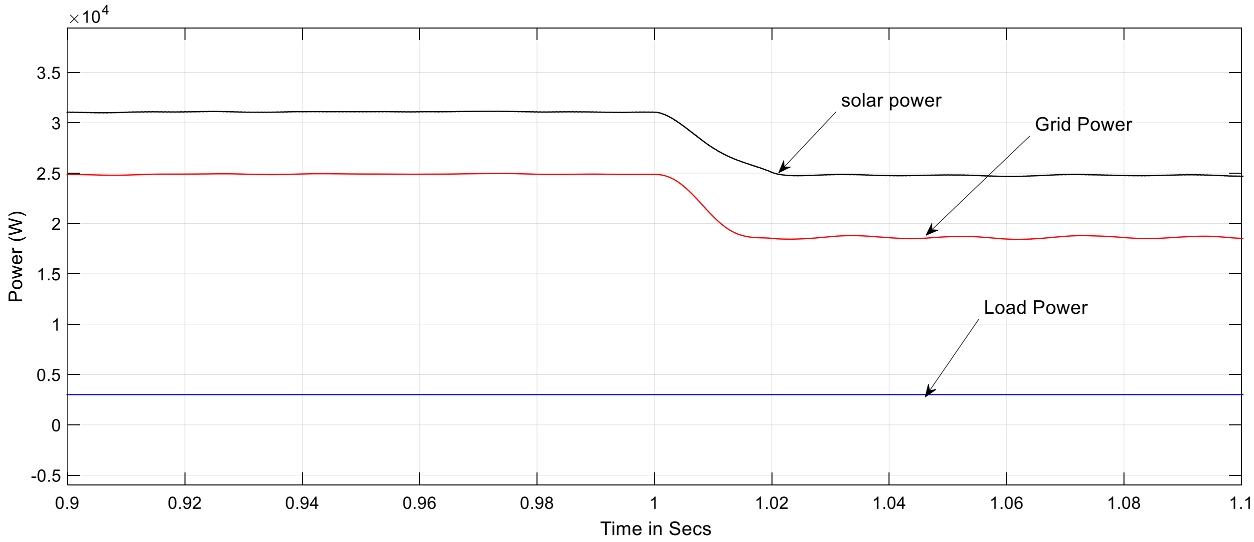


Fig 2.20 Real Power control in PV System

CHAPTER III

HYBRID POWER GENERATION SYSTEM

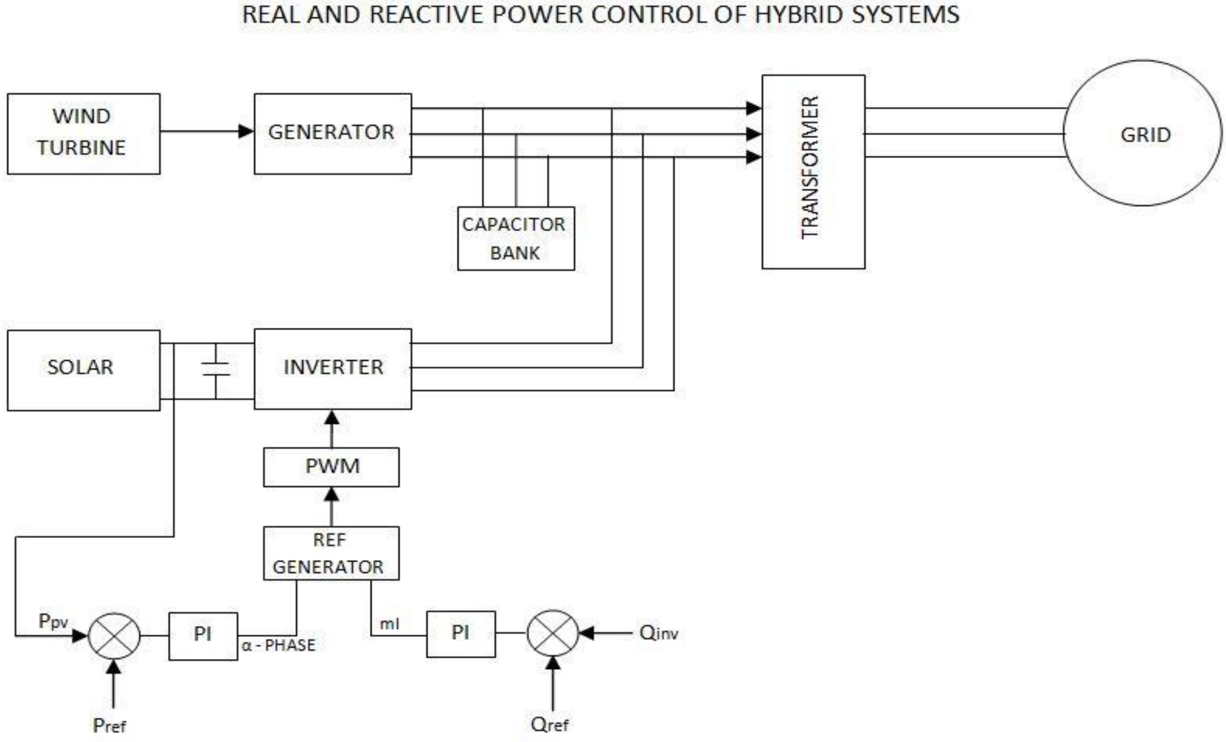
3 .1 INTRODUCTION

With the increase in the power demand and limited fossil fuels the renewable energy source plays a vital role to overcome these challenges. The fossil fuels based energy source causes environmental pollution. This led to the need for renewable energy sources (solar, wind, biomass) which is abundant and pollution free. Although the initial cost and space requirement of renewable system is high but they are derived from nature hence the running becomes less. Among renewable sources solar and wind energy have a great potential of supplying energy to meet the power demand. Their applications are extended in different areas like distributed generation (DG), micro grid, smart grid, stand-alone systems, rural telephony systems etc. The inherent drawbacks of renewable systems are that they are unpredictable and intermittent in nature. Thus there is a need for emergence of hybrid renewable energy system came to existence with two or more sources usually wind and solar. Hybrid renewable energy systems improve the efficiency and life cycle of the system also it reduces the need of storage to some extent. But due to the multiple sources the capital cost becomes high and becomes complex. The Various methods of hybrid wind-solar system are as follows. The systems require separate DC/DC converters for each source and they are connected in parallel. They require a supervisory control for switching of sources. They require additional back up source like fuel cell unit, diesel generators, or battery energy storage systems.

The hybrid power generation concept implemented in WTRS kayathar aimed at the production and utilization of electrical energy coming from more than one source within an integrated arrangement. Since the 200KW Micon WTG is underperforming, a 75KW solar system is integrated for the optimised utilisation of existing infrastructure facilities.

Other advantages of the hybrid system are the stability and reliability of the system and the lower maintenance requirement thus reducing downtime during repairs and routine maintenance. The implemented hybrid power generation system makes use of solar PV and wind turbine to produce electricity and supply the Grid through 200KVA Transformer.

