Performance Analysis of SPV System at Different Load Conditions

C.S. Sharma[1] Gaurav Jain[2] Rahul Tamrakar[3]

[1]Associate Professor

[1,2,3]Department of Electrical Engineering Engineering

[1,2,3]Samrat Ashok Technological Institute Vidisha, Madhya Pradesh

Abstract— Renewable energy sources play an important part in electric power generation; solar energy is a good choice of an electric power generation. As the solar energy is directly converted by solar photovoltaic modules. In this paper we present the output variation and check compatibility with different load conditions. R, L, C type loads are used in standalone SPV system. Every system behavior and harmonics are changed according to its designing and modeling. We have designed Simulink model of SPV system. In this model we are discussing different types of factor like temperature, seasonality, soiling, system voltage and loads. This reviews the generalized mathematical modeling and simulation of Solar Photovoltaic System. a diode equivalent circuit is employed in order to investigate load characteristics of a solar module MPPT algorithm, Step up DC-DC converter and a Single phase grid tied inverter using MATLAB/Simulink.

Key words: DC-DC Boost Converter, Grid, Inverter, Maximum Power Point Technique (MPPT), Pulse Width Modulation (PWM), Solar Photo-voltaic System (SPV), Photo-voltaic modeling, Standard Test Condition (STC), Matlab/Simulink R2013a

I. INTRODUCTION

The utilization of photovoltaic (PV) systems as a safe and clean source of energy from the sun has been rapidly growing. The application of PV systems in power systems can be divided into two main fields: off-grid or stand-alone applications and on-grid or grid-tied applications. Stand-alone PV systems can be utilized to give energy for remote loads that do not have any operation to power grids while grid-connected applications are utilized to provide energy for local loads and for the exchange power with utility grids. The first large grid-connected PV power plant with 1 MW capacity was introduced in Lugo, California,USA. The second plant with 6.5 MW capacity was installed in Carissa Plains, California, USA. Currently, many large grid tied PV systems with different ranges of power are operating in various countries, as Switzerland, Germany, Australia, Spain, and Japan. PV systems can upgrade the operation of power systems by improving the voltage profile and by decreasing the energy losses of distribution feeders, the maintenance costs, and the loading of transformer tap changers during peak hours. Nonetheless, in comparison with other renewable technologies, PV systems are still facing major difficulties and may pose some adverse effects to the system, such as overloading of the feeders, harmonic pollution, high investment economy, low efficiency, and low reliability, which hinder their widespread use. Moreover, variations in solar light can cause power fluctuation and voltage flicker, resulting in undesirable effects on high penetrated PV systems in the power system. Some control methods, such as Maximum Power Point Tracking (MPPT) can be utilized to enhance the productivity of PV systems. In such controllers, both the produced voltage and the current of the PV array should be controlled. This may make the PV system complicated with increased possibility of failure while tracking maximum power in unwanted weather conditions. With respect to system protection scheme, the PV system based distributed generations should energize the nearby loads after the system has been disconnected from the utility grid during faulty conditions. In these conditions, any unintentional islanding may increase the risk of safety problems or harm to other parts of the system segments, which can degrade system reliability. These problems mean that accurately analyzing the effects of installing large grid tied PV systems on the performance of the electric network is necessary. This evaluation is important because it can provide practical solutions for potential operational problems that grid tied PV systems can cause to other components in distribution systems.

