

Performance and Evaluation of 5MW Grid Connected Solar PV Plant at Shivanasamudra

Prakash Madiwal¹, Lakshmikant Reddy.V^{2,3}

1. PG Student , Department of EEE, Acharya Institute of Technology, Bangalore.

2. Research scholar, MEMES.

3. Assistant professor, Department of EEE, Acharya Institute of Technology, Bangalore.
prakash.hnr2@gmail.com

Abstract: The recent upsurge in the demand of PV systems is due to the fact that they produce electric power without hampering the environment by directly converting the solar radiation into electric power. However the solar radiation never remains constant. It keeps on varying throughout the day. The need of the hour is to deliver a constant voltage to the grid irrespective of the variation in temperatures and solar insolation. The designed circuit delivers constant and stepped up dc voltage to the load. The open loop characteristics of the PV array with variation in temperature and irradiation levels are studied. The PV array coupled with the boost converter in such a way that with variation in load, the varying input current and voltage to the converter follows the open circuit characteristic of the PV array closely. At various insolation levels, the load is varied and the corresponding variation in the input voltage and current to the boost converter is noted. It is noted that the changing input voltage and current follows the open circuit characteristics of the PV array closely.

Index Terms — Performance Index, Contingency Severity Index, FACTS devices, TCSC, SVC, GA.

I. INTRODUCTION

The conventional sources of energy are rapidly depleting. Moreover the cost of energy is rising and therefore photovoltaic system is a promising alternative. They are abundant, pollution free, distributed throughout the earth and recyclable. The hindrance factor is it's high installation cost and low conversion efficiency. Therefore aim of the project is to increase the efficiency and power output of the system. It is also required that constant voltage be supplied to the load irrespective of the variation in solar irradiance and temperature. Before going to this entire plant operation has to be done in practically, so

taken the existing 5MW Shivanasamudra solar PV plant as a reference. The plant was installed on July-2013 and this is situated at Shivanasamudra, Mandya district, Karnataka. PV arrays consist of parallel and series combination of PV cells that are used to generate electrical power depending upon the atmospheric conditions (e.g. solar irradiation and temperature). So it is necessary to couple the PV array with a boost converter. Moreover the system is designed in such a way that with variation in load, the change in input voltage and power fed into the converter follows the open circuit characteristics of the PV array. The system can be used to supply constant stepped up voltage to dc loads. The major problems faced in Existing installed plant is:

- Switching loss of boost converter is more and due to this Efficiency of plant will be less.
- Using normal three phase inverter the THD of the plant will be more.

These constraints affect the Efficiency of power delivered. However, these constraints can be suppressed by enhancing the switching device and multi-level inverter. Types of the methods have taken to improve the efficiency of the plant such as, (i) Using a ZCS buck converter, (ii) Using a ZCS buck-boost converter, (iii) Using a ZCS buck converter, (iv) Using a ZCS boost converter & Replace the multilevel inverter with normal inverter. The last method is considered in this study.

The zero-current switching is to switch the converter under zero-current conditions. Although in ideal case, it can achieve zero-switching loss. In fact, the switching device usually has a junction capacitor. When the device is under off-state, the device behaves as a capacitor and it will be charged with the off-state voltage. The energy will then dissipated internally when the device is turned on. The loss appears in every switching cycle. Therefore, its loss increases as the switching frequency increases and the operational voltage increases. A simple calculation can illustrate

the significance of this loss. For example, a switching device is operating under device voltage V_{sw} 300V DC and the switching frequency is 1MHz. The junction capacitance C_j is 500pF. The loss is then:
 $Loss_{sw} = 1/2 C_{sw} V_{sw}^2 f_s = 1/2 * 0.611 * 10^9 * 300^2 * 100 * 10^3 = 27W$ These switching loss can be avoid using ZCS boost converter where switching loss of ZCS boost converter is nearly Zero. That can be clearly shown in below simulation result. A 500pF junction capacitance represents a small power device. Therefore it can be seen that the efficiency of the converter will be very poor. An alternative method to cure this problem is to use zero-voltage switching. Zero-voltage switching operates in a way very similar to the zero-current switching. In fact, they operate in a dual manner and will be illustrated in this work.

