RESEARCH ARTICLE OPEN ACCESS

Design and Development of Solar Roof Top PV Power Systems

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Abstract:

The main objective of this project is to design and develop a 100kW solar PV power system in commercial buildings. In most of the countries production and consumption of electricity is expanding. So in this project a system is developed to extract some energy from solar power systems and convert into electricity. Engineering analysis is developed using PV SYST in this solar power system. All components are selected based on commercially available off the-shelf components. A Matlab simulink model is developed for both DC and AC power system and the results are compared with PV Syst model performance. Costing analysis of the solar power plant is performed to identify the sensitivity parameters on levelized cost of energy (LCOE). Hence this project was concluded with an identified future research needs for reducing the LCOE.

Keywords — **Photovoltaic system (PV Syst), Direct current (DC), Alternating current (AC).**

I. INTRODUCTION

With its economy growing at fast clip, the Indian industry is in a time of unprecedented opportunities for growth. Along with this growth comes the need for higher energy consumption, as energy demand/consumption is highly correlated to economic growth[1].

India needs a sustained growth rate of 8-9% over the next twenty years to meet its growth objective[9]. This implies that it will need to increase its primary energy supply by a factor of three to four and to the electricity generation by a factor of five to six[5]. India receives nearly 300 to 330 days of solar energy and there is a large potential available for generating solar power using unutilized space on rooftops of individual houses, industrial buildings, educational institutions or any other type of buildings can be used to partly fulfill the requirement of the building occupants and surplus, if any, can be fed into the grid. So the best suitable long term design solution for India would be a highly distributed set of individual rooftop power generation systems connected through a local grid[4].

Thus a rooftop solar PV system could be with or, without having grid interaction. In grid interactive system, the DC power generated from solar PV panels is converted to AC power using power conditioning unit and is then given to the grid either of 11 KV three phase line or, of 220V single-phase on the basis of the system that has installed at various places like commercial buildings, residential complexes etc[9]. It generates power during day hours so that the generated power can be utilized by loads and the excess power is supplied to the grid[10].

If solar power is not sufficient i.e. during monsoons and rainy days loads can be served by the power supplied from the grid. The grid-interactive rooftop solar PV systems thus work on 'net-metering' basis wherein the beneficiary pays to the utility on net meter reading basis only.

Net-metering will facilitate the self-consumption of the electricity generated by the roof top PV power system and the excess power can be fed into the network of distribution licensee. This type net net-metering based solar systems will be a vital factor for defining different models of rooftop PV power systems.

II. SYSTEM DESCRIPTION

The proposed solar PV power system consists of solar PV array, inverter, cables/wires, mounting structure, protection mechanisms and batteries, Distributed control systems etc. and shown in the below figure[1].

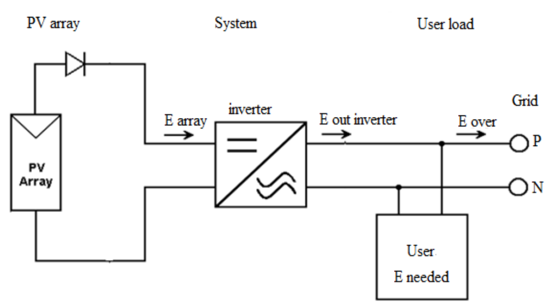

Fig. 1 Block diagram of grid connected PV power system

A. PV MODULES

PV modules generate electricity by absorbing sunlight and the generated power is supplied to the load. If there occurs any excess power, it is given to the grid. The output of panel is DC[15]. The produced power is proportional to the intensity of the light and the angle at which the light strikes the panel. In this project, we have selected PV modules of 225 to 250 watts consisting of 60 cells in series connected. There are other modules also available in the market with higher power capacity, but the selection of 225 to 250W is mainly availability of large off the self modules[9].

B. INVERTER

The DC power which is produced from the panels is fed to inverter and then the further process of converting DC into AC occurs. The output of inverter is fed to grid either at 11KV or 440V three phase systems depending upon the installed system and requirement of load[1].

