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Grid Interactive Photovoltaic Power Generation

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Abstract -Photovoltaic systems are solar energy supply systems, which either supply power directly to an electrical load or feed energy into the utility grid. Extraction of abundant of power from the solar and interfacing to the electric grid through the power electronic components plays a significant role. Simulation of the solar energy conversion has been demonstrated. A photovoltaic based 3.5 KW solar inverter system is developed which consists of PV arrays, H bridge solar inverter, filters and transformer. The system works on both solar and AC mains depending on the load requirement. The aim of this project is to simulate and develop a PV based inverter system which converts DC power generated by the solar cells into AC power and provide it to the load connected to the utility grid, when the photovoltaic power is greater than the load, the excess power is fed to the grid. With this approach we can reduce the use of power from the grid and even sell back the excess power to grid. The system uses single stage high performance Maximum power point tracker (MPPT) for solar power generation. This system can be guaranteed to access power at home or industry, even if the solar energy fails or is insufficient and reduce the Energy Consumption and give a reliable support to the Grid

Index Terms- Photovoltaic power generation, Power flow, SPWM, Grid tied solar inverter, MPPT

I. INTRODUCTION

With the increasing population energy demand is increasing and therefore to meet this ever increasing demand solar energy could prove to be really effective and sustainable energy source as compared to other types of energy sources such as wind, tidal etc .Solar energy is a kind of energy which converts solar radiation into electricity. A solar system is made up of solar modules. Number of cells combines to form a module and these modules are in turn connected to form the PV system. Grid-interactive photovoltaic power system or grid-connected PV system is an electricity generating solar PV system that is connected to the utility grid. A grid-connected PV system consists of solar panels, DC to DC Converter one or several inverters, a power conditioning unit and grid connection equipment. In a grid interactive or grid connected system what plays an important role is the grid tied inverter which controls the power flow from the source to the load which can be implemented with or without MPPT to track maximum possible power from the solar panels. The block diagram of the PV connected system is shown in Fig 1. The main objective of this paper is to simulate a single stage grid tied inverter with MPPT so as to extract maximum power and compare the results for the same system without MPPT.

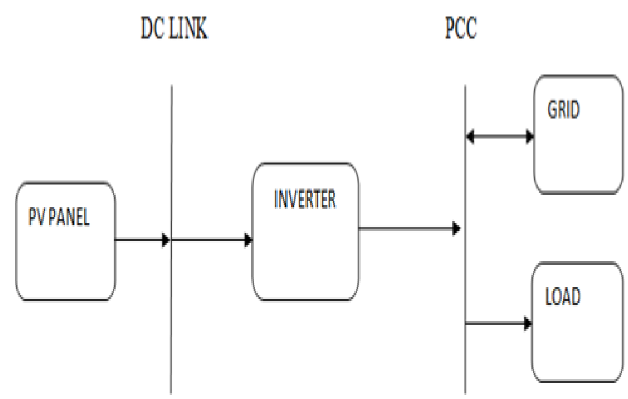

Fig 1. Single line diagram of grid interactive photovoltaic power generation.

The model is run for different irradiance throughout the day i.e. from 9am to 6pm. For every hour the PV output varies and is so considered in the simulation. The load is assumed to be fixed. Inverter system has to basically operate in two modes

1. When the load power is greater than the PV power, the PV supplies its generated power and the remaining power is taken from the grid, power consumed by the grid is shown positive in the Simulink result.
2. When the load power is less than the PV power the load is supplied by the PV power and the excess power is supplied back to the grid. The power supplied to the grid is shown negative in the simulink result.

II. MODEL OF GRID CONNECTED PV SYSTEM

A. Solar photovoltaic array.

The PV array model implements a PV array built of series and parallel connected pv modules. It allows modeling of variety of preset PV modules available from NREL system advisor model as well as user defined PV module. The PV array block has two inputs that allow you to supply varying sun irradiance (input in W/m^2) and temperature (input in deg .C)

The PV array consists of one string of 15 Sanyo HIP225HDE1 modules connected in series at 25 deg C and with solar irradiance of 1000W/m^2 the string can produce 3500W.