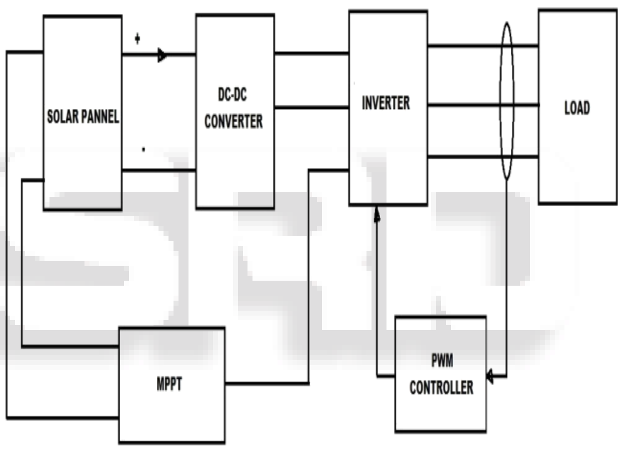

Fig. 1: Grid connected solar pv system

II. SIMULINK MODEL

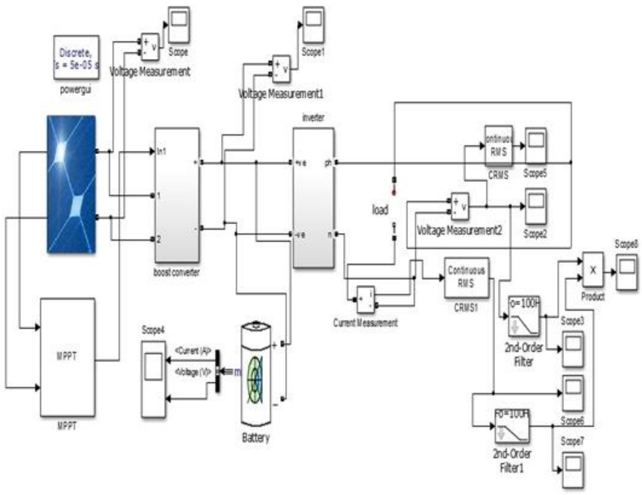

Fig. 2: Simulink model of SPV system

A. *Photovoltaic Module:*

Cells are arranged in an edge to frame a module. The PV cells are connected in series (for high voltage) and in parallel (for high current) to design a PV module for desired output. Separate diodes may be needed to avoid reverse currents, in case of partial or total shading. The p-n junctions of mono-crystalline silicon cells may have adequate reverse current characteristics. Reverse currents waste energy and can also lead to overheating of shaded cells. Solar cells turn out to be less efficient at higher temperatures and installers try to provide good ventilation behind solar panels.

B. *Photovoltaic Array:*

The modules in a PV array are initially connected in series to obtain the desired voltages, the individual modules are then connected in parallel to allow the system to create more current.

C. *Efficiency Of Pv Cell:*

The efficiency of a PV cell is described as the ratio of peak power to input solar power. The efficiency will be maximum if we find the maximum power from the PV system at different environmental condition such as solar irradiance and temperature by using different technique for maximum power point tracking.

D. *Maximum Power Point Tracking (Mppt)*

Power output of a Solar PV module alters with change in direction of sun, changes in solar insolation level and with differ temperature. The PV curve of the module there is a single maxima of power. That is there having a peak power relating to a particular voltage and current. Since the module efficiency is low it is needed to operate the module at the highest power point so that the maximum power can be delivered to the load under varying temperature and insolation. Hence maximization of power improves the utilization of the solar PV module. A maximum power point tracker (MPPT) is used for separating the maximum power from the solar pv module and transferring that power to the load. A dc-dc converter serves the object of transferring maximum power from the solar PV module to the load. Maximum power point tracking is used to make that the panel output is always achieved at the maximum power point. Using MPPT significantly expanding the output from the solar power plant.

E. *Dc-Dc Boost Converter:*

A boost converter is nothing but a dc to dc voltage converter with an output dc voltage greater than input dc voltage. This is an SMPS having at least two semiconductors switches, diode which act as freewheeling diode two ensure a path of the current during the off condition of other switch and a transistor connecting in series of the source voltage). Filters made of capacitor and inductor is used to decrease the ripple in voltage and current respectively, is used at the output of the converter. The basic operating principle of the converter consists of the two distinct states. In on condition, switch is closed, resulting in an increase in the inductor current. In off state, switch is open, resulting in decrease in the inductor current

1) Buck converter
2) Boost converter
3) Buck- boost converter
4) Cuck converter

S.NO.	PARAMETER	VALUE
	Input Voltage(Vs)	75V
	Output Voltage(V0)	250V
	frequency(Fsw)	2567Hz
	Resistance(R)	50Ω
	Inductor(L)	1e-3
	Capacitor(C)	1e-6

Table 1: System parameter used.

III. INVERTER

PV generation system generates electricity by converting the Sun‘s energy directly into electricity. PV generated energy can be delivered to power system networks via grid tied inverters. A single-phase grid-connected inverter is used for residential or less power applications of power ranges less than 10 kW . Types of single-phase grid-connected inverters have been introduced. A device that converts dc power in to ac power at desired output voltage and frequency is said to be an inverter. Phase controlled converters when operated in the inverter mode, are called line commutated inverters, but line commutated inverters need at the output terminal an existing ac supply which is used for their commutation.

