# A PV Based Grid Connected Single Phase Inverter With Step Up Boost Converter

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***Abstract*— Nowadays, due to the depletion of fossil fuels & conventional energy sources, inverters connected to grid, powered by renewable energy sources such as PV are gaining popularity. A boost converter is used to step up the PV output before connecting it to grid, because of its low cost, high efficiency & simplicity in implementation. A single phase PWM inverter with fast switching is proposed. An L-C filter is used to reduce the total harmonic distortion and grid connection. The boost converter performance is compared with a flyback converter. All goals, design procedures, tests, data, and conclusions have been documented. A straightforward modelling of PV powered single phase inverter is described . The simulation was done in MATLAB SIMULINK and the results are presented.**

***Keywords*— *PV Array, Boost Converter, Single Phase Inverter , LC Filter , Step Up Transformer ,Flyback converter.***

## I. INTRODUCTION

As the world's power demand is increasing and availability of power from the conventional sources is decreasing, more focus is to be given to renewable sources. The power from the PV is more attracted due to its clean mode of generation, no rotating mechanisms & less losses etc. But compared to traditional energy sources, not many PV systems have been incorporated in grid connection because of its high installation cost [1].Now a downward tendency on the cost of PV modules is a motivation for the massive production of PV based single phase or three phase grid connected inverter . Focus has therefore been given to inverter solutions with cheap & innovative techniques [1].

This paper presents a single phase PV powered grid connected inverter with boost converter as dc-dc converter. Usually a single PV cell generates very low power. So such cells arranged in series to produce maximum power output [2]. Dc-dc converters are used to reduce the no. of cells, which will generally boost up's the output from the PV array and hence the no of PV cells required at beginning can be reduced, thus initial cost can be saved.

The topology of the solar system is simple. It consist of following three stages

1) A boost converter stage to perform boosting of PV array voltage.
2) A low voltage single phase H-Bridge Inverter.
3) An L-C Filter arrangement and step up transformer to interface with the grid.

The advantages of this system are low voltage rated switches which reduces the overall cost and increases reliability. The best suitability for this type of inverters is coming for rating less than a kilowatt. But topologies with high frequency link transformers are much better than these types with bulky interface transformers [3].

Some applications other than dc lighting loads & dc motors requires converters to process the PV generated power [4]. Also the voltage and current may regulated by these converters. However a dc-dc boost converter is necessary to produce a regulated dc output voltage. A voltage source inverter, interfacing the PV module can provide an ac output voltage. Conventional PWM technique is used in inverters to produce pulses, due to its simple and easy control mechanism. But power quality issues generates at the inverter side due to the generation of harmonics which originates from high dv/dt and di/dt semiconductor switching transients [5]. Passive filters are used to remove harmonics, even though it exhibits drawbacks such as tuning problems, series and parallel resonance etc.

## II.DESIGN OF PV SYSTEM

*A. Equivalent Circuit of PV Cell*

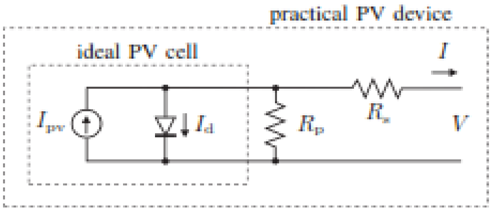



Fig. 1.Single-diode model of the theoretical PV device

## *B. Modelling of PV Array*

Fig 1: shows the equivalent circuit of the ideal photovoltaic cell. The basic equation which describes the I-V characteristics of ideal PV cell is given as

$$I = I_{PV,cell} - I_d \quad (1)$$

That is

$$I = I_{PV,cell} - I_{O,cell}\left[\exp\left(\frac{qV}{akT}\right) - 1\right]$$

Where

$$I_d = I_{O,cell}\left[\exp\left(\frac{qV}{akT}\right) - 1\right]$$

Where

$I_{PV,cell}$ = Current generated by incident light

$I_d$ = Shockley diode current in A,

$I_{O,cell}$ = Reverse saturation current of diode in A,
$q$ = electron charge [$1.602\times 10^{-19} C$],

$k$ = Boltzmann constant [$1.308\times 10^{-23} J/K$],

T[K] = temp.of p-n junction

But practically (1) requires an inclusion of additional parameters as follows:

$$I = I_{PV} - I_O\left[\exp\left(\frac{V+R_sI}{V_ta}\right) - 1\right] - \frac{V+R_sI}{R_P} \quad (2)$$

Where

$R_s = series\ resistance\ of\ PV\ device$

$R_P$ = shunt resistance of PV device

&

$$V_t = \frac{N_s kT}{q}$$

Where

$N_s = no.of\ PV\ cells\ in\ series.$

All PV array data sheets brings the basic information about the PV cell such as :

1) The nominal open circuit voltage ,$V_{OC,n}$
2) Nominal short circuit current , $I_{sc,n}$
3) Voltage & current at maximum power point , $V_{mp}$ , $I_{mp}$
4) Maximum peak output voltage, $P_{max}$ .