The parameters of single module

Table No.1: The Parameters of Single Module

Parameter	**Value**
Number of modules	15
Short circuit current(A)	7.138 A
Open circuit voltage (V)	41.798 V
Voltage at max power point	33.9 V
Current at max power point	6.634 A
Fixed circuit temperature	25^{0}C

B. Inverter design

The inverter is module using a sine PWM – controlled single phase full bridge IGBT module (H-Bridge). The topology of the grid side filter is the classical RLC configuration with the inductors split equally between the line and the neutral branches.

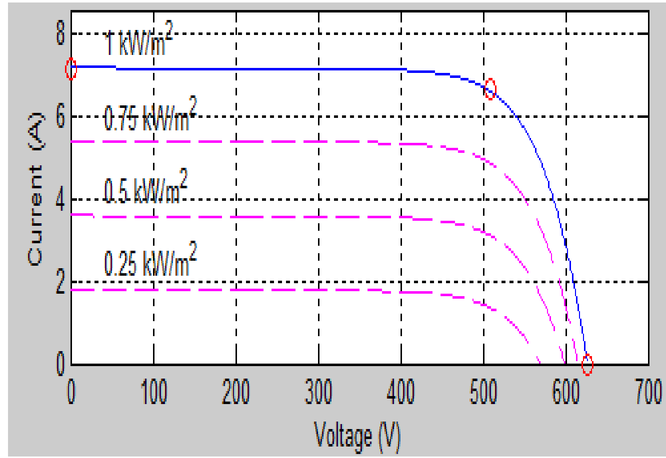

Figure 2: VI Characteristics of an array for different irradiance

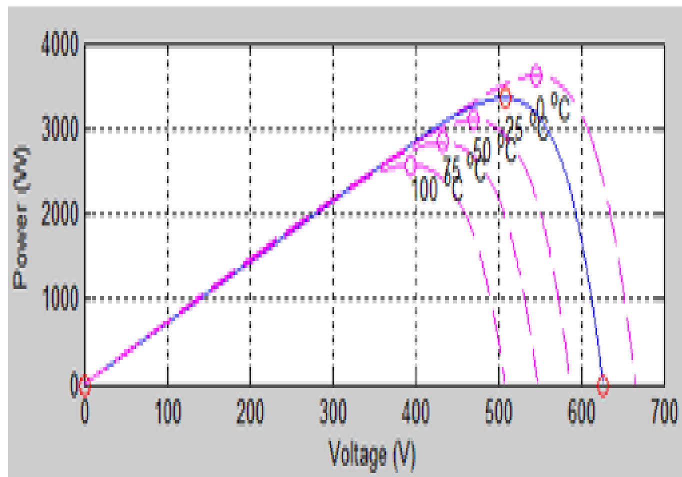

Figure 3: PV Characteristics of an array for different irradiance

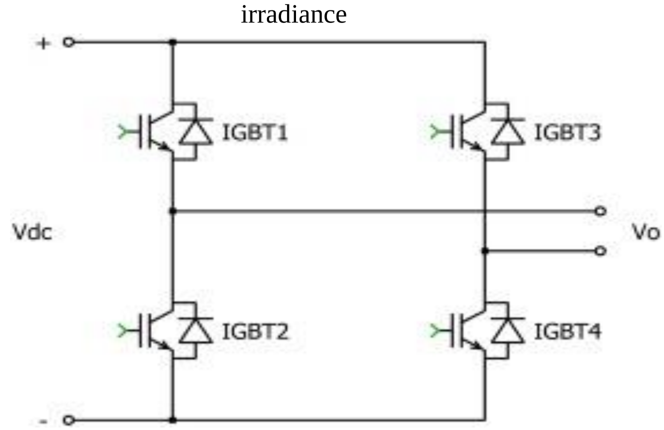

Figure 4: H bridge inverter

C. *MPPT algorithm*

Maximum power point tracking is a technique used to improve the efficiency of PV (photo voltaic) systems by extracting maximum power available from them at all times of the temperature and irradiance conditions The PV systems when connected directly to the load result in poor efficiency of the system, so MPPT is required to improve the efficiency of the systems. MPPT is not a mechanical system, it is based on the maximum power transfer theorem and it matches the source (PV systems) and load impedance electronically by using dc/dc converter. There are different techniques to track maximum power point. The most popular techniques available for MPPT are Perturb and Observe and Incremental Conductance. The technique employed is Perturb and Observe method because