A. *Inverter Efficiency:*

A solar PV inverter is a type of electrical inverter that is made to change the direct current (DC) electricity from a photovoltaic array into alternating current (AC) for use with home appliances or to be fed into the utility grid. These inverters may be stand alone inverters, which are used in isolated systems, or grid tie inverters which are used to connect the power plant to the grid. The efficiency of an inverter has to do with how well it converts the DC voltage into AC. The currently available grid connected inverters have efficiencies of 96 to 98.5%, and hence choosing the correct inverter is crucial to the design process. There are less efficient inverters below 95% also available. Inverters are also much less efficient when used at the low end of their maximum power. Most inverters are most efficient in the 30% to 90% power range.

B. *Advantages:*

A single phase multilevel inverter has the following merits over other existing multilevel inverter topologies.

1) It contains single phase conventional H-bridge inverter, bi directional auxiliary switches (number varies depending upon level) and a capacitor voltage divider.
2) Improved output waveform.
3) Smaller filter size.
4) Less electromagnetic interference (EMI) and total harmonic distortion (THD) as the levels increment.
5) Reduced number of switches employed.
6) Less complexity of the circuit as the levels increment.
7) Attains least 40% drop in the number of main power switches required.

IV. SOLAR PHOTOVOLTAIC (SPV) TECHNOLOGIES

Photovoltaic converters are semiconductor devices which convert part of the incident solar radiation directly into electrical energy. The most common PV cells are made of single crystal silicon but there are many variations in cell material, design and techniques of manufacture. Solar PV cells are available as crystalline silicon, amorphous silicon cells as Cadmium Telluride, copper indium gallium dieseline (CIGS), dye sensitized solar cells DSSC and other new technologies such as silicon Nano particle ink, carbon nanotube CNT and quantum dots.

Wafer-based c-Si		Thin Films		
Mono-Si	Multi-Si	a-Si; a-Si/μc-Si	CdTe	CIS/CIGS
15-20%	15-17%	6-9%	9-11%	10-12%

Table 2: Commercial efficiencies of photovoltaic modules

Crystalline silicon (c-Si) modules represent 85-90% of the global annual market today. C-Si modules are subdivided in two main categories: i) single crystalline (sc-Si) and ii) multi-crystalline (mc-Si). Thin films currently account for 10% to 15% of global PV module sales. They are subdivided into three main families: i) amorphous (a-Si) and micro morph silicon (a-Si/μc-Si), ii) Cadmium-Telluride (CdTe), and iii) Copper-Indium-Dieseline (CIS) and Copper-Indium-Gallium-Dieseline (CIGS). Emerging technologies encompass advanced thin films and organic cells. The latter are about to enter the market via niche applications. Concentrator technologies (CPV) use an optical concentrator system which focuses solar radiation onto a small high-efficiency cell. CPV technology is currently being tested in pilot applications. The above technologies are mainly used on roof tops of commercial and residential buildings, and as large scale grid connected power plants. For optimum output, larger installations use tracking devices which change the orientation of the panels to correspond with the trajectory of the sun to focus sunlight directly onto the panels.

Fig. 3: Different types of SPV modules used at NISE,Delhi.

A. *Components of Spv Systems*

The stand-alone PV system consists of PV generator, battery, controller, inverter and load.

1) *Solar Panels (PV) Modules* : A large portion of the stand-alone PV systems need to be managed properly. The user should know the limitations of a system, the energy consumption according to how sun radiation is as well as the state of charge (SOC) of the battery. The solar panels need to be arranged in order to match the system DC voltage, which is determined by the battery. The system voltages are typically, 12V DC and 24V DC.
2) *Charge Controllers* : The charge controllers are intended to protect the battery from over-charging and over-discharging normally referred to as low voltage separate that disconnects the battery from the load when the battery reaches a certain depth of discharge (DOD) and to make that the system has a long working life without affecting the efficiency.
3) *Batteries:* The power requirements of PV systems are rarely in synchronized with the battery charging. Appliances and loads need to be powered when there is much solar irradiation, during overcast weather and during the night. Under ideal conditions, a newer deep cycle battery would be 90% efficient. The important characteristics to look for are: Capacity, cycle life, price, performance, size and space requirements, efficiency, self-discharge rate, installation etc.
4) *Cables and Accessories*: Cables should to be ultra violet resistant and suitable for outdoor applications. It is very important to keep power losses and voltage drop in the cable to a minimum.