The practical PV device has a series resistance $R_s$ which influence more when the device operates in voltage source region, and a parallel resistance $R_P$ influence more when the device works in current source region of operation. The value of $R_P$ is very high and some authors will neglect this resistance for simplification [4]. This system is designed for a maximum load of 150W. Fig 2 shows PV array o/p voltage.

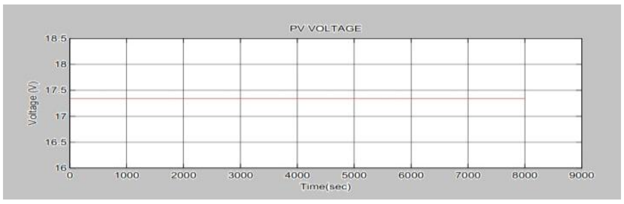



Fig 2: Output Voltage from PV array

From the figure it is clear that a voltage of 17.2 V is obtained from PV device.

## III.BOOST CONVERTER

*A. Modelling Of Boost Converter*

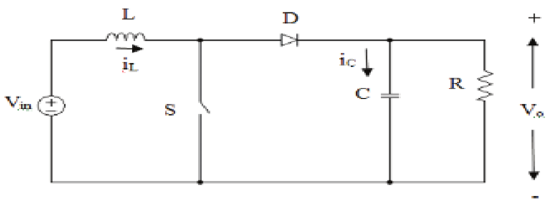



Fig 3: Typical Boost Converter

Fig .3 shows the circuit showing the components of DC-DC converter. It consists of DC input Vin, an inductor L, a controlled switch S, a diode D, a filter capacitor C, and the load resistance R. The equations for the modelling of boost converter is given as :

$$\frac{V_o}{V_{in}} = \frac{1}{1-d} \quad (3)$$

Where

$d$= duty cycle of converter switch,

$V_o$ & $V_{in}$ are the input and output voltage from the converter. The selection of inductor value is based on the continuous flow of current through the inductor. Generally 5% of the output current $I_o$ is assumed as current ripple ($\Delta I$) and 3% of output voltage $V_o$ is assumed as the voltage ripple ($\Delta V$) [5]
The inductor (L) & capacitor (C) values obtained from equations (4) & (5):

$$L = \frac{1}{8} \times \frac{V_{in} d}{\Delta I f_s} \quad (4)$$

$$C = \frac{I_0 d}{\Delta V f_s} \quad (5)$$

Where $f_s$ = device switching frequency.

It is observed that with a PV input of 17.2 V, an output of 40V is obtained. The parameters for the PV array & boost converter is shown in table I. Fig 4 shows the output of converter.

TABLE I
PV Device & Boost Parameters

| Parameter | Value |
|---|---|
| Output from PV source | 17.34V |
| Boost converter output | 40V |
| Device switching frequency | 40kHz |
| Inductor (L) value of converter | 0.38mH |
| Capacitor (C) value of converter | 44.8$\mu$F |

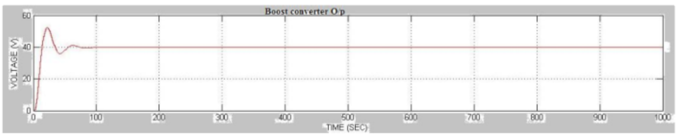


Fig 4: Output Voltage of DC-DC BOOST converter

## IV SINGLE PHASE INVERTER

The single phase inverter is used to generate a single phase AC supply from a DC input through a set of controllable switches. The switches are controlled by Pulse width modulation technique. Fast switching of semiconductor switches with high frequency noise generation is achieved with PWM inverter.

### *A. Modelling*

Switching frequency for the switches is same as in the case of converter side. All the designs are made such that maximum power rating = 150W.Fig 5. shows a typical single phase H-Bridge inverter and Fig 6 shows the output from the inverter section without filter .