II. PROBLEM FORMULATION

1. CURRENT RIPPLE FACTOR (CRF):

According to IEC harmonics standard, CRP should be bounded within 30%.

i.e. $\Delta I_1 / I_1 = 30\%$

2. VOLTAGE RIPPLE FACTOR (VRF):

i.e. $\Delta V_o / V_o = 5\%$

3. SWITCHING FREQUENCY (f_s):

$f_s = 100$ KHz

GIVEN DATA:

□ Input voltage, $V_g = 25V$

□ Output voltage, $V_o = 300V$

□ Output load current, $I_o = 1A$

Step 1 : Calculation of Duty cycle (D):

$V_o / V_g = 1 / (1 - D)$

□ $1 / (1 - D) = 300 / 25$

□ $D = 11 / 12 = 0.9166$

Step 2: Calculation of Ripple Current (ΔI_L):

$I_L = 1$ A

$\Delta I_L = (0.3 * 1)A = 0.3$ A

Step 3: Calculation of Inductor value (L):

$L = (V_g \cdot D / f \cdot \Delta I_L) = (25 * 0.9166) / (0.3 * 10^5) = 7.63 * 10^{-4}$ H.

Step 4: Calculation of capacitor value (C):

We have, $\Delta V_o / V_o = D T_s / R_o C$

$R_o = V_o / I_o = 300 / 1 = 300\Omega$.

$C = D / f * R_o * (V_o / V) = (0.9166) / (10^5) * (300) * (0.05) = .611 \mu F$

The transfer function of the boost converter used for the modeling is given by:

By trial and error, we get the value of K_p which gives desired results as 6.03.

III. General Scheme of The Plant

The general scheme of the Solar Power System shall be of 5 megawatt peak capacity. Approximately 25 acres will be available for a 5 megawatt installation. The whole installation shall have a minimum of 25 years design lifetime. The solar power system shall be offered in equal sub arrays and the system comprises the following major equipment's:

- Solar Grid connected inverters of 250kW capacity of each.
- Power evacuation through 66KV line that will be within approximately 500 meters of the site.
- A SCADA/ data logging system to enable monitoring of the system locally and remotely to be provided.
- The solar modules will be installed on suitable frames with all interconnection and cabling. The DC bus voltage will be in the range of 450 to 750 Volts maximum.
- In the plant 20 grid connecting inverter is present. These will be indoor type.
- The plant shall feed power to the line identified by KPCL.
- The inverter shall automatically turn on and off successively as the available solar irradiation varies over the day. The inverter is having all the necessary synchronization equipment installed as necessary. The voltage range will be -20% to +15%. Capability to do voltage correction will be an advantage.
- SPV modules are having minimum declared output of 200 watt peak capacity per module under standard test condition.
- Each solar PV module warranted by the manufacture for at least 95% of its rated power for 10 years and 85% of its rated power for 25 years from the date of system acceptance. Modules have confirmed to IEC standards IEC 61215, IEC 61646, IEC 61730 or IEEE 1262 or equivalent.
- Modules shall have 1000 volts DC rating

BLOCK DIAGRAM :