B. *Performance of Solar Power Plants:*

The performance of solar power plants is defined by the Capacity Utilization Factor (CUF) , which is the ratio of the electricity output from the plant, to the maximum possible output during the year. The estimated output from the solar power plant depends on the design parameters and can be calculated , using standard software’s. But since there are many variables which contribute to the final output from a plant, the CUF varies over a wide range. These could be on account of poor selection /quality of panels, dating of modules at higher temperatures, other design parameters like ohmic loss, atmospheric factors such as cloud cover and mist. It is essential therefore to list the various factors that add to plant output variation. The performance of the power plant however depends on several parameters involving the site location, solar isolation levels, climatic conditions specially temperature, technical losses in cabling, module mismatch , soiling, MPPT, transformer losses and the inverter losses. There could also be losses due to grid inaccessibility and the module decreasing through aging. Some of these are specified by the manufacturer, such as depending on the power output on temperature, known as temperature coefficient. The following factors are considered key performance indicators:

1) Radiation at the site
2) Losses in PV systems
3) Temperature and climatic conditions
4) Design parameters of the plant
5) Inverter efficiency
6) Module Degradation due to aging

C. *Pv Performance Factors:*

The factors affecting PV performance are summarizes as follows:

1) *Temperature :* The effectiveness of the photovoltaic cell increments by producing high currents at cold temperatures. Also the voltage across the photovoltaic cell increments by 0.3-0.5% for every degree Celsius below 250C. In temperature climates, PV will produce less energy in winter than in summer, but this is due to the shorter days, lower sun angles, greater cloud cover, not the cooler temperatures.

2) *seasonality* **:** The effect of shade on power output of a PV installations is non-linear. A small amount of shade on a portion of the array can cause a large reduction in the output power.
3) *soiling:* Any material on the PV module glass which interferes with the incoming radiation will adversely affect the power generating potential of the module. Frequently taking the form of dust and snow, the magnitude of soiling losses depends heavily on the climate of the installation site.
4) *system voltage:* PV cells operate at a stable voltage. The current and power output of photovoltaic modules is approximately proportional to the solar insolation.
5) *aging :* The output of any PV module will decrease gradually over the course of its lifetime once the initial break-in period has elapsed.
6) *loads :* the Electrical Load is The part or component in a circuit that converts electricity into light, heat, or mechanical motion.

V. Types of Loads

A. Resistive Load:

Resistive loads are loads which consumes electrical energy in sinusoidal manner. This means that the current flow is in time with and directly proportional to the voltage. When a resistive load is energized the current rises instantly to its steady state value without first rising to higher value. The electrical current and the voltage in a resistive load are be in phase with each other. As voltage rises or falls, the current also rises and falls with it.

B. Capacitive Load:

A capacitor is device which stores electrical energy. Two conductive surfaces are separated by a non-conductive insulator. When an electrical current is given to a capacitor, electrons from the current gather on the plate attached to the terminal to which the electric current is given. When the current is removed, the electrons will to flow back through the circuit to achieve the other terminal of the capacitor. Capacitors are used in electric motors, radio circuits, power supplies and many other circuits. The ability of a capacitor to store electrical energy is called capacitance (C). The unit of measure is the farad, but most capacitors are measured in micro farads. The current leads the voltage of a capacitor. The voltage over the terminals starts out at zero volts while the current is at its maximum. As the charge expands on the capacitors plate, the voltage rises and the current falls. As a capacitor discharges, the current rises as the voltage falls.

C. Inductive Load:

An inductor may be any kind of conductive material. When a changing current passes through an inductor, it induces a magnetic field around itself. Transforming the inductor into a coil increases the magnetic field. A similar principal occurs when a conductor is set within a changing magnetic field. The magnetic field induces an electrical current inside the conductor. Examples of inductive loads include transformers, electric motors and coils. Two sets of magnetic fields in an electric motor contradict each other, forcing the motor's shaft to spin. A coil stores energy in the magnetic field when a changing current passes through it and releases the energy when the current is eliminated. Inductance (L) is measured in henries. The changing voltage and current in an inductor are out of phase. As current rises to a maximum point, the voltage falls.