this technique is simpler and efficient whereas Incremental Conductance method is not simpler because of its complicated judgment procedure. The general working of the algorithm is displayed in the flowchart below (Fig. 1): The method is based on the power difference of nth and (n-1)th iterations. If the difference is positive i.e. power has increased then the perturbation is continued in the same direction. If the difference is negative i.e. power has decreased.

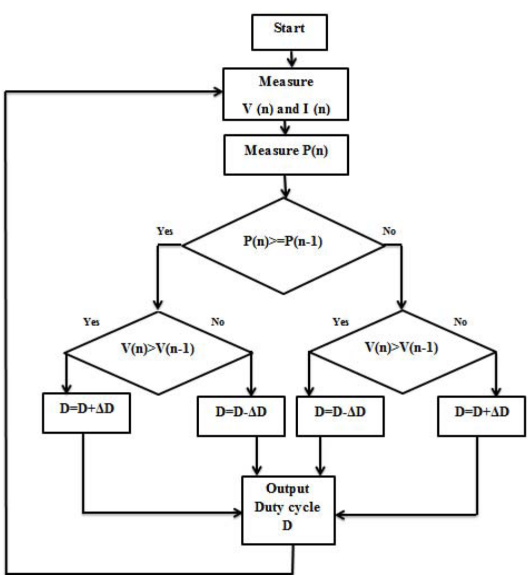

Figure 5: Perturb and Observe algorithm

III. CONTROL STRATEGY OF GRID INTERACTIVE PV SYSTEM

A. Inverter control-The main components of inverter control are

1. Maximum power point tracker system (MPPT) using perturb and observe algorithm.
2. PLL and measurement block.
3. DC voltage regulator.
4. Current regulator.
5. PWM modulator.

PLL and measurement block**:** It is a measurement block used for extraction of angle and frequency from Voltage and Current. The output obtained is V_dV_q from Vgird, I_d I_q from Igrid. Output of PLL block are V_d Vq, I_d I_q, V_{dc} mean and wt.

DC voltage regulator: The error between V_{dc} ref and V_{dc} mean is given to the PID controller which will give Id reference, this I_d ref is compared with the measured Id and I_q ref is given zero. We can say that it determines the required Id reference for the current regulator.

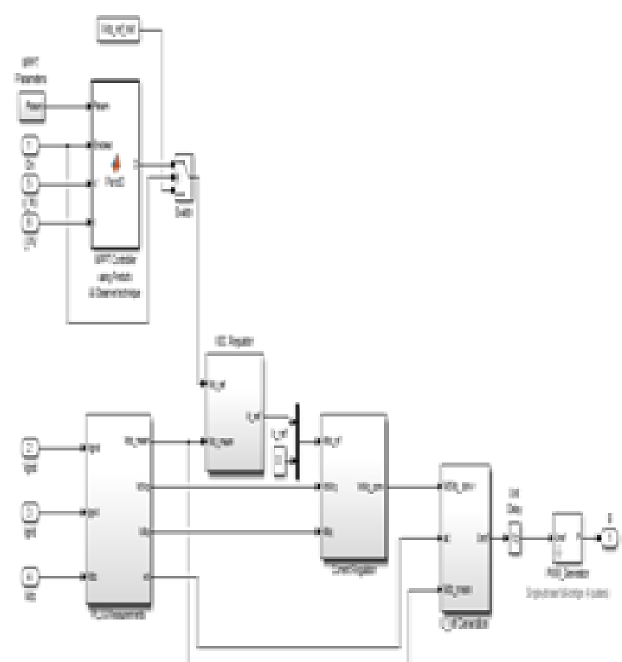

Figure 6: Inverter control

Current regulator**:** Based on the current reference Id and Iq the regulator determines the required voltage for the inverter. In our simulation the Iq reference is set to zero.

