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Grid Interactive Photovoltaic Power Generation

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ABSTRACT: In the past decade the utilization of renewable energy is ever increasing due to the scarcity of fossil fuels. The excessive power from renewable energy is considered mandatory in integration that improves the performance of the electric transmission system in terms of better reliability and eco green power generation. Extraction of abundant of power from the solar and interfacing to the electric grid through the power electronic components plays a significant role. Uninterrupted power supply is another major requirement by the users for providing speed and reliability for their work. Many times renewable energy sources find shortage in their availability and therefore it is essential that user have a second option for providing constant power supply. Here the smart grid plays a vital role. The smart grid architecture ensures uninterrupted power supply to the load. Smart grid consists of set of electrical circuitry which traps energy from renewable energy sources & supplies it to the load. Besides this circuitry is connected to the normal grid which sources power from the AC mains. Both these grids are interconnected with the help of switching system. 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 the 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. Simulation results are provided to demonstrate the effectiveness of the design.

KEYWORDS: Grid-interactive System, Hybrid Inverter, Solar Resource, Battery Storage.

I. INTRODUCTION

The worldwide vitality utilization is expanding regular because of expanded populace and propelled advances. Be that as it may, because of temperamental electrical framework, our nation is confronting extreme power deficiency issues. India and China are the two nations in charge of significant utilization of vitality. Because of Global warming worries, there is a solid need to send clean vitality sources and actualize vitality effective answers for take care of future vitality demand. Manageable vitality sources are required to take care of the power demand to defeat the danger of vitality security. Sustainable power source approaches to tackle the above issue. The greatest type of sustainable power source to profit by this is sun oriented PV frameworks. PV frameworks is the immediate procedure of changing over sun powered vitality into power. It is the most potential path, because of the accessibility, straightforwardness, bring down upkeep and dependable operation. The primary utilizations of PV frameworks are in either off lattice or matrix associated arrangements. Off lattice PV era frameworks are alluring as fundamental power hotspot for remote zones. Be that as it may, test to use sunlight based vitality from off framework PV framework is nearly high capital cost, bring down effectiveness, bigger limit of capacity battery and more operation and support cost than lattice associated setup. Vitality designs everywhere throughout the world are concentrating on sun based ventures to expand the era limit. The

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sunlight based photovoltaic vitality is of the most decentralized nature among every one of the wellsprings of vitality on the planet and tackling power from sun based vitality is exclusively contamination free. India gets around 300 clear radiant days in a year. This is equivalent to more than 5000 trillion kWh/year, which is significantly more than the aggregate vitality utilization of the nation in a year. A nearby planetary group is comprised of sun oriented modules. Number of cells consolidates to shape a module and these modules are thus associated with frame the PV framework. The lattice associated frameworks are introduced in those regions where a vigorous network is available, and ready to acknowledge vitality nourishing from the PV framework. Therefore, framework synchronization is seriously expected to interface PV framework with electrical matrix. A few research works have been done to actualize framework associated inverter. Most of them are reproduction level, some are executed yet they are mind boggling and exorbitant, some of them make impedances with close-by sound signs. Lattice intuitive photovoltaic power framework or matrix associated PV framework is a power creating sun oriented PV framework that is associated with the utility network. A matrix associated PV framework comprises of sun based boards, DC to DC Converter one or a few inverters, a power molding unit and network association hardware

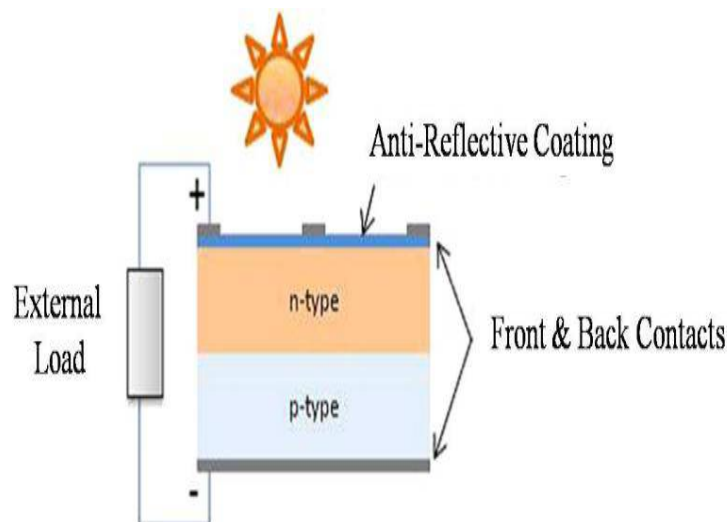


Figure 1: Construction of solar cell

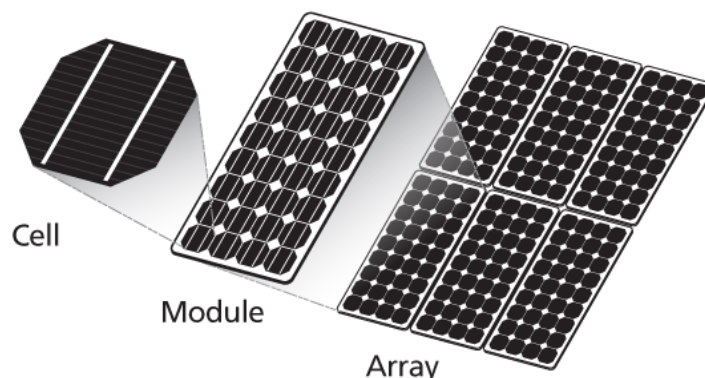


Figure 2: Solar cell, module or panel and solar array

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1.3.3 V-I Characteristics of solar panel

The figure shows the I-V characteristics of the PV array. Characteristics show that, as the voltage of PV array increases current will decrease slowly. And as soon as voltage of the PV array is greater than V_{mp} , current drop suddenly. At the same point, when the voltage of the PV array is V_{mp} , power reaches at its maximum power point. Also, as the PV panel temperature increases, voltage output decreases and vice versa.

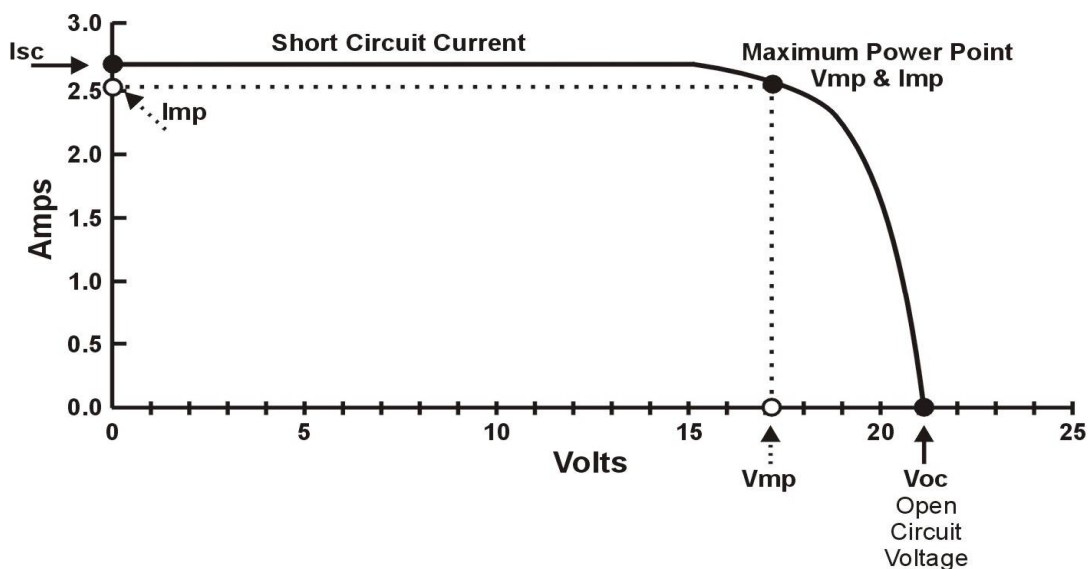


Figure 3: I-V characteristic of solar cell.