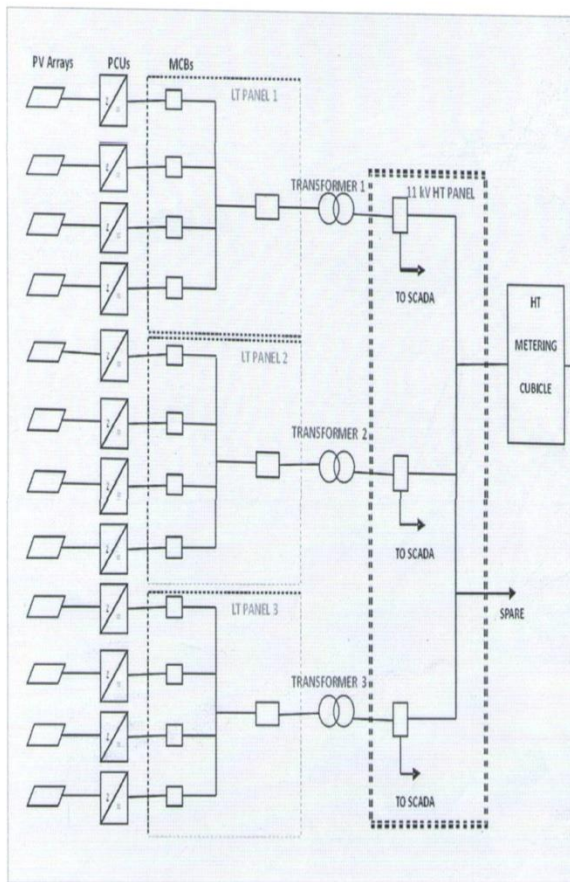


Fig.1 Block Diagram Of PV Plant

A photovoltaic system is a system which uses one or more solar panels to convert solar energy into electricity. It consists of multiple components, including the photovoltaic modules, mechanical and electrical connections and mountings and means of regulating and/or modifying the electrical output.

Technical Details of PV module at Shivanasamudra:

Si no	DESCRIPTION	
1.	Type of SPV module	Mono Crystalline
2	PV module power output	Min 240 watts

3	Total no. of module used	22560 NOs
4	No. of Module per MW	4512 NOs
5	Array rating	250KW
6	Details of series/parallel combination	24 NOs in series 940 parallel string
7	Tilt angle	15°
8	Temperature	Min 15° C Max 40° C

Table.1 Technical Details of PV Module

IV. OBJECTIVE OF THE PROJECT

I have visited the entire plant of Shivanasamudra and then understand the how 5MW Energy will be generated in the plant

The objective of my work is:

- To estimate the 5MW grid connected solar PV plant at Shivanasamudra.
- To rectify the losses, causes for the losses and suggest some methods which can reduce the losses and overall efficiency of the plant.
- Annual energy generation by proposed grid connected SP power plant is also calculated.

Here in this work the normal boost converter and ZVS boost converter are presented and compared using MATLAB software.

V. METHODOLOGY USED

5MW Grid Connected Solar PV Plant at Shivanasamudra is the largest solar plant in Karnataka. PV module is connected with boost converter to get the constant output voltage to the inverter output. But in the Boost converter main disadvantage is the switching losses, and these switching losses will be directly affected to the overall efficiency of the plant. To avoid this switching loss we can replace the boost converter

with ZVS boost converter. Here in this work the normal boost converter and ZVS boost converter are presented and compared using MATLAB software.

VI. DC-DC CONVERTER

DC-DC converters can be used as switching mode regulators to convert an unregulated dc voltage to a regulated dc output voltage. The regulation is normally achieved by PWM at a fixed frequency and the switching device is generally BJT, MOSFET or IGBT. The minimum oscillator frequency should be about 100 times longer than the transistor switching time to maximize efficiency. This limitation is due to the switching loss in the transistor. The transistor switching loss increases with the switching frequency and thereby, the efficiency decreases. The core loss of the inductors limits the high frequency operation. Control voltage V_c is obtained by comparing the output voltage with its desired value. Then the output voltage can be compared with its desired value to obtain the control voltage V_{cr} . The PWM control signal for the dc converter is generated by comparing V_{cr} with a saw tooth voltage V_r . There are four topologies for the switching regulators: buck converter, boost converter, buck-boost converter, cúk converter. However existing project work deals with the boost regulator and further discussions will be concentrated towards this one.