Here $V_{rms} = \frac{V_O}{\sqrt{2}}$ (6)

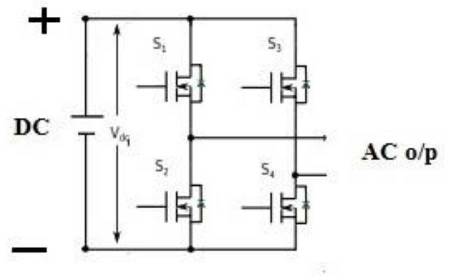


Fig 5: A single phase H-bridge inverter

### *B .Simulation Result*

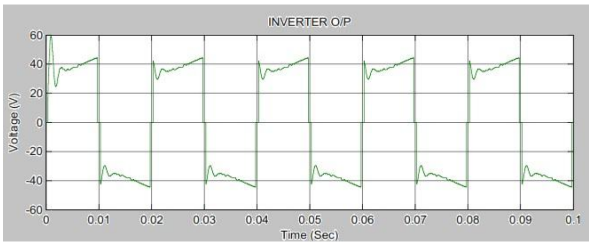



Fig 6: Inverter O/P voltage without filter arrangement

### *C. THD Analysis On Inverter Side Without Filter*

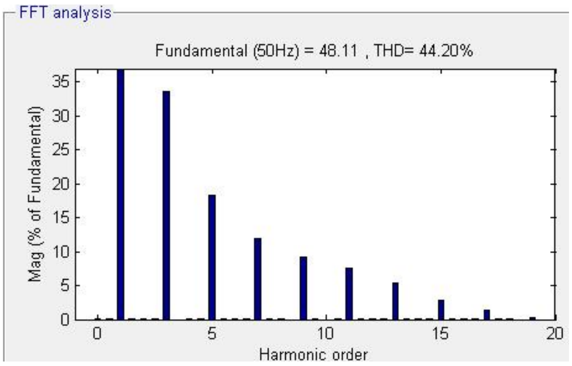



Fig 7: THD Analysis on inverter side without filter

THD analysis at the inverter side reveals that the power electronic switching devices are good sources of harmonics. So proper compensation must be provided at the inverter output side. The following section way of compensation.

## V. L-C FILTER

The output harmonic from the inverter side can be reduced with the help of passive L-C filters. LC circuits are used either for generating signals at a particular frequency, or picking out a signal at a particular frequency from a more complex signal. A passive LC filter contains an inductor connected in parallel with a capacitor.

*A. Design of L-C Filter*

The equation for the inductor (L) value can be chosen from the following equation (7)

$$L = \frac{1}{8} \times \frac{V_{in}}{\Delta_{ripple}\ f_{sw}} \qquad (7)$$

Where
$V_{in}$ = rms input voltage to the filter.
$f_{sw}$ = switching frequency of the inverter switches.
$\Delta_{ripple}$ = assumed as 5% of the rated current.
Capacitor(C) in the L-C Filter provides a low resistance path to ground to attenuate harmonics. The value of C should be such that it should provide good power factor at fundamental frequency and also its value is chosen to be less to reduce damages in switching devices. The equation for capacitor(C) is given as (8)

$$C = \frac{\alpha P}{2\pi f V^2} \qquad (8)$$

Where $\alpha$ = Reactive power factor & range should selected below 5%

$P$ = Rated power of the system.
$f = fundamental\ frequency$ 50Hz.
$V$ = Rms voltage .
Usually the resonant frequency of L-C filter are chosen below the value of switching frequency of switches [5] and is given by (9)

$$f_r = \frac{1}{2\pi\sqrt{LC}} \qquad (9)$$

High frequency harmonics are better attenuated at a lower resonant frequency.
Fig. 8 shows the inverter ouput voltage with L-C filter,by using an L-C filter the oupt voltage distortion is minimised.

*B. Output voltage of Inverter with L-C filter*

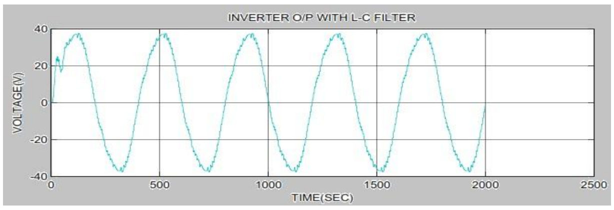



Fig 8: Output voltage of inverter with LC filter

VI. STEP UP TRANSFORMER

Step up transformers are used to step up the voltage to the required level. The winding parameters are adjusted to get required values of output. Here a single phase sine wave is generated.

The basic equations chosen are

$$\frac{V_1}{V_2} = \frac{I_2}{I_1} = K \qquad (10)$$

Also $\qquad V_1 = V_m/\sqrt{2}$

VII. SIMULATION RESULTS

*A. Output from Transformer side after Step Up*

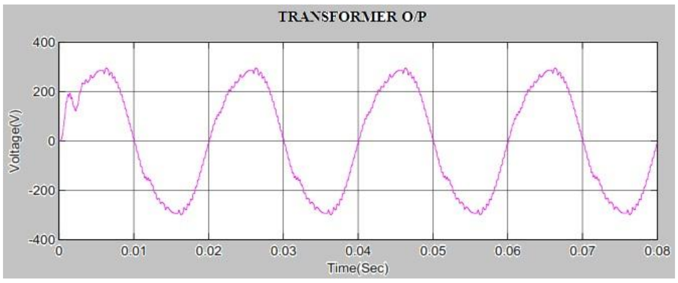



Fig 9: Output Voltage from grid interfacing step up transformer

Fig .9 shows the output from the step up transformer, in which the transformer steeped up the rms L-C filter output voltage to rms rated voltage of the grid.