The AC power produced from the inverter should synchronize automatically to the grid AC voltage and frequency.

The design of an inverter should be in such a way that it should operate the PV system near its maximum Power Point (MPP). Maximum power point is the operating point where the maximum operating power is obtained by combining the values of the current and voltage of the solar modules. The selected inverter should be a true sine wave inverter for a grid interactive PV power system.

C. MOUNTING STRUCTURE

For mounting the modules and panels, hot galvanized iron structures can be used. Mounting should be done in such a way that panels must be placed at appropriate places and appropriate tilt angles so that maximum amount of sun light can be received and the output can be increased correspondingly.

D. POWER AND CONTROL CABLES

These power and control cables of appropriate rating are required for interconnecting Modules or panels in an array, between array and charge controller, between charge controller and loads. Depending upon the fault distribution level and full load current of the system the size of 11KV power cables are to be chosen appropriately. But for 440V systems, the size of power cables are selected by considering full load current and the voltage drop. At full load conditions, the maximum drop of 2.5% is allowable. While selecting the size of conductor, derating factors must be taken into consideration[14].

E. EARTHING EQUIPMENT/MATERIAL

In order to protect the equipment and also the working personnel, earthing must be done. System earth and equipment earth are the two main grounds used in power equipment.In system earth, protection is provided by grounding one leg of the circuit[1].

In equipment earth, metal parts which do not carry any current are connected to the earth by bonding them together. So that shocks to the operating personnel can be prevented during accidents.

F. JUNCTION BOXES OR COMBINERS

Junction boxes used for wiring must be able to withstand dust, water etc. Even junction boxes of appropriate rating must be selected. Fuses of adequate rating must be provided in order to protect the solar arrays from short circuit conditions.

III. DESIGNING OF SYSTEM

A. DESIGNING OF MODULE

1) Maximum number of Modules in Series:

Nmax ≤ maximum dc input voltage for the inverter / maximum module voltage (Voc max)

Voc max = Voc + (temp differential x temp coefficient of Voc)

Voc max = Voc+ ((Tmax – Tstc) x temp coefficient of Voc) ……………… eq (1)

Where Nmax = Maximum number of Modules in Series

Voc = Open circuit voltage of the module

Voc max = Maximum module voltage

Tmax = Maximum temperature for the site

2) Minimum number of Modules in Series:

Nmin ≥ inverter's minimum input voltage / minimum expected module maximum power voltage (Vmp min)

Vmp min = Vmp + (temp differential x temp coefficient of Vmp)

Vmp min = Vmp + ((Tmax – Tstc) x temp coefficient of Vmp) ………… eq(2)

Where

Nmin = Minimum number of Modules in Series

Vmp = Maximum power voltage

Vmp min = Minimum expected module maximum power voltage

Tmax = Maximum temperature for the site

3) Maximum number of Strings in Parallel:

N ≤ maximum inverter input current /maximum power current at STC[14]

Where

N= Maximum number of Strings in Parallel

Tstc = Temperature at Standard Test Conditions

4) Maximum Array Capacity:

The equation for calculating the maximum number of modules in this manner is:

Inverter Power ≤ N x PTC x CEC weighted efficiency

PTC = fixed module power derating factor of 0.90 × Pmp STC

Where N = Maximum no of modules to the inverter

PTC = Power Test Condition

CEC = California energy commission.

Pmp STC =Maximum power at standard test condition

B. INVERTER SELECTION:

A photo voltaic installation needs several components other than the photo voltaic panels. These components are jointly referred to as the balance of system. DC to AC converters (inverters) for AC loads and grid connected systems, supporting structures for mounting the photo voltaic panels, protection relays and so on[1]. This chapter discusses inverter designing. Interfusing the direct current (DC) power and alternating current (AC) power. In this system by using grid-tied inverter. From table 1 is the inverter specifications.