D. Combination Loads:

All conductors have some resistance under typical conditions and also exhibit inductive and capacitive impact, but these small impacts are generally dismissed for practical purposes. Other loads make use of various combinations of inductors, capacitors and resistors to perform particular functions. The tuning circuit of a radio uses variable inductors or capacitors in combination with a resistor to sift through a scope frequencies while allowing just one narrow band to pass through to the whole circuit.

VI. Simulation Results

A. Output Pulses of Pwm Block:

These are the comparison of Sinusoidal wave and carrier wave.

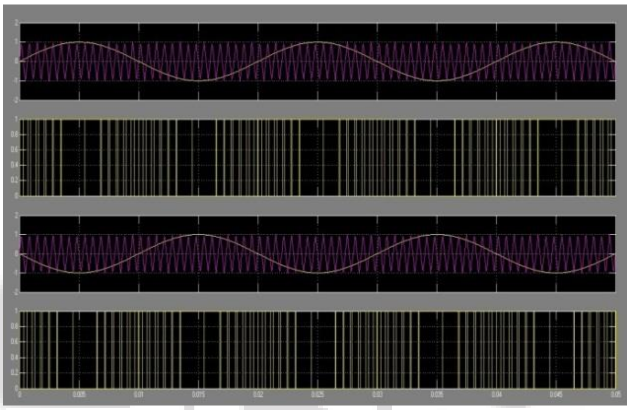

Fig. 4: Principle of control signal generation.

B. Output Waveform Of Inverter Voltage:

The Output waveform of inverter

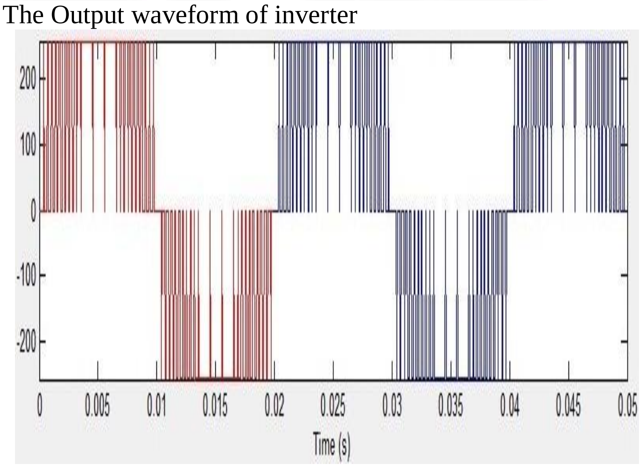

Fig. 5: waveform of Inverter

C. FFT Analysis Of The Output Voltage:

The fundamental frequency (50 Hz) = 256.7 and THD = 6.53%

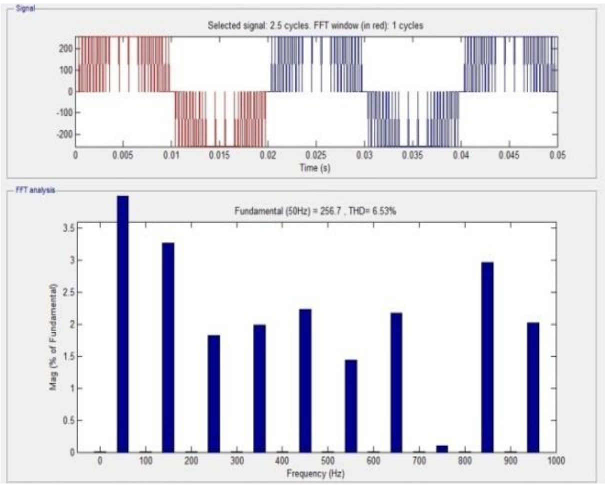

Fig. 6: FFT of output voltage of Inverter

D. Output Current:

This is the output current waveform of single phase Seven level Inverter.