1. BOOST CONVERTER AND ITS OPERATION.

The Fig. (2) Below shows a step up or PWM boost converter. It consists of a dc input voltage source V_g , boost inductor L , controlled switch S , diode D , filter capacitor C , and the load resistance R . When the switch S is in the on state, the current in the boost inductor increases linearly and the diode D is off at that time. When the switch S is turned off, the energy stored in the inductor is released through the diode to the output RC circuit.

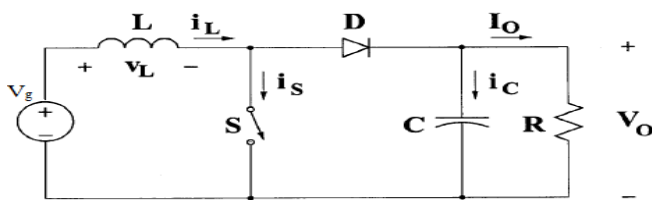


Fig. 2 Circuit diagram of boost converter

2. INTERFACING OF THE PV ARRAY WITH BOOST CONVERTER

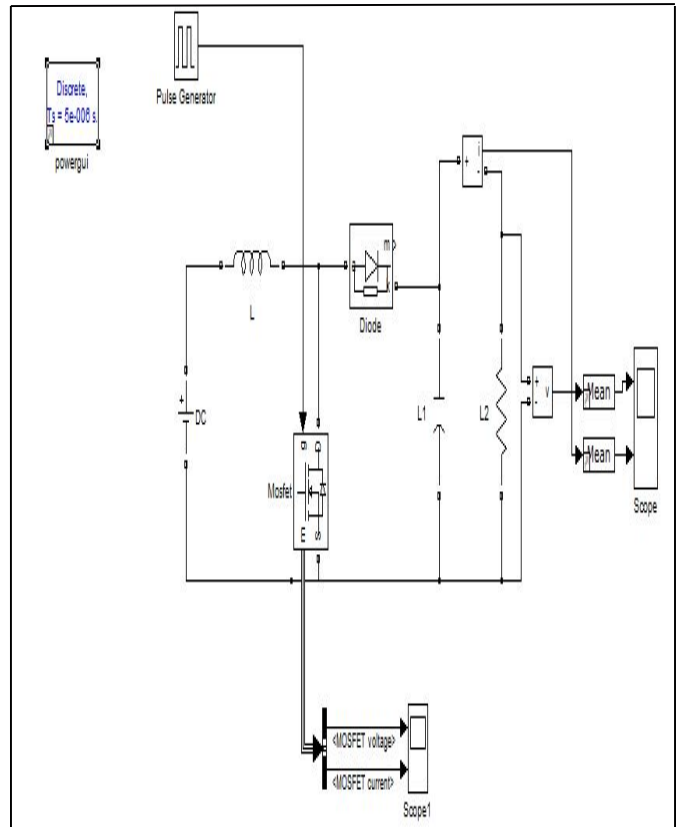


Fig.3.Normal Boost Converter Simulink Circuit Model

VII.SIMULATION RESULTS

The output I_{out} and V_{out} curves obtained across the load resistance of the boost converter of the Simulink model as shown in below Fig.(4) &(5) is drawn below.