TABLE 1
INVERTER SPECIFICATIONS

Manufacturer		• SMA Solar Technology AG • SC 500CP XT
Input data	Max PV power (kw)	• 20.4 KW
	Max. Voc (vdc)	• 800 V
	MPPT range (Vdc)	• 580-800 V
	Max. Dc input current(Adc)	• 36 V
Output data	Max.Output power(Pac)kw	• 20 KW
Nominal output voltage(Vac)		• 400 V
	AC output wiring	• 3-wire w/ neut
Max. Output current(Aac)		• 29 A
Maximum efficiency (%)		• 98.5
Transformer (star-delta)		• 125 KVA

C. MOUNTING STRUCTURE:

• Before beginning an installation, make sure that all equipment is at hand. This includes tools, materials, necessary spares and information resources[1]. Many solar electric installations are conducted in remote areas where equipment and spares are not available[7]. Delays are expensive and they often occur because basic spares like cables, connector strips or special bolts went missing.

• While installing, follow the manuals of all the components carefully.

• Follow the recommended sequence of installation. Do not connect appliances, lamps, batteries or solar cell modules to the controller, until the last step. Follow the final connection sequence carefully.

• If you are not experienced with electrical installations, complete the installation with help from a competent expert.

• Always use the proper tools for each task.

• Maintain high work standards. Work standards refer to the way the wires are laid, the consistency of switch placement, the method with which fixtures are attached to walls and the general neatness of the work.

D. PV roofing:

PV modules can be installed on flat or sloped roofs. Modules may be mounted in the same plane as the roof or may be inclined with respect to the roof surface[6]. For the applications in the north hemisphere, the panel should be mounted facing south. When modules are sloped relative to the roof surface, a shadow will be formed and adequate space must be maintained between rows of modules to minimize energy collection losses due to shading[10]. The latitude and longitude of our project is

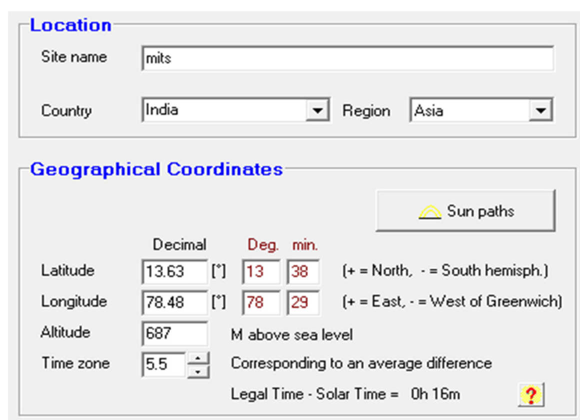

Fig. 2 latitude and longitude of project location

E. CABELING:

Wire sizing:

While making electrical connections between any two components of a pv system we need to select an appropriate wire /cable to minimize the voltage drop and power losses in cable. Following are some specifications that we need to identify for a wire[11].

- Length of a wire
- Operating current
- Operating voltage
- Allowed potential voltage drop
- Wire operating temperature

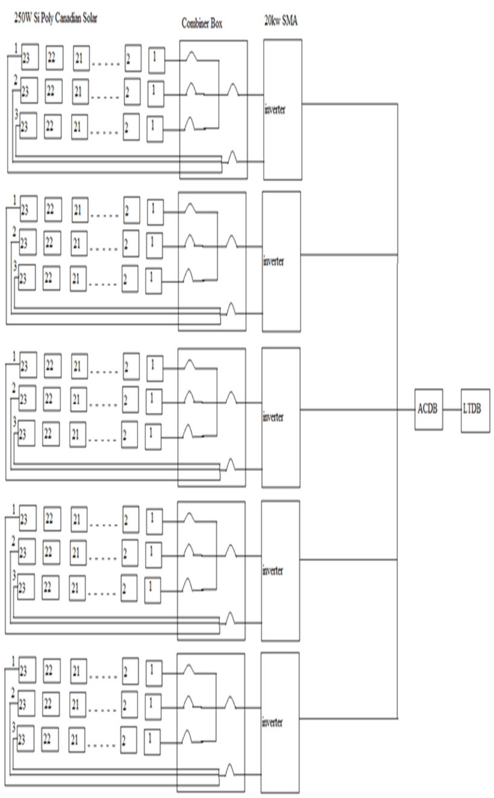

Fig. 3 wiring diagram for 100KW solar PV power system

F. POWER FLOW CALCULATIONS FOR 100KW POWERPLANT

PV MODULE SPECIFICATION:

TABLE 2

PV MODULE SPECIFICATIONS

Specification	Module	String	Panel	Array (per inverter)
P mp (w)	249.83	5476.09	16428.27	82141.35
Voc (V)	37.2	855.6	855.6	855.6
I sc(A)	8.87	8.87	26.61	133.05
Vmp(V)	30.10	692.3	692.3	692.3
Imp(A)	8.30	8.30	24.9	124.05
Po(w)	329.964	7589.17	22769.892	113849.46

IV. ENGINEERING ANALYSIS

A. PV SYST:

PVSYST V6.19 is a PC software package for the study, sizing and data analysis of complete PV systems. It deals with grid-connected, stand-alone, pumping and DC-grid (public transport) PV systems, and includes extensive meteo and PV systems components databases, as well as general solar energy tools[1].

This software is geared to the needs of architects, engineers, researchers. It is also very helpful for educational training[10].

PVSYST V6.19 offers 3 levels of PV system study, roughly corresponding to the different stages in the development of real project.

1) Project Design:

It aims to perform a thorough system design using detailed hourly simulations. Within the framework of a "project", the user can perform different system simulation runs and compare them. He has to define the plane orientation and to choose the specific system components. He is assisted in designing the PV array (number of PV modules in series and parallel), given a chosen inverter model, battery pack or pump[1].

2) Preliminary design:

This is the pre-sizing step of a project. In this mode the system yield evaluations are performed very quickly in monthly values, using only a very few general system characteristics or parameters, without specifying actual system components. A rough estimation of the system cost is also available.

3) Measured data analysis:

When a PV system is running and carefully monitored, this part (located in the "Tools" part) permits the import of measured data (in almost any ASCII format), to display tables and graphs of the actual performances, and to perform close comparisons with the simulated variables. This gives a mean of analyzing the real running parameters of the system, and identifies even very little misrunning's[1].

To design our system in PV syst following procedure should be followed

Step1: Selection of location of our project.

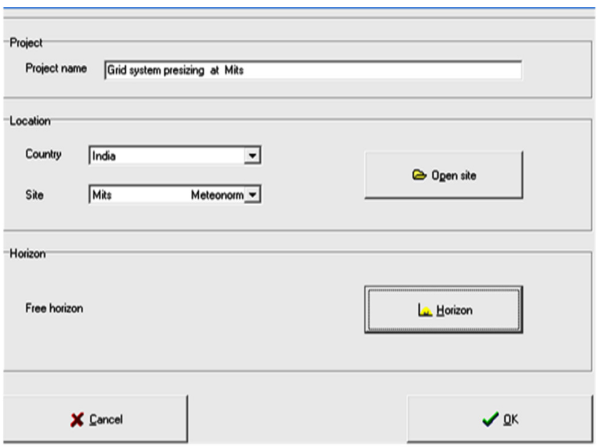

Fig. 4 Location of 100 KW solar PV system

Step2: shows the annual yield

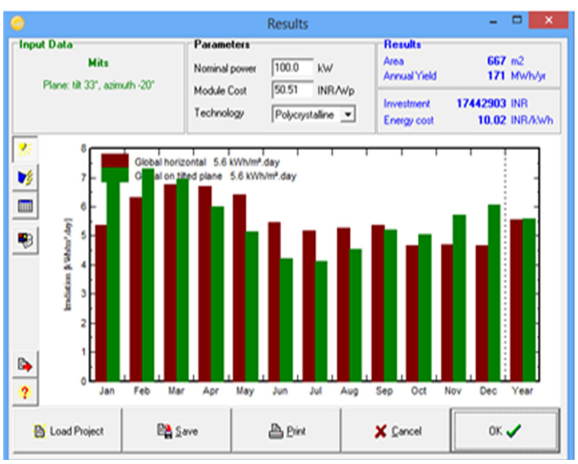

Fig. 5 Annual energy graph

The above figure shows the annual yield of the system per annum.