*B. THD Analysis with the grid Interfacing transformer*

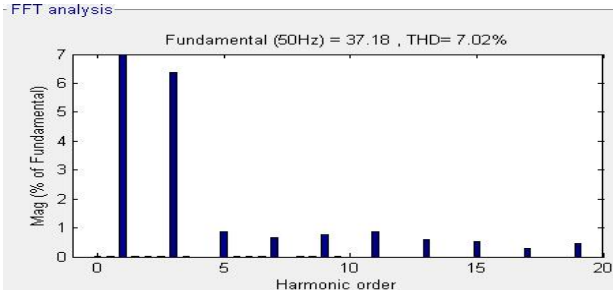
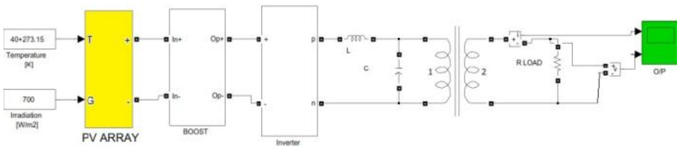



Fig 10: THD with interfacing transformer

Fig .10 shows the final harmonic spectrum with L-C Filter and interfacing transformer. It is clear that the design of L-C filter reduces the THD and this output can be connected to grid as an incoming supply.

*C. Simulink Model*




*D. Comparison of THD Analysis With & Without L-C Filter*

## VIII COMPARISON

*A. Comparison of boost with flyback converter*

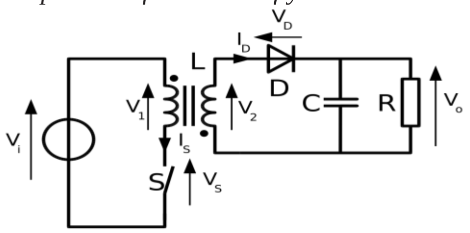



Fig11: Typical Flyback Converter

The flyback converter is placed instead of boost converter for comparison. The advantages of flyback converter over boost are:

1. Ease of design.
2. Simplicity.
3. Isolation between input & output side etc.

*B. Design Parameters*

| Parameter | Value |
|---|---|
| Primary Inducatance ($L_p$) | 1.3μH |
| Switching frequency ($f_s$) | 40kHz |

*C. THD On Inverter side Without L-C Filter*

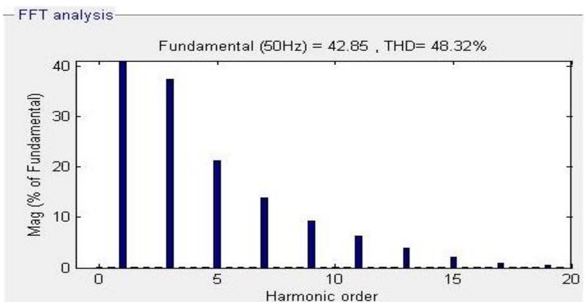



Fig 12: THD without L-C filter

*D. THD On Transformer Side With L-C filter*

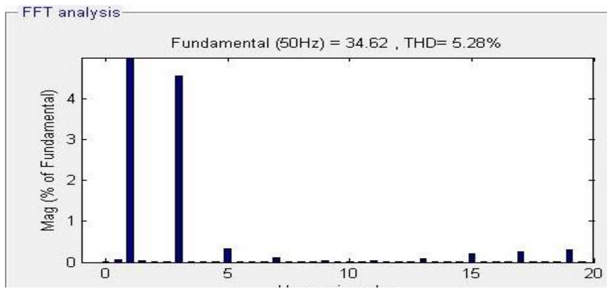



Fig. 13: THD Of flyback with L-C filter

TABLE II
Evaluation of THD With& Without L-C filter

| *THD ANALYSIS* | *BOOST CONVERTER* | *FLYBACK CONVERTER* |
|---|---|---|
| *WITHOUT L-C FILTER* | *44.20%* | *7.02%* |
| *WITH L-C FILTER* | *48.32%* | *5.28%* |

## VIII CONCLUSION

A single phase inverter supplied by solar energy is proposed. A simple boost converter is proposed as the dc-dc converter, since it provide an efficient output . An L-C filter is proposed to reduce the harmonics at the inverter side. The choice of flyback dc-dc converter provides an output with less power quality issues than boost converter since it provides isolation between input and output side. It is clear from the THD analysis that the harmonics of any order can be reduced to 5% by the use of flyback converter & L-C filter, which is acceptable by IEEE-519 standards.

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