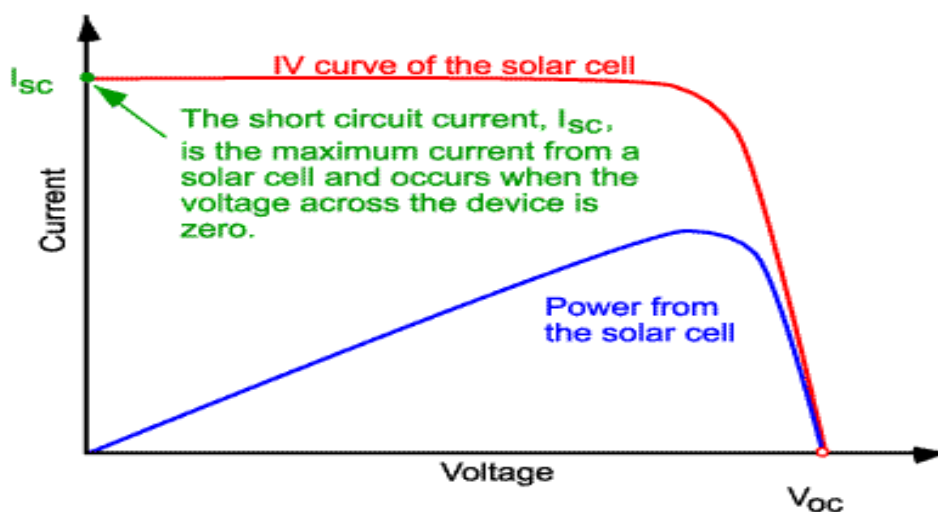


Figure 4: I-V curve and power curve of solar cell

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II. REVIEW & LITERATURE SURVEY

K. Arulkumar, D Vijaykumar, K.Palanisamy "Productive Control Design for Single Phase Grid Tie Inverter of PV system"[6]

Goes for designing a 3KW single stage lattice associated PV inverter and is approved utilizing MATLAB/Simulink/PLECS. Likewise utilizes single stage elite most extreme power point following (MPPT) for sun powered Photovoltaic power era .

V.Seenivasagan, A.ManikandanGowtham, " Design And Implementation Of Solar Energy With Grid Interfacing" [8]

Proposes a lattice interfaced sun based photovoltaic power producing framework comprising of photovoltaic cell, DC-DC support converter, Inverter, Capacitor bank, transformer, single stage matrix feeder . Presents interfacing of sun oriented power with network mulling over recurrence. Synchronization between sun based yield recurrence and brace recurrence is accomplished . Power is conveyed to the framework by manual breaker. Microcontroller is utilized to check the recurrence of lattice and sun powered. And furthermore recognizes zero intersection of the sine wave to drive the circuit. Unfluctuated stack with synchronized recurrence is been conveyed to the network.

Monika Verma , HarshitAgarwal, NamanRawat, VivekKashyap, Akshay Kumar "Synchronization Between Solar Panel and AC Grid Supply For Different Loads"[9]

Goes for building up an ongoing, vigorous and wise matrix associated sun oriented board so as to give energy to the heaps from sun based board at day time and change the ability to the steady DC sources when the sunlight based power falls beneath a pre-characterized restrain.

The keen exchanging between sun oriented board and consistent DC Source is finished utilizing twofold post twofold toss strong state hand-off. They have utilized Data Acquisition Card which will take advanced contribution from the program composed in LabView and give computerized yield to incite the exchanging circuitry.The primary exchanging circuit is planned utilizing LM324 IC, 4N35 Optocoupler, OEN 57 hand-off and a consistent 24 volt d.c supply for transfer loop.

M. Gohul, T. Jayachandran, A. Mohamed Syed Ali, T.G. Raju,N. Santhosh Kumar, M.R. Saravanan "A New Design of Grid Tie Inverter for a Grid Interactive Solar Photovoltaic Power Generation – An Innovative Option for Energy Conservation and Security" [10]

Presents the New Design, Development and Performance Analysis of a Grid Connected PV Inverter. The sun based power which might be accessible in abundance of the request amid time of high daylight is sustained to the matrix and is used somewhere else. The framework has been intended to supply constant energy to a devoted nearby load with the ability to the heap conveying from the sun oriented cluster, lattice, or battery bank in the request of inclination. It is fit for operation in a matrix intuitive mode and will naturally change over to the remain solitary operation without soften up control in case of the lattice floating out. Here three stage alternator is utilized as framework.

VikasKulkarni, Rajesh Nehete. "Reenactment and Analysis of PV based Solar Inverter System",[11] in this paper photovoltaic based 500W sunlight based inverter framework is created. This framework includes sun oriented board, charge controller, battery bank and inverter. Reenactment of the framework is finished by MATLAB. A PIC controlled SPWM inverter is utilized as a part of this framework. This framework can be chipped away at AC mains and in addition an inverter.

Satheeshkumar D. Ramya .N.D Indira .R, R Ashok. "Plan And Analysis of Single Phase Grid associated Inverter",[13].In this paper single stage matrix associated Inverter framework has been examined and reenacted utilizing

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MATLAB/SIMULINK. The yield of sun based PV control era framework is utilized to infuse control into the utility lattice and furthermore used to sustain single stage private loads. The PWM beats are produced with the assistance of Arduino Atmel 3285 controller. Hysteresis current controller is utilized to modify inverter recurrence up to the brace recurrence.

Manisha Joshi, Prof. Dr. Mrs. G.A. Vaidya. "Displaying and Simulation of Single Phase Grid Connected Solar Photovoltaic System", [14] This paper shows the analysis and outlining of single stage 1.8KW framework associated sun powered Photovoltaic framework. A Low pass channel is utilized to Minimize the Total Harmonic Distortion caused by the inverter. Framework Parameters are computed and from these parameters demonstrate is planned and reproduction comes about are displayed.

III. GRID CONNECTED PV SYSTEM

Stand alone solar systems are self contained fixed or portable solar PV systems that are not connected to any local utility or mains electrical grid as they are generally used in remote and rural areas. This generally means that the electrical appliances are a long way from the nearest fixed electrical supply, or were the cost of extending a power line from the local grid may be very expensive.