Step3**:** system specifications

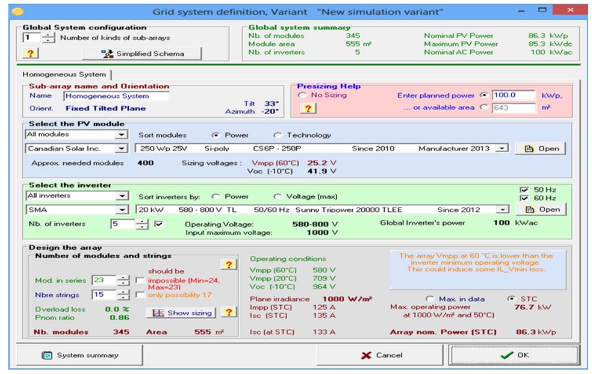

Fig. 6 System specifications

From the above figure 6, required number of modules can be determined by selecting module and inverter. Even nominal PV power, voltage and current are determined with the help of PV syst software.

B. PV SYST RESULTS:

Design of the system is done through PV syst software. Proper selection of module and inverter is made for designing the system. With the help of this software they are simulated and certain results are obtained. Power loss calculations are made from the results obtained from the simulation[1].

Even characteristics of module are obtained by simulation. These characteristics include the plots that are drawn between voltage and current. The other plot is between voltage and power. These plots are obtained at different conditions of temperature and irradiance values. The plots obtained by simulating the design through PV syst software are:

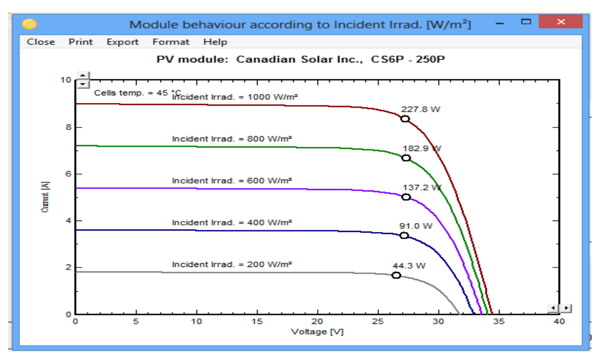

Fig.7 Voltage and current characteristics

From the above figure 7, voltage and current characteristics can be known for different irradiance levels at constant temperature. Also the graph indicates maximum power points at respective irradiance levels.

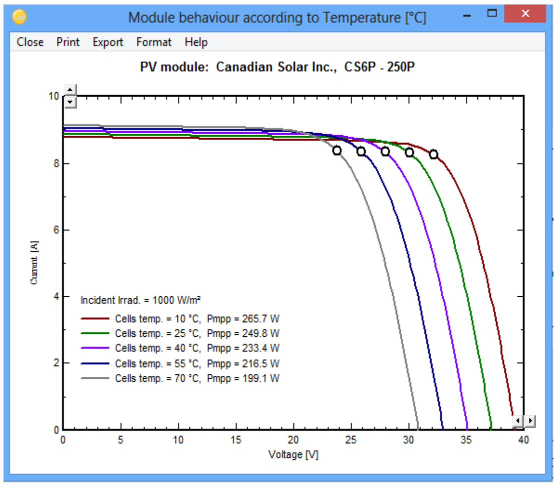

Fig. 8 Voltage and current characteristics

From the above figure 8, voltage and current characteristics at constant irradiance and different values of temperature can be obtained. As the MPP varies with temperature, different values of MPP can also be obtained at respective temperature values.