PWM modulator: Use the SPWM bipolar modulation method to generate firing signal to the IGBTs.

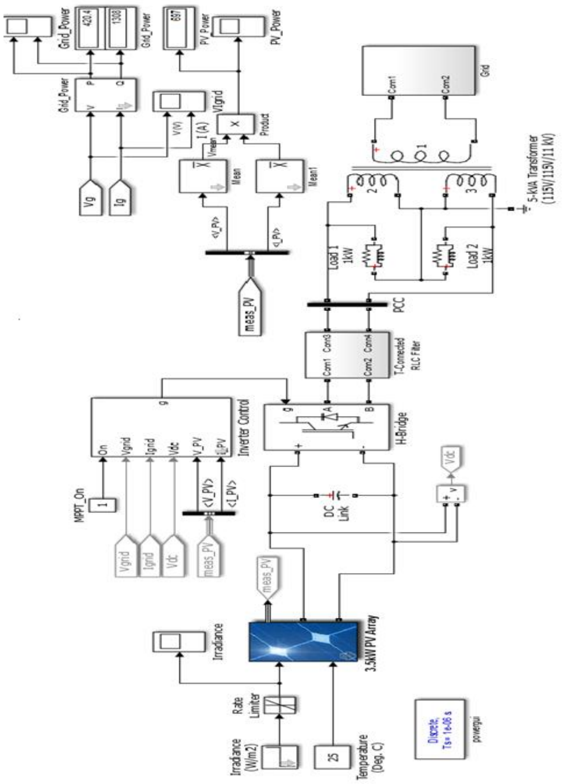

Figure7.Complete system model

IV. SIMULATION RESULTS

Irradiance

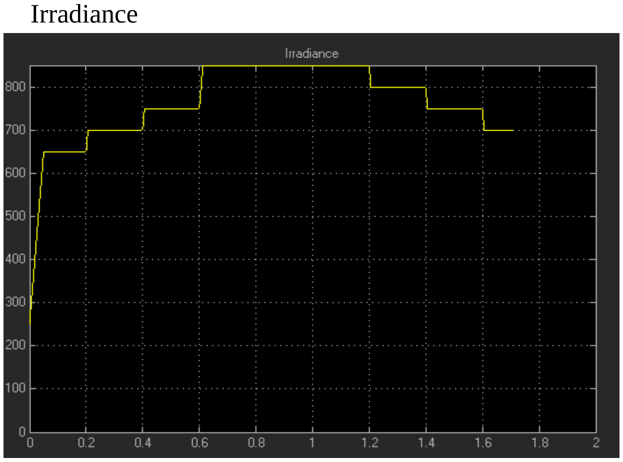

Figure.8 Output of irradiance

Inverter system output before filter

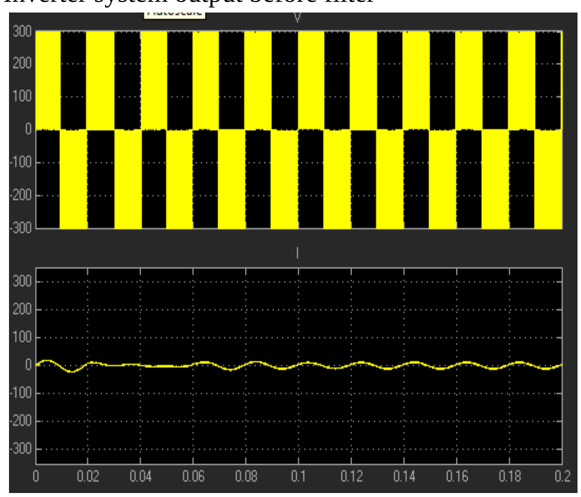

Figure.9 Output of inverter with filter