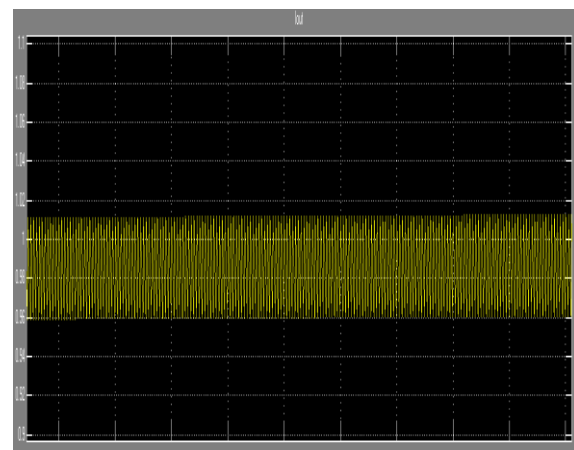


Fig.4. The current output of the system

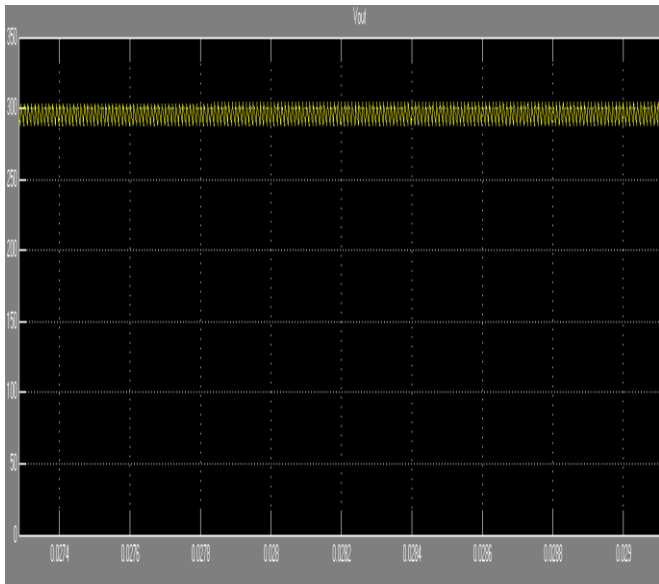


Fig.5. The current output of the system

Switching loss of the network using boost converter is calculated using the formula

$$Loss_{sw} = 1/2 C_{sw} V_{sw}^2 f_s = 1/2 * 0.611 * 10^9 * 300^2 * 100 * 10^3 = 27W$$

Switching loss of the network using ZCS boost converter is calculated using the formula

$$Loss_{sw} = 1/2 C_{sw} V_{sw}^2 f_s = 1/2 * 0.611 * 10^{12} * 300^2 * 1000 * 10^3 = 0.027 W$$

Where to get switching loss is zero we can implement the normal boost converter with ZVS- converter.

VIII. CONCLUSION AND FUTURE SCOPE

1. CONCLUSION

The open circuit P-V, P-I, I-V curves we obtained from the simulation of the PV array designed in MATLAB environment explains in detail its dependence on the irradiation levels and temperatures. The entire energy conversion system has been designed in MATLAB-SIMULINK environment. The various values of the voltage and current obtained have been plotted in the open circuit I-V curves of the PV array at insolation levels of 100 mW/cm² and 80 mW/cm². The voltage and current values lie on the curve

showing that the coupling of the PV array with the boost converter is proper. However the performance of the photovoltaic device depends on the spectral distribution of the solar radiation. ZVS boost converter provides good zero voltage switching conditions for both the transistors and diode. A ZVS circuit realized and its waveforms were observed. Parasitic capacitances of the transistors and the diode parasitic inductances of connections are all parts of the resonant circuit. Switching of the transistor and the rectifying diode at zero voltage in the converter enables high operating frequency of the system while high energy efficiency is maintained. The range of the converter's operating frequency in which ZVS is assured is variable and dependent on load resistance. ZVS Boost converter generates dc voltage which can be applied in power supply systems where high energy efficiency is required.

2. FUTURE SCOPE

This project can be improved as current-fed zero-voltage switching isolated boost converter suitable for fuel cell applications. Preserving the inherent advantages of the current-fed converter which include smaller input current ripple, lower diode voltage rating, and lower transformer turns ratio, the proposed converter does not require any clamping and start-up circuits unlike the conventional current-fed converters. The voltage ratings of the primary switches and secondary diodes of the proposed converter are significantly reduced. Some alternative schemes of the proposed converter without the voltage-second unbalance are presented. These characteristics of the proposed converter lead to a high overall efficiency over wider load range.

IX. REFERENCES

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