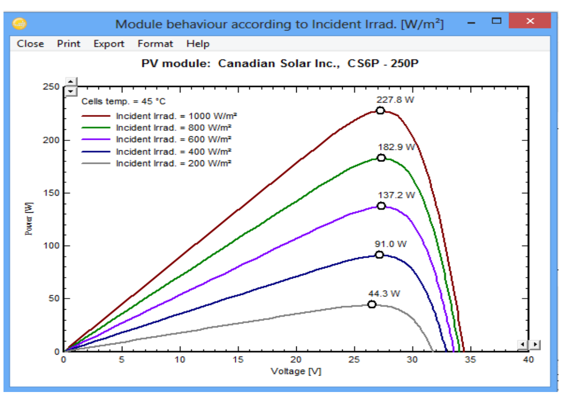

Fig.9 Voltage and power characteristics

From the above figure 9, voltage and power characteristics at constant temperature and various irradiance levels can be obtained. Power increases with increase in voltage and after reaching MPP, it decreases.

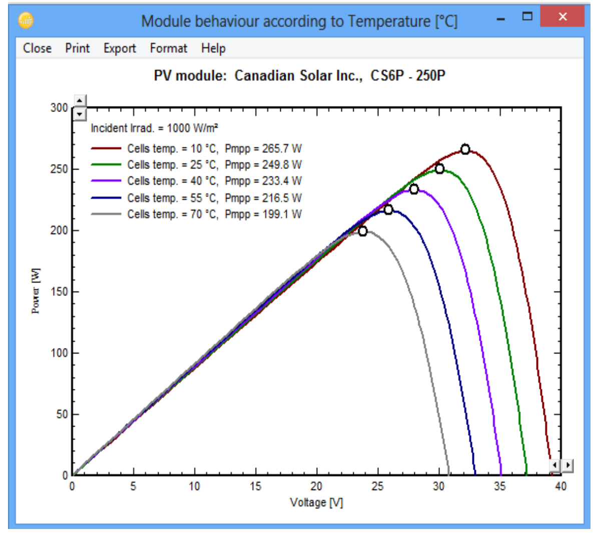

Fig. 10 Voltage and power characteristics

From the above figure 10, voltage and power characteristics at constant irradiance and different values of temperature can be obtained. Here the power increases linearly with the increase in voltage and after reaching MPP, it decreases[1].

V. SIMULINK MODEL FOR ROOF TOP PV POWER SYSTEM

MATLAB was developed by Math works inc. and the name MATLAB stands for matrix laboratory. In this software numerical computations can be performed. It has flexibility. Even the reliability of the system is more. It has hundreds of built in mathematical functions which can be performed accurately[5]. With these functions, several problems like complex arithematic linear systems, differential equations, optimization, nonlinear systems and other type of specific computations can be solved[4].