In recent years, however, the number of solar powered homes connected to the local electricity grid has increased dramatically. These Grid Connected PV Systems have solar panels that provide some or even most of their power needs during the day time, while still being connected to the local electrical grid network during the night time.

Solar powered PV systems can sometimes produce more electricity than is actually needed or consumed, especially during the long hot summer months. This extra or surplus electricity is either stored in batteries or as in most grid connected PV systems, fed directly back into the electrical grid network.

In other words, homes and buildings that use a grid connected PV system can use a portion or all of their energy needs with solar energy, and still use power from the normal electrical mains grid during the night or on cloudy dull and rainy days, giving the best of both worlds. Then in grid connected PV systems, electricity flows back-and-forth to and from the mains grid according to sunlight conditions and the actual electrical demand at that time.

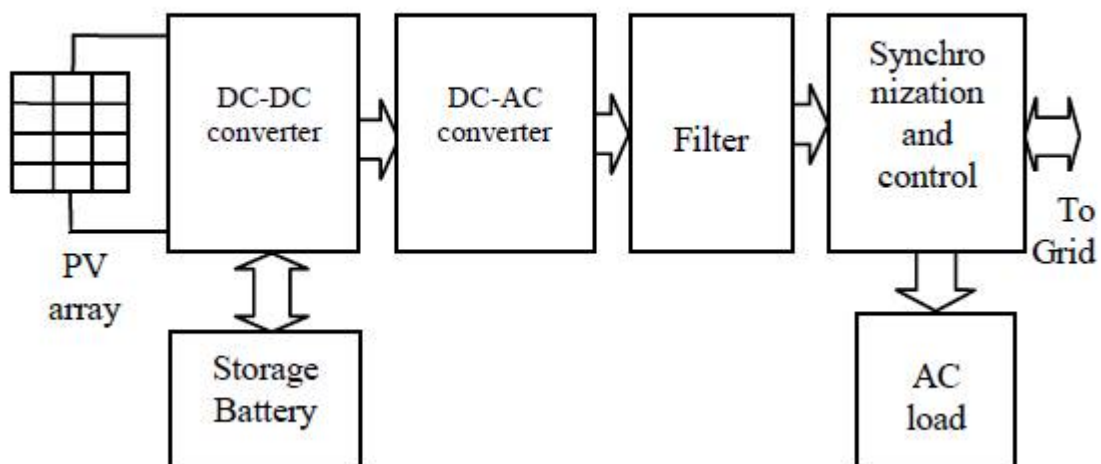


Figure 5 : Block diagram of grid connected PV system .

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In a grid connected PV system, also known as a “grid-tied”, or “on-grid” solar system, the PV solar panels or array are electrically connected or “tied” to the local mains electricity grid which feeds electrical energy back into the grid.

The main advantage of a grid connected PV system is its simplicity, relatively low operating and maintenance costs as well as reduced electricity bills. The disadvantage however is that a sufficient number of solar panels need to be installed to generate the required amount of excess power.

Since grid tied systems feed their solar energy directly back into the grid, expensive back-up batteries are not necessary and can be omitted from most grid connected designs. Also, as this type of PV system is permanently connected to the grid, solar energy consumption and solar panel sizing calculations are not required, giving a large range of options allowing for a system as small as 1.0kWh on the roof to help reduce your electricity bills, or a much larger floor mounted array that is large enough to virtually eliminate your electricity bills completely.

3.1 Types of PV system

Photovoltaic-based systems are generally classified according to their functional and operational requirements, their component configuration, and how the equipment is connected to the other power sources and electrical loads (appliances). The two principle classifications are Grid-Connected and Stand Alone Systems.

3.1.1 PV System Grid Tie (Battery free) :

The simplest and most cost effective PV design for most sites is the "Grid-Tie" (sometimes referred to as intertied or utility-interactive) system. This system does not provide backup power during a power outage (even if the sun is shining) but for sites with reliable grid power, this is usually the logical system choice

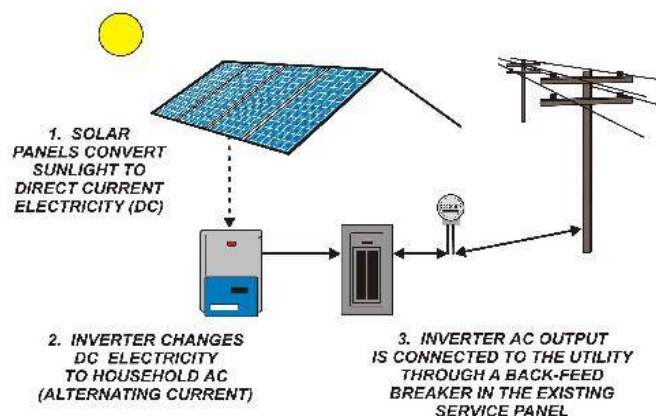


Figure 6: PV System Grid Tie (Battery free)

3.1.2 PV System Grid Tie(With batter Backup)

The Grid-Tie With Battery Backup system can also push excess electricity produced to the electric utility grid but has the added feature of batteries in order to power some selected backup loads when the grid is down. With this benefit comes increased complexity, cost and maintenance requirements

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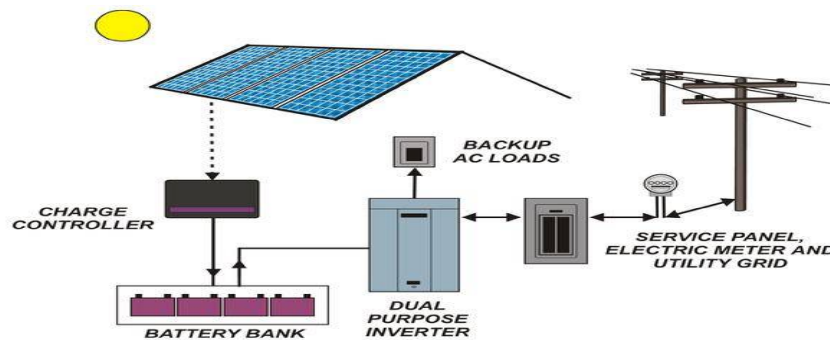


Figure 7: PV System Grid Tie (With battery Backup)

IV. EXPERIMENTAL SET UP

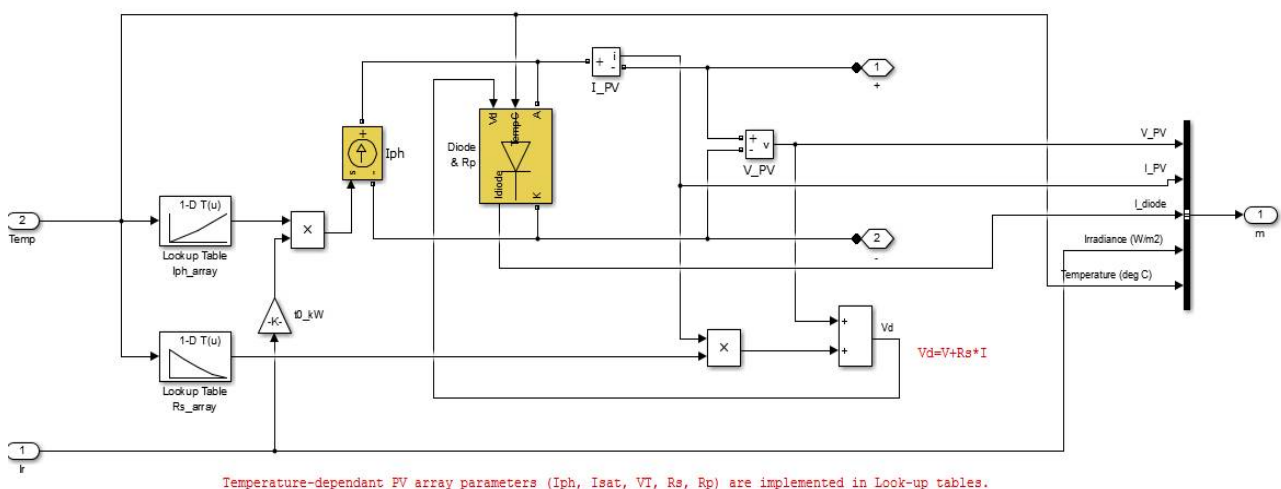
5.1 Complete system model:

The following section shows the obtained results simulating the complete system with a fixed load connected to the system. The simulation diagram of the complete system is shown in the fig. The simulation consists of 3.5KW PV array connected to a H bridge inverter. The load is connected through the point of common coupling and is shared between solar power and grid power and the excess power is given back to grid.

5.2 PV array simulation :

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



Temperature-dependant PV array parameters (I_{ph} , I_{sat} , V_I , R_s , R_p) are implemented in Look-up tables.

Figure 8: Model of PV array

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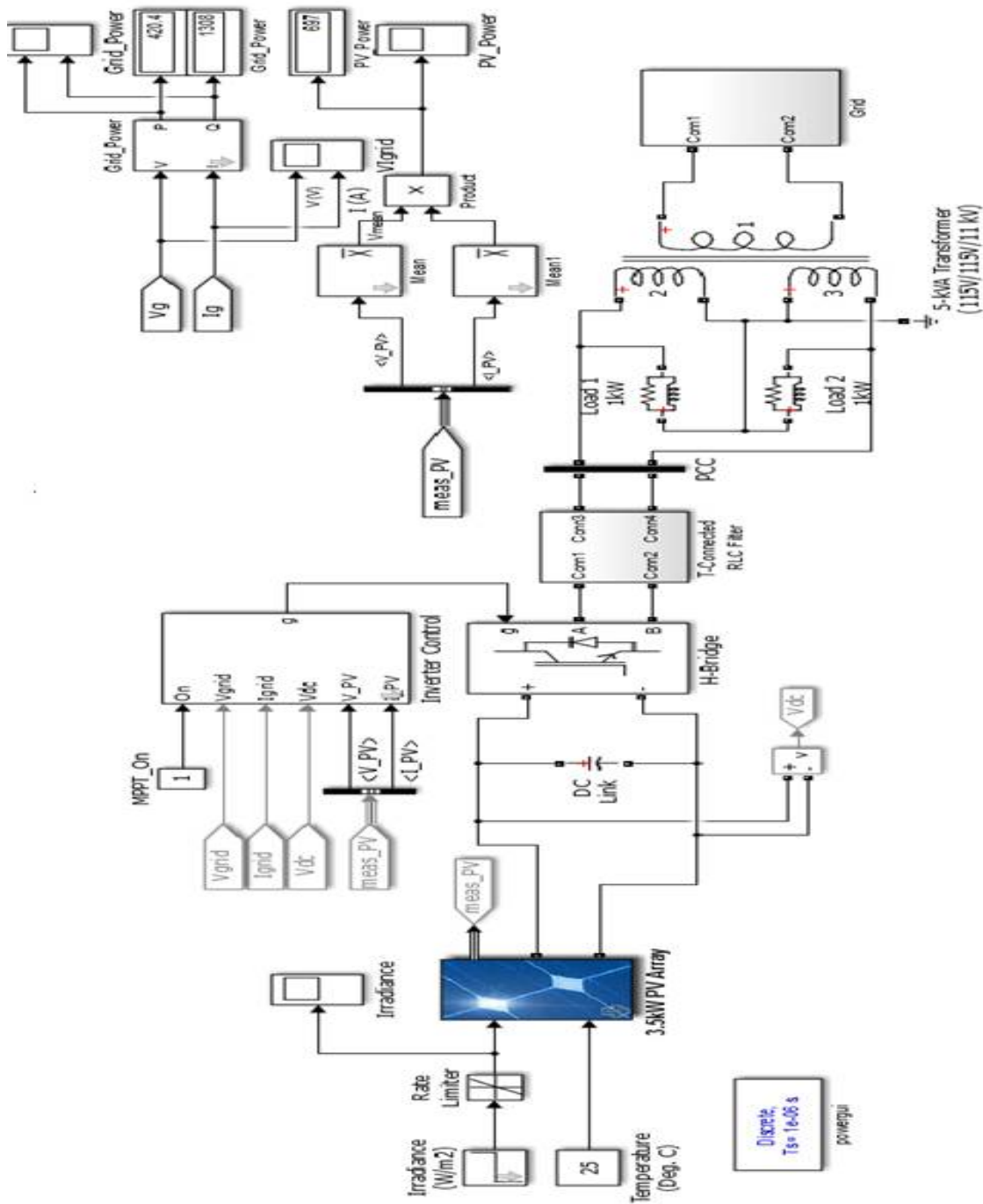


Figure 9: Simulation of complete Model.

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5.2.1 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 ^o C