3. Inverter output after filter

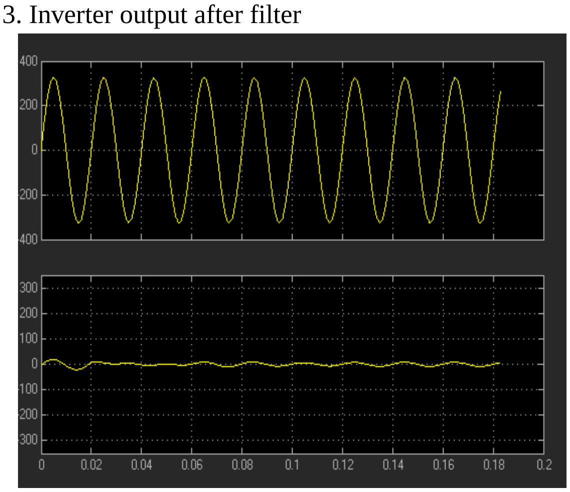

Figure.10 Output of inverter without filter.

Grid Voltage and Current

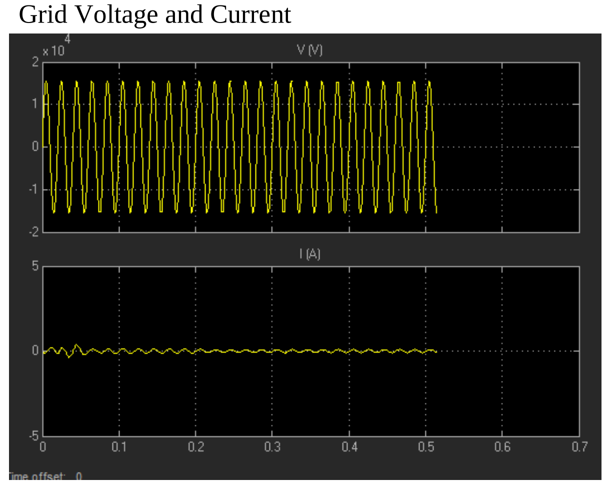

Figure11. Grid voltage and current.

Grid power

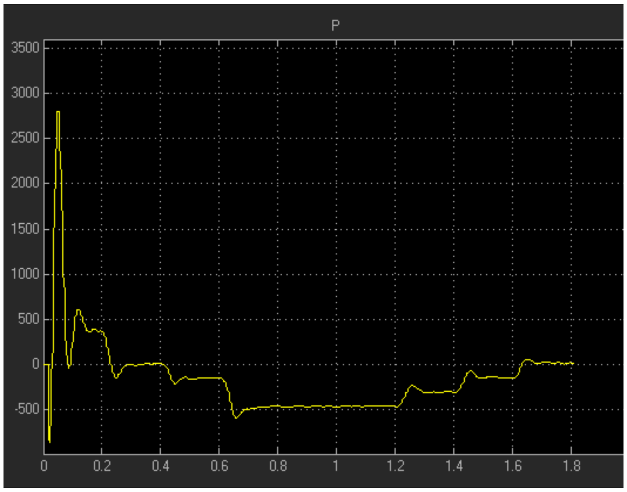

Figure12. Grid power

PV power output

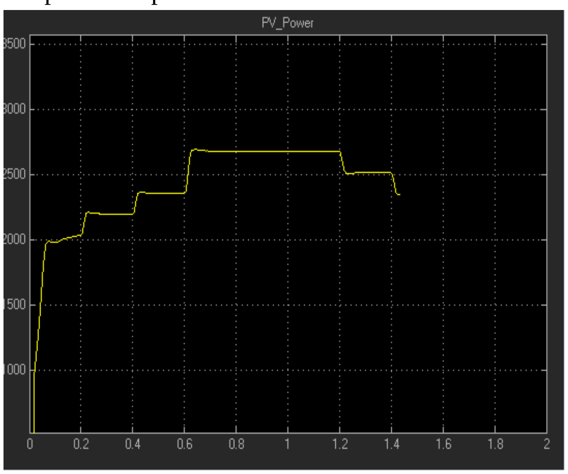

Figure.13. PV power output

Observation table of simulates results:

Load sharing between PV and Grid from 9am to 6pm keeping 2KW of fixed load is shown below
With MPPT and without for 2KW load.

Sir no	**Time (Hrs)**	**Irradiance (W/m^2)**	**PV power (W)**	**Grid power (Watts)**	
				P	**Q**
1	9.00am	650	1989	184.3	576.6
2	10.00am	700	2089	329	388.2
3	11.00am	750	2244	4.411	398.1
4	12.00noon	850	2407	-151.6	400.6
5	1.00pm	850	2679	-462.4	404.6
6	2.00pm	850	2678	-461.1	398
7	3.00pm	800	2631	-463.3	399
8	4.00pm	750	2392	-288.5	396.4
9	5.00pm	700	2193	-25.24	416.5
10	6.00pm	650	2112	18.14	396.3

Table no 2: Load sharing between PV and Grid with MPPT for 2KW load

The above table shows the reading for time, irradiance, PV power and Grid power with MPPT for 10hrs of the day. The power flow from solar to grid is shown in the above table .Negative power indicates power flow in to the grid. It is observed that around 2pm the PV power obtained is maximum.

Sr no	Time (Hrs)	Irradiance (W/m^2)	PV power (W)	Grid power	
				P	Q
1	9.00am	650	1948	419.5	457.6
2	10.00am	700	2028	249.3	387.3
3	11.00am	750	2110	108.2	398.3
4	12.00noon	850	2297	-44.95	396.4
5	1.00pm	850	2554	-336.7	399
6	2.00pm	850	2554	-340.9	399.1
7	3.00pm	800	2509	-337.7	403.1
8	4.00pm	750	2321	-187.5	400.2
9	5.00pm	700	2206	-35.7	399.1
10	6.00pm	650	2086	114	400.8

Table no 3: Load sharing between PV and Grid without MPPT for 2KW load

The above table shows the reading for time, irradiance, PV power and Grid power without MPPT for 10hrs of the day .We can see the change in power flow with change in irradiance. The power flow from solar to grid is shown. Negative power indicates power flow in to the grid. It is observed that around 2pm the PV power obtained is maximum.

Remarks - (With and Without MPPT):
During 12noon to 3pm the irradiance is maximum therefore the PV power obtained is also maximum which is shown in the table 2 and 3 ie from observation 4 to 10. The PV power obtained with MPPT for the same day is more than the PV power obtained without MMPT. The grid power which is positive is assumed to be the power taken from the grid whereas the power which is negative is the power fed back to the grid. During the time 9.00am to 12.00 noon the irradiance is less therefore the power is taken from grid as well .During the time 1.00 pm to 3pm we can conclude that the PV power generated is maximum ie out of which the load is been supplied and remaining is given back to grid whereas for the same time of day the power without MPPT obtained is less.

V. CONCLUSION

The proposed design of grid interactive photovoltaic power generation has been analyzed and simulated by using MATLAB/SIMULINK. The output of the solar PV power generation system is used to inject power in the utility grid and also to feed the residential load. The proposed configuration can greatly reduce the existing power demand, limit the use of conventional power generation techniques and also it is the only, means to tackle the future power requirement.
An extraction of 3.5KW of power from PV array using a single stage conversion given to the grid with efficient control design of MPPT controller, is able to automatically adjust the operating point of the PV system to the maximum power point. The entire system efficiency after feeding the converter losses, filter losses and transformer losses is to be 90.50%

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