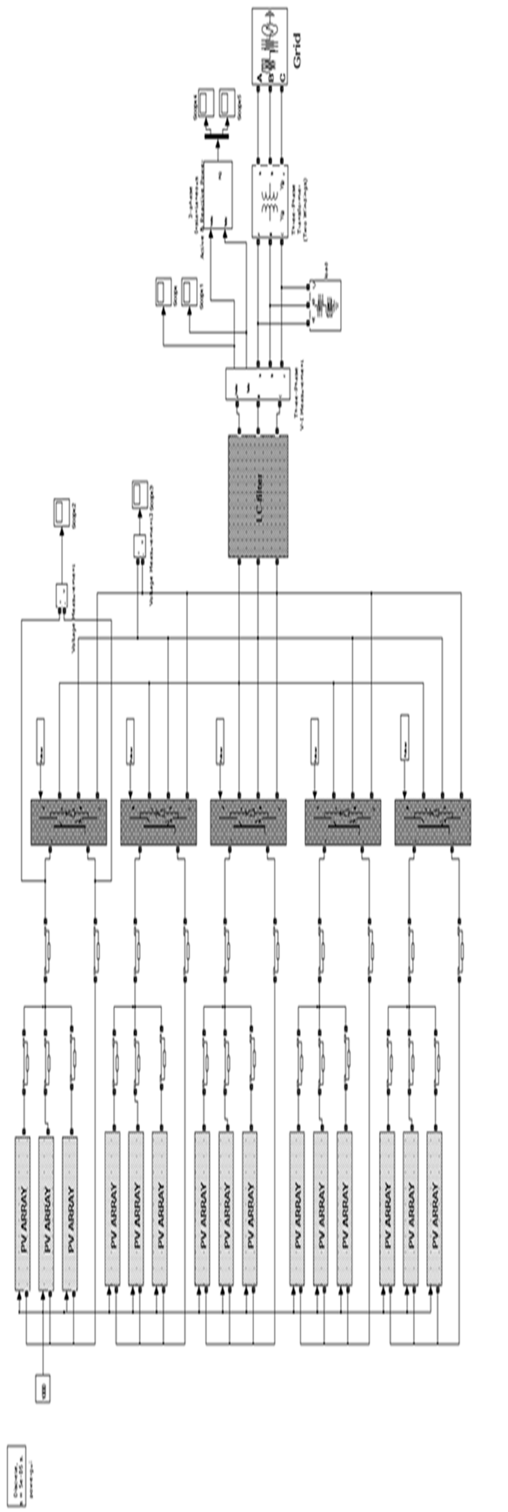

Fig. 11 Simulink model for 100 KW Solar roof top PV power system

VI. RESULT ANALYSIS

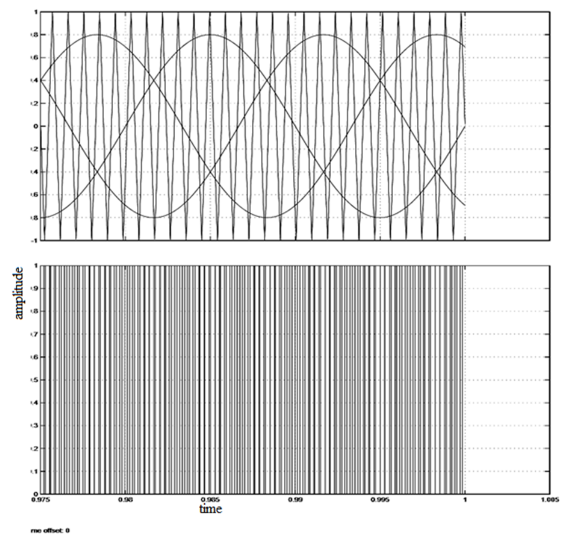

Fig. 12 Pulse width modulation

The above Figure 12 shows the pulses that are generated by PWM technique. In this graph, amplitude is taken along the ordinate and time is taken along the abscissa.

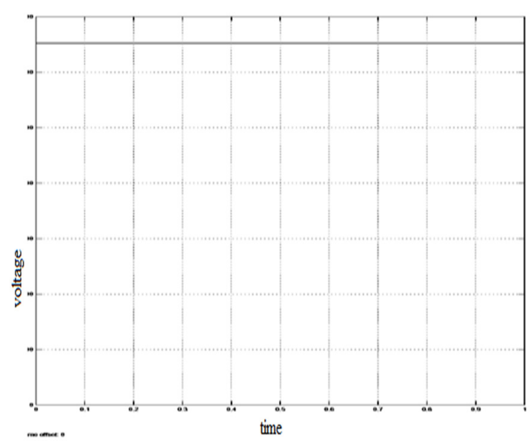

Fig. 13 Output voltage from PV array

The above figure 13 shows the constant voltage i.e. the output of PV array. In this graph, voltage is taken along ordinate and time along the abscissa.

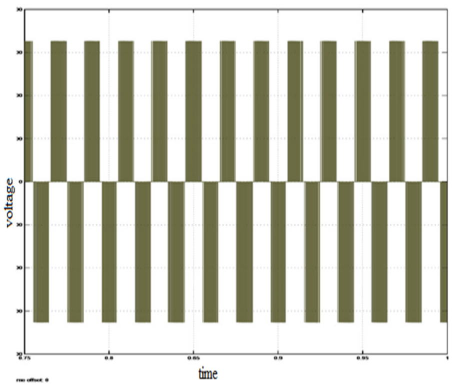

Fig. 14 Output voltage of inverter

The above figure shows the output voltage from inverter with ripple content. In this graph, voltage is taken along ordinate and time is taken along abscissa.