Table no : The parameters of single module

5.2.2 The V-I characteristics of photovoltaic array are given below:

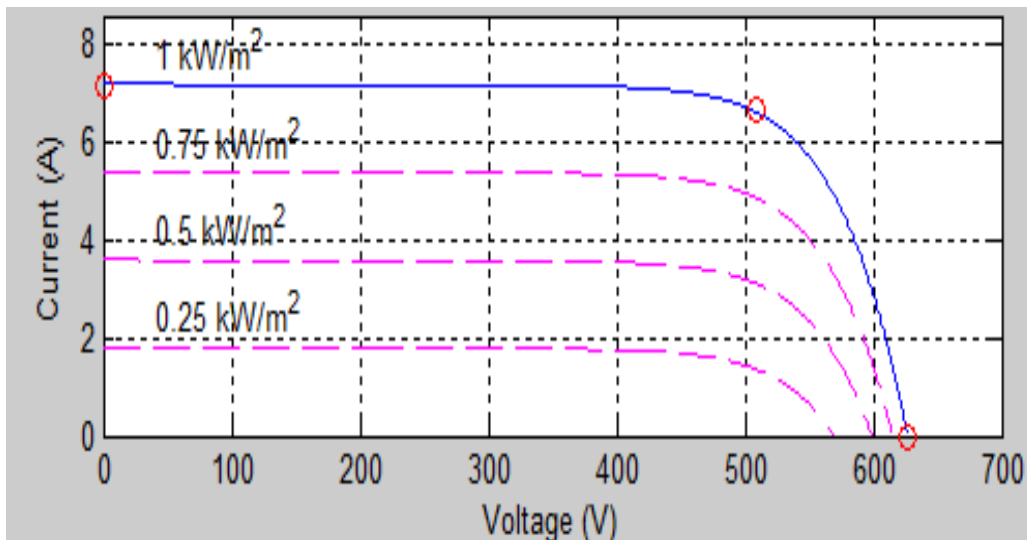


Figure 10: V-I characteristics of photovoltaic array

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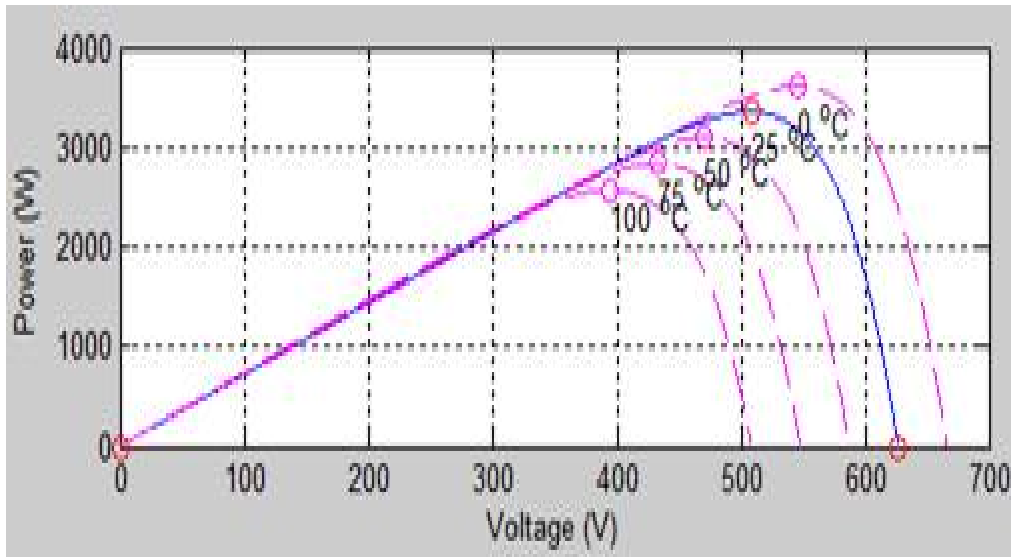


Figure 11: The V-P characteristics of photovoltaic array

5.3 Inverter simulation :

5.3.2 Proposed design

The inverter is modulated 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 .

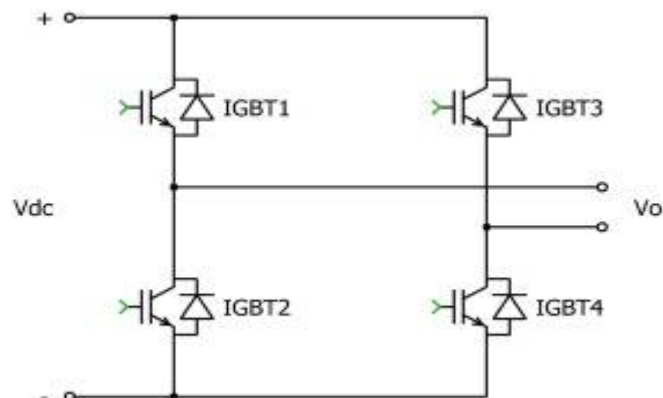


Figure 12: H bridge inverter

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5.3.3 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

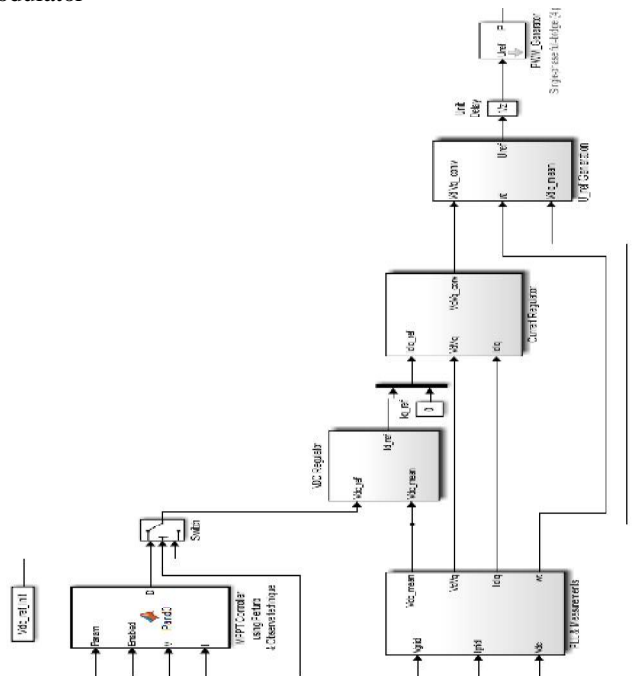


Figure 13: Inverter control system

1. Maximum power point tracking

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

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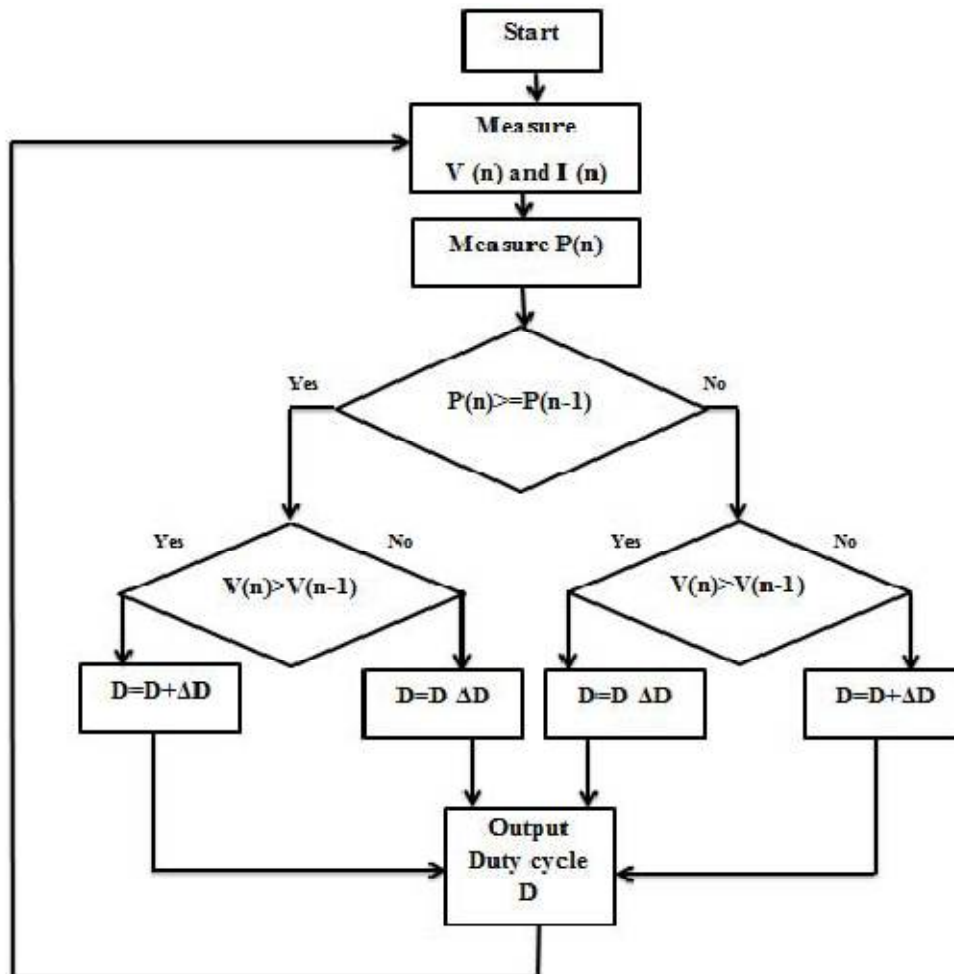