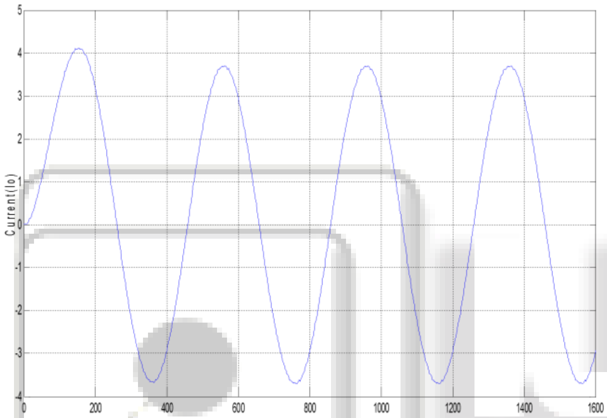

Fig. 7: output current waveform of Inverter

E. FFT Analysis Of Output Current:

The fundamental frequency (50 Hz) = 5.134 and THD = 6.53%

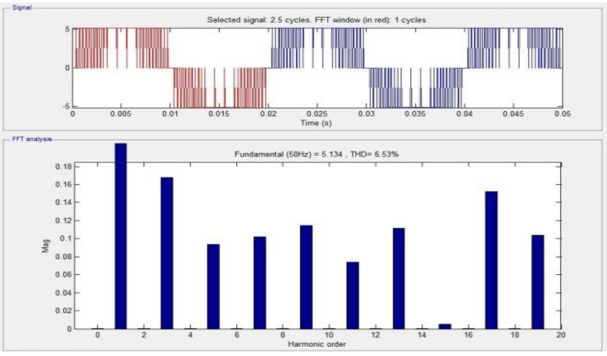

Fig. 8: FFT analysis of output current of Inverter

F. Output Rms Waveform At Different Load Conditions:

1) R LOAD:

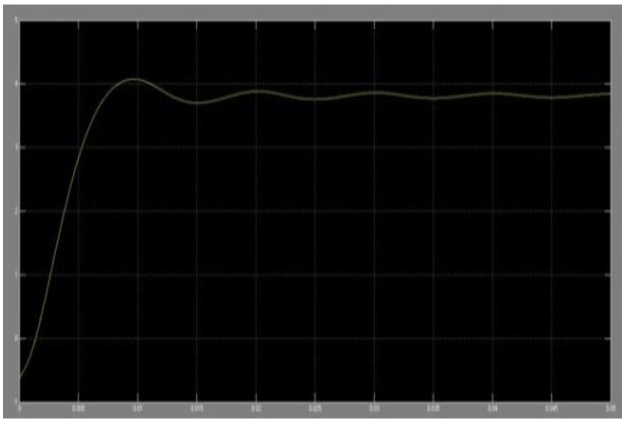

Fig. 9:

2) L LOAD:

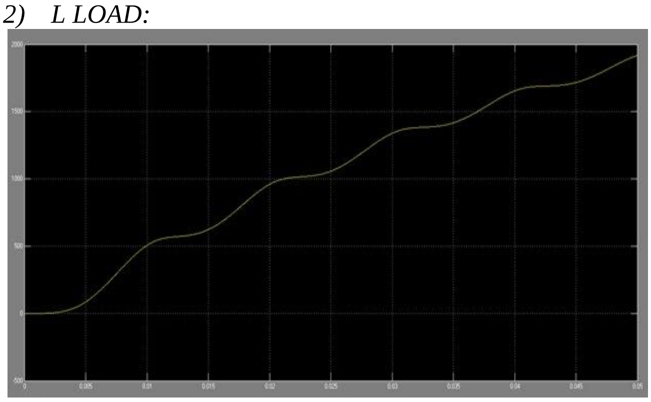

Fig. 10:

3) C LOAD:

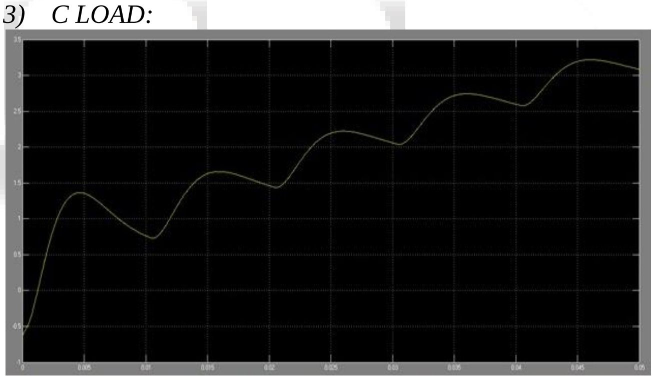

Fig. 11:

4) RL load:

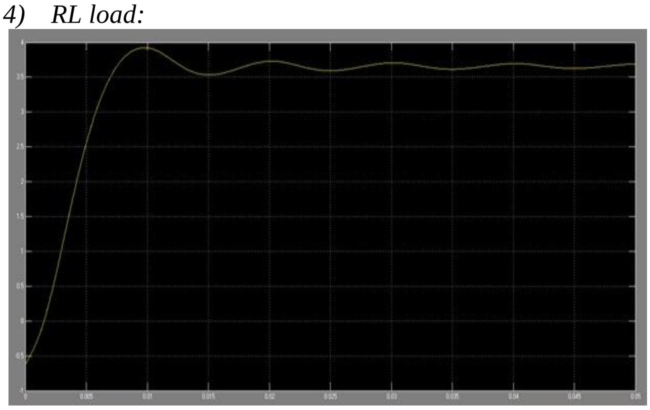

Fig. 12:

5) RC LOAD:

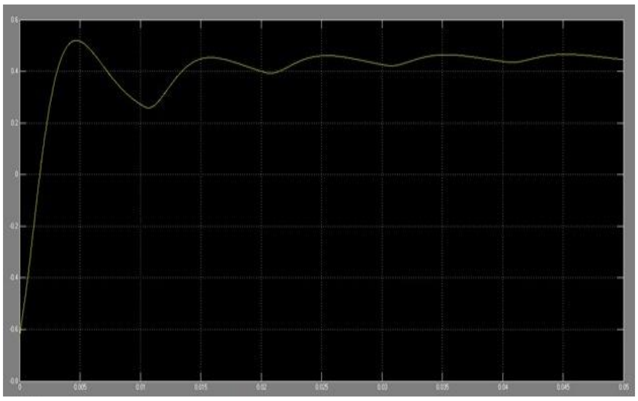

Fig. 13:

6) *LC LOAD:*

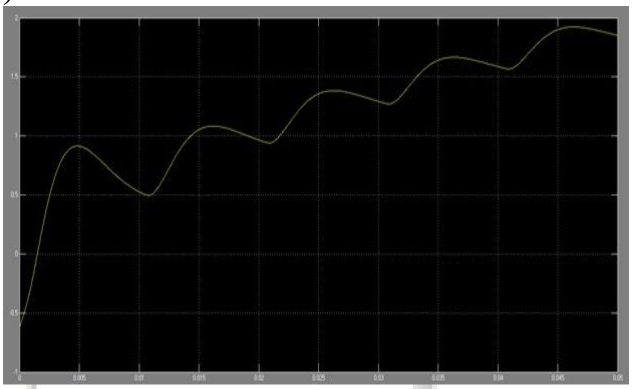

Fig. 14:

7) *RLC LOAD:*

Fig. 15:

8) *OPEN CIRCUIT:*

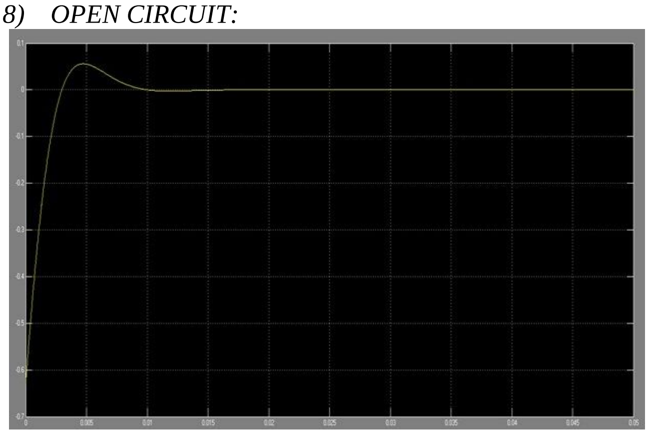

Fig. 16:

VII. CONCLUSION

The performance of the SPV systems depends on material technology and load conditions. The output of our system is changed according to R-L-C load conditions. As per our analysis power and THD varies with different types of loads connected in the system. As a result resistive load is best suited for the SPV module because it gives lower THD and maximum power. Losses in a PV system simulation may be determined by loads, module behaviors etc.

ACKNOWLEDGEMENT

On the accommodation of the paper report of critical review of an inverter for grid connected photo voltaic (SPV) generation system. We amplify our appreciation and genuine on account of my supervisor Asso. Prof. C.S. Sharma for their consistent inspiration and support during the course of our paper. We truly appreciate and value their esteemed guidance and motivation from the beginning to the end of this paper.