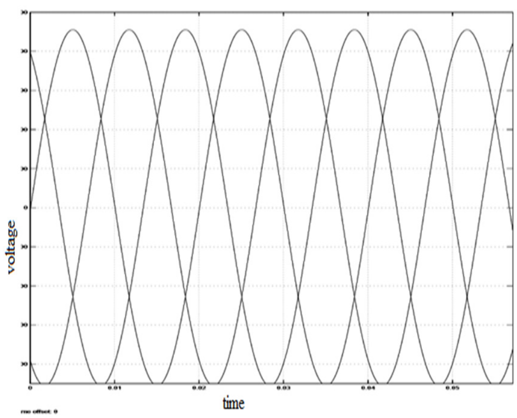

Fig. 15 Output voltage of LC filter

The output of inverter contains ripples. In order to reduce ripple content, an LC filter is connected. Thus the above graph shows pure sinusoidal voltage which is the output of LC filter. In the above figure 15, voltage is taken along ordinate and time is taken along abscissa.

VII CONCLUSION

The performance of 100KW roof top PV power system has been analyzed. The total parameters of the system were taken on real time basis. The generated energy is used for serving the increasing demand and the remaining is injected into the grid. The design is obtained through the PV syst software. Theoretical calculations have been made for modules, inverters, and cables including both DC cables and AC cables and then output of them are determined. The results obtained from the PV syst software are analyzed by a Matlab simulik model. Thus the system 100KW rooftop PV power system is designed, engineering analysis is done and simulation results are obtained.

REFERENCES

1. P. Karki, B. Adhikary and K. Sherpa, "Comparative Study of Grid-Tied Photovoltaic (PV) System in Kathmandu and Berlin Using PV syst," IEEE ICSET, 2012.
2. M. G. Villalva et al. 2009
3.K. Ishaque, Z. Salam, H. Taheri, Accurate MATLAB Simulink PV system simulator based on a two-diode model, Journal of Power Electronics 11 (2011) 179-187.
4. H.L. Tsai, C.S. Tu, Y.J. Su, Development of generalized photovoltaic model using MATLAB/SIMULINK, in: Proceedings of the World Congress on Engineering and Computer Science, San Francisco, USA, 2008.
5. H. Patel, V. Agarwal, MATLAB-based modeling to study the effects of partial shading on PV array characteristics, IEEE Transactions on Energy Conversion 23 (2008)302-310.
6.M.G. Villalva, J.R. Gazoli, E.R. Filho, Comprehensive approach to modeling and simulation of photovoltaic arrays, IEEE Transaction on Power Electronics 24 (2009) 1198-1204
7.K. T. Tan et al. 2010 Modeling and Control of a Photovoltaic Energy System
8. A. Hassan, F. H. Fahmy, A. E.-S. A. Nafeh and M. A. El-Sayed, "Modeling and Simulation of a Single Phase Grid Connected," WSEAS TRANSACTIONS on SYSTEMS and CONTROL, pp. 16-25, 2010.
9. O. Wasynczuk, Dynamic behavior of a class of photovoltaic power systems, IEEE Transactions on Power Apparatus and Systems 102 (1983) 3031-3037.
10. J.T. Bialasiewicz, Renewable energy systems with photovoltaic power generators: Operation

and modeling, IEEE Transactions on Industrial Electronics 55 (2008) 2752-2758.

11.Anita Marangoly George 2012 utility scale solar pv plant a guide for developers and investors

12. K. T. Tan et al. 2010 Modeling and Control of a Photovoltaic Energy System

13. Array to Inverter Matching Mastering Manual Design Calculations solar weekly By John Berdner

14. Scaling Up for Commercial PV Systems solar weekly By John Berdner

15. Crystalline Silicon Photovoltaic Modules solar weekly by John Berdner.