Figure 14 : Perturb and Observe algorithm

1. **PLL and measurement block:** It is a measurement block used for extraction of angle and frequency from Voltage and Current . The output obtained is $V_d V_q$ from V_{grid} , $I_d I_q$ from I_{grid} .output of PLL block are $V_d V_q$, $I_d I_q$, V_{dc} mean and ωt .
2. **Dc voltage regulator:** The error between V_{dc} ref and V_{dc} mean is given to the PID controller which will give I_d reference, this I_d ref is compared with the measured I_d and I_q ref is given zero .we can say that it determines the required I_d reference for the current regulator.
3. **Current regulator:** Based on the current reference I_d and I_q the regulator determines the required voltage for the inverter. In our simulation the I_q reference is set to zero.
4. **PWM modulator:** Use the PWM bipolar modulation method to generate firing signal to the IGBTs.

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5.4 Simulation results :

1.Irradiance

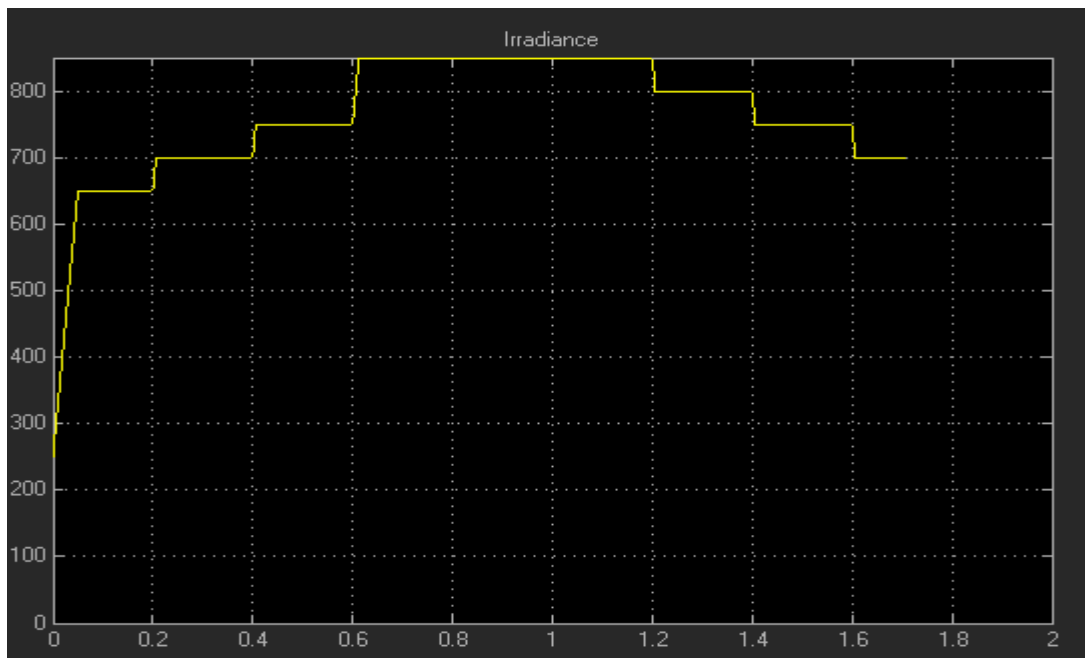


Figure.15: Output of irradiance

2.Inverter system output before filter

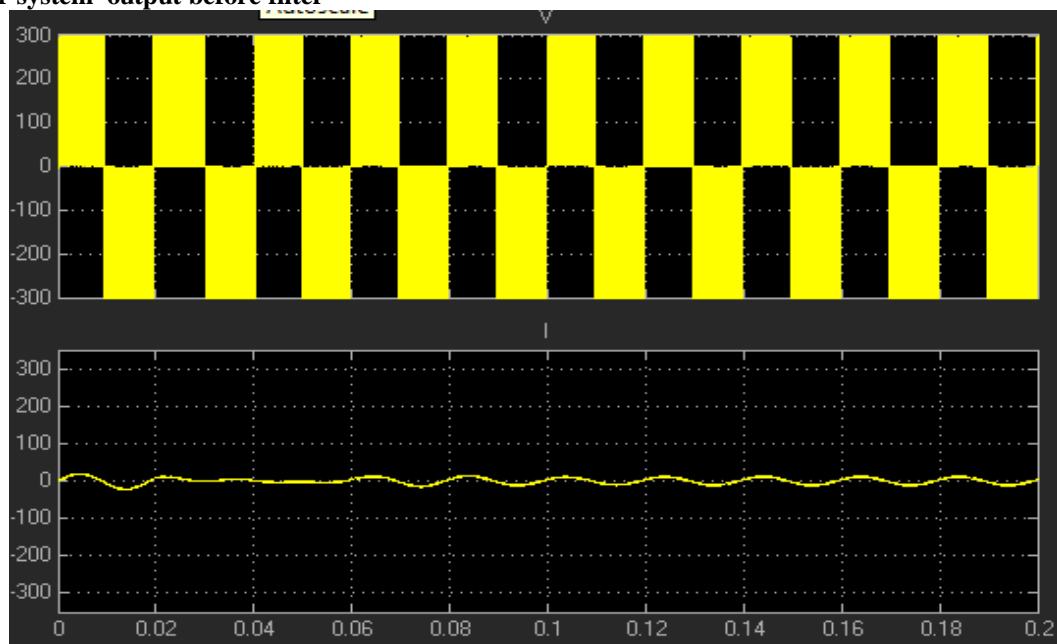


Figure.16: Output of inverter with filter

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3. Inverter output after filter