REFERENCES

[1] A. Mahdi, W. Tang, and Q. Wu, “Improvement of a mppt algorithm for pv systems and its experimental validation,” in International Conference on Renewable Energies and Power Quality, Granada, Spain, 2010.

[2] Characterization of Power Optimizer Potential to Increase Energy Capture in Photovoltaic Systems Operating Under Nonuniform Conditions”, Sara M. MacAlpine, Robert W. Erickson, Fellow, IEEE, and Michael J. Brandemuehl, IEEE TRANSACTIONS

[3] C.S. Solanki, Solar Photovoltaic, undamentals, Technologies and Applications, 2nd Edition, PHI earning Pvt Ltd, New Delhi, 2011.

[4] "IEC/IEEE/PAS 63547 ed1.0, Interconnecting distributed resources with electric power systems," IEC/IEEE, 2011.

[5] s. Naresh kumar*, s. Nareshsivakanth **, k. Siva kumar, “multi-level inverter for Power quality improvement in renewable power generation system, international Journal of engineering research & technology (ijert) vol.3 issue8, august-2014 ijert Issn: 2278-018.

[6] reddaiah polisetty, nadendla sharief, gopi pasala, “simulation analysis of multi level Inverter for solar power applications “international journal of advanced electrical and Electronics engineering, (ijaeee).

[7] karthika n, sangari a, uma maheswari r “performance analysis of multi level inverter With dc link switches for renewable energy resources” international journal of Innovative technology and exploring engineering (ijitee) issn: 2278-3075, volume-2, Issue-6, may 2013.

[8] ieee transactions on industrial electronics, vol. 53, no. 5, october 2006 Interfacing renewable energy sources to the Utility grid using a three-level inverter Salvador alepuz, member, ieee, sergio busquets-monge, student member, ieee, josep bordonau, member, ieee, Javier gago, david gonzález, member, ieee, and josep balcells, member, ieee

[9] ieee transactions on industrial electronics, vol. 61, no. 1, january 2014 Optimal multiobjective design of hybrid active Power filters considering a distorted environment Ahmed faheem zobaa, senior member, ieee

[10] Ieee transactions on power electronics, vol. 31, no. 4 april 2016 Power and voltage balance control of a novel

Three-phase solid-state transformer using Multilevel cascaded h-bridge inverters for Microgrid applicationsLiang wang, student member, ieee, donglai zhang, member, ieee, yi wang, member, ieee, Bin wu, fellow, ieee, and hussain s. Athab, senior member, ieee

[11] C. Zou et al., “Influence of delay on system stability and delay optimization of grid-connected inverters with LCL filter,” IEEE Trans. Ind. Informat., vol. 10, no. 3, pp. 1775–1784, Aug. 2014.

[12] L. Nousiainen et al., “Photovoltaic generator as an input source for power electronic converters,” IEEE Trans. Power Electron., vol. 28, no. 6,pp. 3028–3038, Jun. 2013.

[13] G. Buticchi et al., “Digital control of actual grid-connected converters for ground leakage current reduction in PV transformerless systems,” IEEE Trans. Ind. Informat., vol. 8, no. 3, pp. 563–572, Aug. 2012.

[14] Y. Errami, M. Maaroufi, and M. Ouassaid, “Variable structure direct torque control and grid connected for solar energy conversion system based on the pmsg,” in Complex Systems (ICCS), 2012 International Conference on, 2012, pp. 1–6

[15] IEEE Recommended Practice for Electric Power Distribution for Industrial Plants, IEEE Std. 141-1993, Apr. 29, 1994.

[16] R. Yan and T. K. Saha, “Voltage variation sensitivity analysis for unbalanced distribution networks due to photovoltaic power fluctuations,” IEEE Trans. Power Syst., vol. 27, no. 2, pp. 1078–1089, May 2012.

[17] S. X. Duarte and N. Kagan, “A power-quality index to assess the impact of voltage harmonic distortions and unbalance to three-phase induction motors,” IEEE Trans. Power Del., vol. 25, no. 3, pp. 1846–1854, Jul. 2010.

[18] A. E. Emanuel, “On the definition of power factor and apparent power in unbalanced polyphase circuits with sinusoidal voltage and currents,” IEEE Trans. Power Del., vol. 8, no. 3, pp. 841–847, Jul. 1993..

[19] NATIONAL INSTITUTE OF SOLAR ENERGY,DELHI.www.nise.res.in