3.2 Designing and Modelling of Hybrid System



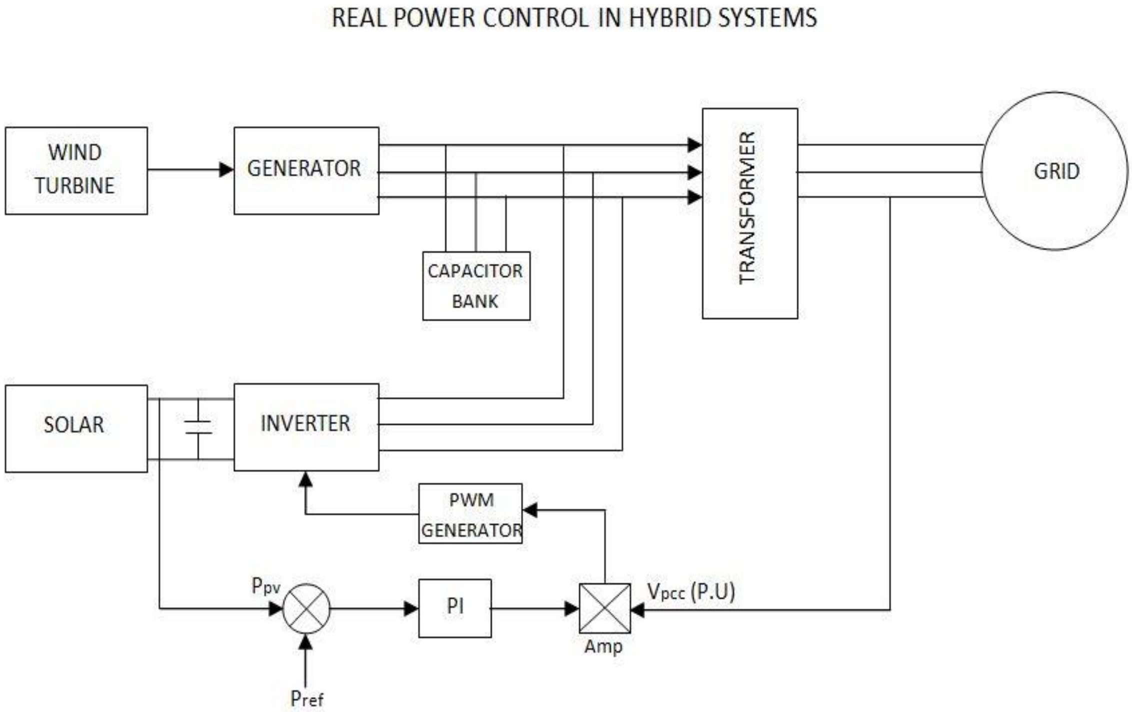


Fig. 3.1 Block Diagram for Hybrid System with Power Control Network

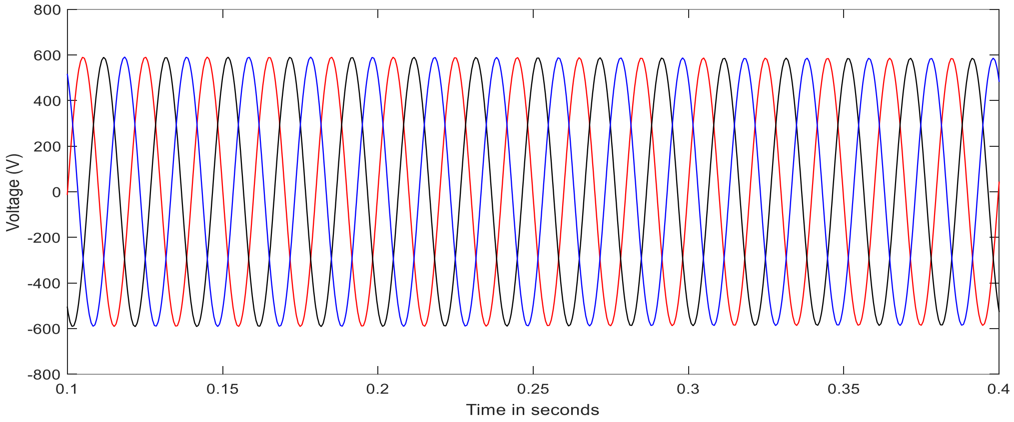


Fig 3.2: Voltage at PCC

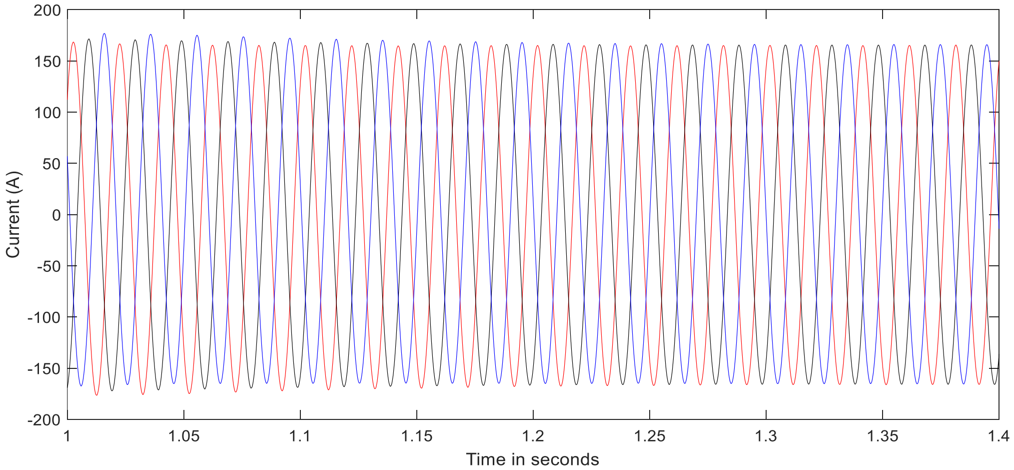


Fig 3.3 Current at PCC

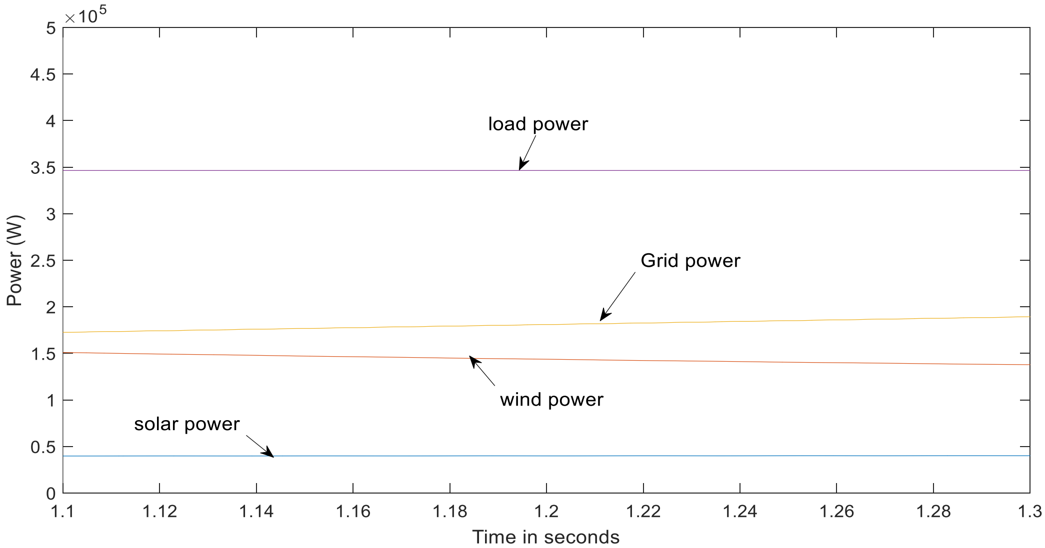


Fig 3.4: Comparison of power in hybrid system

CHAPTER IV

CONCLUSION & FUTURE SCOPE

CONCLUSION:

Wind (200 KW) and solar (75KW) hybrid system was modelled and simulated in MATLAB/Simulink 2016a separately like,

i) wind energy conversion system (275 KW)

ii) Solar energy system (75 KW)

iii) Hybrid wind and solar system.

The result was compared and analysed under various load.

FUTURE SCOPE:

After analysing the power generation of solar and wind for the month of July, August and September 2014, it is observed that, the maximum power generation from the hybrid system is always less than the maximum transformer rating of 200KVA. Hence it is concluded that, battery storage system is not necessary for this particular hybrid system. But if the rating of the PV system is increased to 150KW, a battery storage system can be used to increase the maximum power extraction from the PV system. In that case, an intelligent controller will be designed for the control of the hybrid systems.