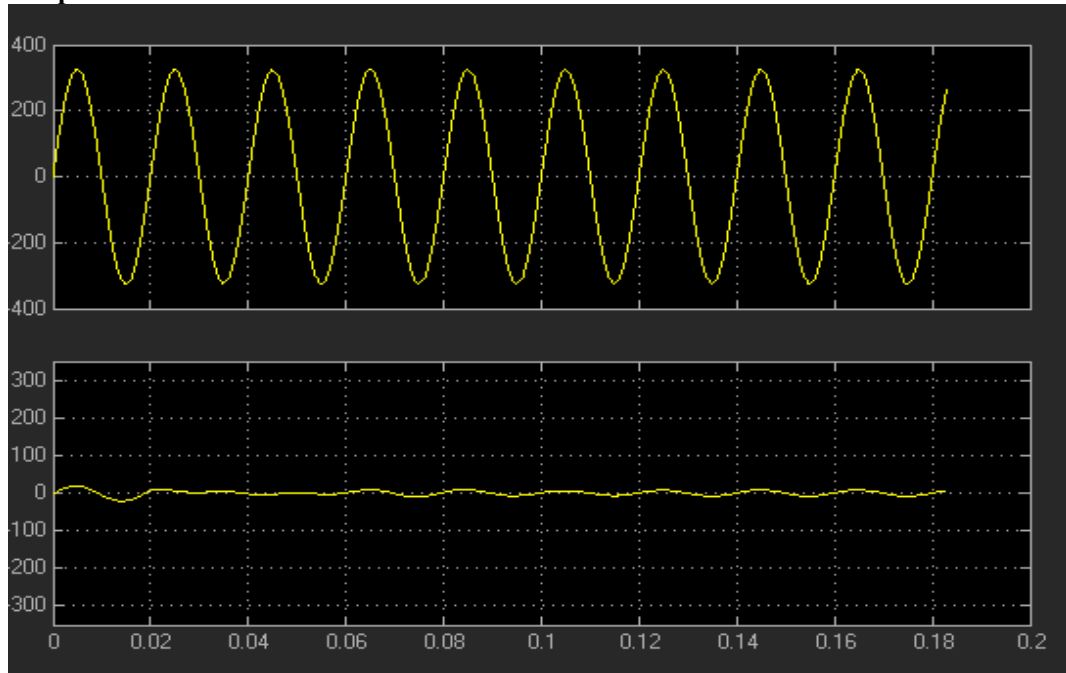


Figure .17 Output of inverter without filter.

4. Grid Voltage and Current :

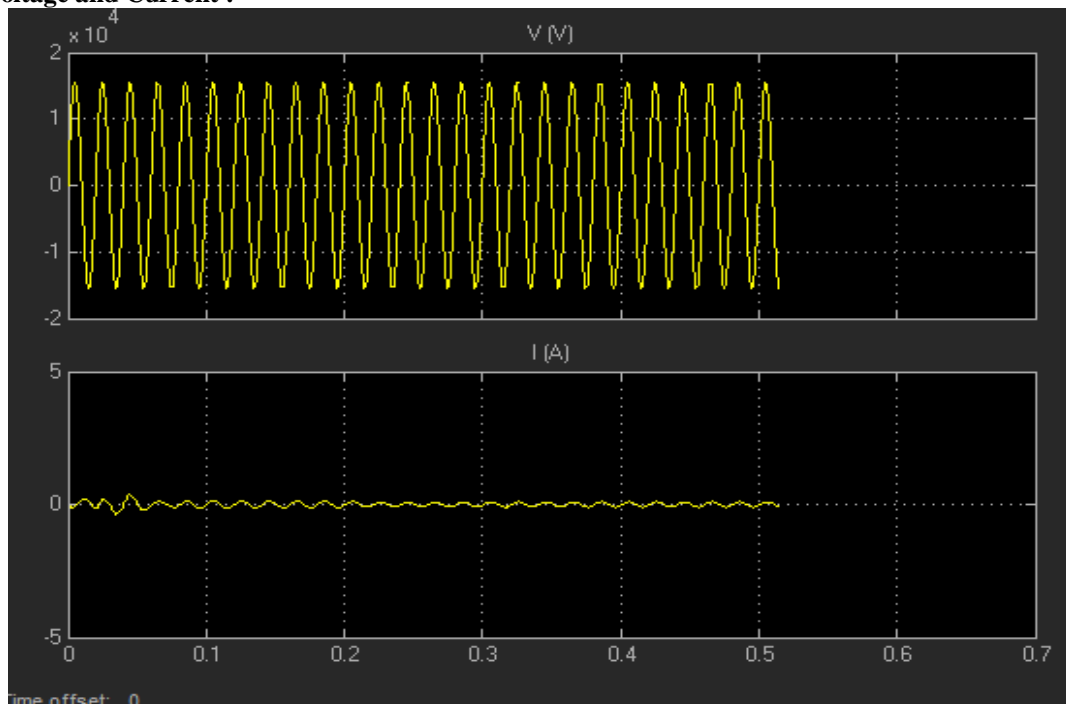


Figure.18: Grid voltage and current.

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5. Grid power:

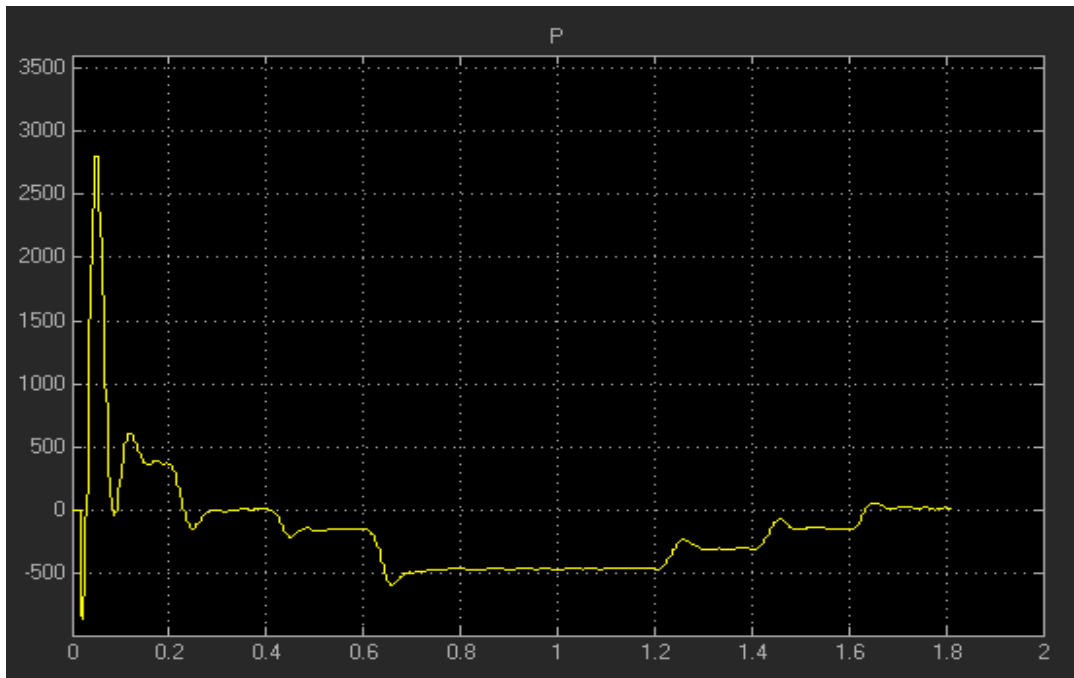


Figure.19: Grid power.

6. PV power output:

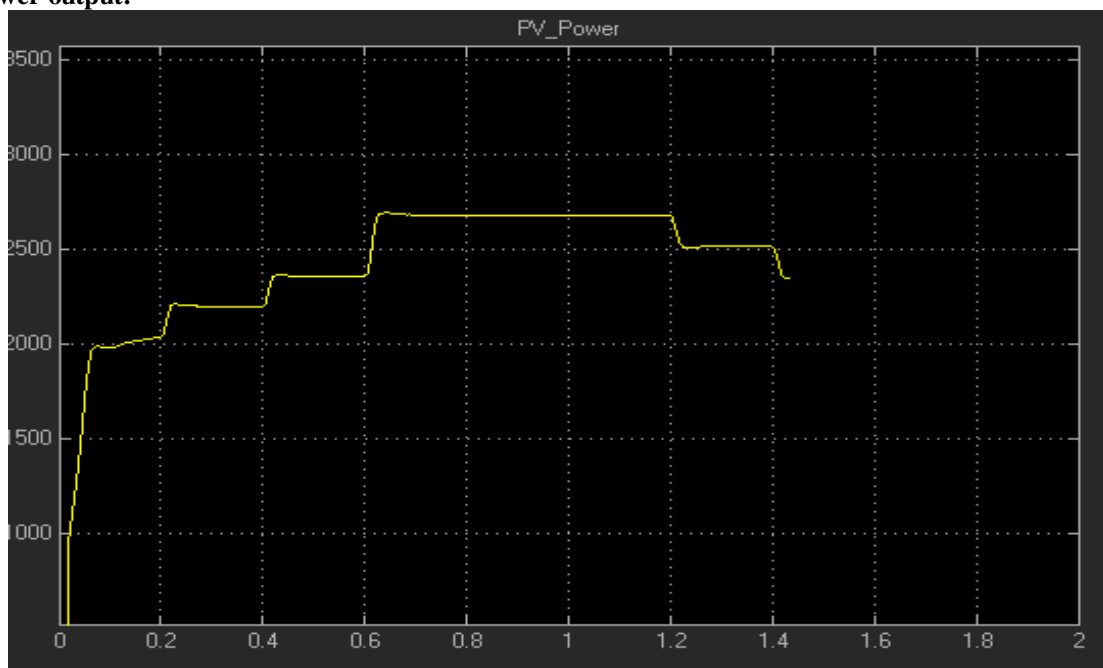


Figure: 20 PV power output

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5.5 Observation table of simulates results:

Load sharing between PV and Grid from 9am to 6pm keeping 2KW of fixed load is shown below

1. Load sharing between PV and Grid With MPPT for 2KW load

Sr no	Time (Hrs)	Irradiance (W/m ²)	PV power (Watts)	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 01: 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.

1. Load sharing between PV and Grid Without MPPT for 2KW load

Sr no	Time (Hrs)	Irradiance (W/m ²)	PV power (Watts)	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 2: 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 se 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):

1. During 12noon to 3pm the irradiance is maximum therefore the PV power obtained is also maximum which is shown in the table ie is from observation 4 to 10.
2. The PV power obtained with MPPT for the same day is more than the PV power obtained without MMPT.
- 3.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 .
4. During the time 9.00am to 12.00 noon the irradiance is less therefore the power is taken from grid as well

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5. During the time 1.00 pm to 3pm we can conclude that the PV power generated is maximum i.e. out of which the load is been supplied and remaining is fed back to the grid. Whereas for the same time of the day the power obtained without MPPT obtained is less.

VI. CONCLUSION

The proposed design of grid interactive photovoltaic power generation has been analysed 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%

REFERENCES

1. M. Gohukul, "A New Design Of Grid Tied Inverter For A Grid Interactive Solar Photovoltaic Power Generation – An Innovative Option For Energy Conservation And Security", IJECT Vol.2 ,Issue 3, Sept .2011.
2. Danish Hameed , "Solar Grid –Tied , With Battery Back-up, For Efficient Solar Energy Harvesting",2016th 4th IEEE International Conference on Smart Energy Grid Engineering.
3. Prof S .N Rawat, "Design OF Solar Based Integrated Dual Mode Inverter", Volume , Issue(4) July, Technovision-2014, ISSN 2249-071X.
4. Prof p. Manikandan. "Design And Implementation Of Solar Energy With Grid Interfacing", International Journal of Science, Engineering and Technology Research (IJSETR) Volume 2, Issue 7, July 2013.
5. Monika Verma, HarshitAgarwal, NamanRawat, VivekKashyap, Akshay Kumar "Synchronization Between Solar Panel & Ac Grid Supply For Different Loads", International Journal Of Scientific & Technology Research Volume 4, Issue 09, September 2015.
6. K. Arulkumar, D Vijaykumar, K.Palanisamy "Efficient Control Design for Single Phase Grid Tie Inverter of PV system",2014 International Conference on Advances in Electronics ,Computers and Communication
7. Md. Jahangir Hossain , Md. RaqibullHasan , MonowarHossain and Md. Rafiqul Islam. "Design And Implementation Of a Grid Connected Single Phase Inverter for Photovoltaic System". Department of Electrical and Electronic Engineering; Khulna University of Engineering &Technology; Khulna Bangladesh .
8. V. Seenivasagan, A. ManikandanGowtham, " DesignAnd Implementation Of Solar Energy With Grid Interfacing" , International Journal of Science, Engineering and Technology Research (IJSETR) Volume 2, Issue 7, July 2013.
9. Monika Verma, HarshitAgarwal, NamanRawat, VivekKashyap, Akshay Kumar "Synchronization Between Solar Panel & AC Grid Supply For Different Loads", International Journal Of Scientific & Technology Research Volume 4, Issue 09, September 2015.
10. M. Gohul, T. Jayachandran, A. Mohamed Syed Ali, T.G. Raju, N. Santhosh Kumar, M.R. Saravanan, Dept. of EEE, KNSK College of Engineering, India Maintenance Engineer, Brahmos Aerospace, DRDO, India "A New Design of Grid Tie Inverter for a Grid Interactive Solar Photovoltaic Power Generation – An Innovative Option for Energy Conservation & Security", ISSN : 2230-9543(Print) Issue 3, Sept. 2011.
11. VikasKulkarni, Rajesh Nehete. "Simulation and Analysis PF PV based Solar Inverter System", International Journal of Soft Computing and Engineering (IJSCE) ISSN: 2231-2307, Volume-3, Issue-6, January 2014.
12. Prakash Kumar Dewangan, Prof Umesh T. Nagdeve. " Inverter For Grid Connected PV System A Review", International Journal OF Advanced Research in Electrical Electronis And Instrumentation Engineering, Vol.3, Issue 10, October 2014.
13. Satheshkumar D. Ramya .N.D Indira .R, R Ashok. "Design And Analysis of Single Phase Grid connected Inverter", International Journal Of Innovative research in Computer And Communication Engineering , Vol 3, Issue 2, Februray 2015
14. Manisha Joshi, Prof. Dr .Mrs G.A. Vaidya. "Modeling and Simulation of Single Phase Grid Connected Solar Photovoltaic System", 2014 Annual IEEE India Conference (INDICON)
15. GANATRA B. H.1, Dr. Jha A. K.2 "Salient Features Of Grid-Connected Photovoltaic System And Its Impact On Power Supply", International Journal of Modern Trends in Engineering and Research.
16. NishijGanpatrao Kulkarni1, VasudeoBapuji Virulkar2 "Power Electronics and Its Application to Solar Photovoltaic Systems in India", Copyright © 2016 by authors and Scientific Research Publishing Inc.