ISSN 2349-0292
Impact Factor (PIF): 2.365

GLOBAL JOURNAL OF ADVANCED ENGINEERING TECHNOLOGIES AND SCIENCES

DESIGN AND SIMULATION OF GRID CONNECTED PV FED SINGLE PHASE INVERTER WITH CLOSED LOOP BOOST CONVERTER

Ch Nayak Bhukya[*1] & Bereket Azmeraw[2]
[*1&2]Department of Electrical and Computer Engineering, Assosa University,Assoa, Ethiopia

ABSTRACT
Solar energy is considered as fastest growingrenewable energy source after wind energy for electricity generation. Solar energy is a free, clean abundant sun energy considered as inexhaustible source for electricity generation. Solar photovoltaic system is characterised with variable output power due to its operation dependency on solar irradiance and cell temperature. To maximize the energy generation potential of solar PV, research effort is focused on solar cell manufacturing technology to increase its generation efficiency and exploring advancement in power electronic devices for small and large scale deployment. Presented in this paper is a single phase inverter with no transformer for solar PV application. A closed loop DC-DC boost converter that accepts wide input DC voltage from 40 V – 60 V to produce constant 330 V DC voltage is modelled in Matlab/Simulink. An H-bridge 2-level inverter was used to convert the DC voltage to chopped AC voltage which was then filtered to give pure sinusoidal AC of 230 V RMS. The output voltage of the inverter has a very low total harmonic distortion of less than 1 % which makes the system suitable for local AC load and grid connection.

KEYWORDS: DC-DC converter; Inverter; Unipolar PWM; Photovoltaic system.

1. INTRODUCTION
In order to meet the rising global energy demand from sustainable environmental friendly sources, various renewable energy are now given adequate attention. Renewable energy comes from energy sources that naturally regenerate over a short period of time. Some are derived from the sun like thermal and photoelectric and other from natural movements of the environment like the wind, rain fall, and geothermal energy [1]. In the nearest feature, solar and wind energy are expected to contribute more than 30 % of renewable energy within the power industries [2]. Solar energy is presently considered as fastest growing renewable energy source after wind energy for electricity generation [2]. In a span of five years, the world solar PV electricity generation increased from below 10 GW in 2007 to over 100 GW operating capacity in year 2012 [3]. Research efforts towards maximising solar energy advantage are now focused on how to increase efficiency of solar cells via manufacturing technologies and to explore the advancement in power electronic devices to be able to adapt the solar PV generation for small and large scale power system application.

The link between solar energy generator and the loads is an efficient power converter that delivers the generated energy. Power converters are used to improve the power quality of solar photovoltaic system because of associated intermittency and continuous variation. The generated power from solar PV are DC component and mostly at different level from the load demand, so there is a need for voltage regulation and conversion to AC component for AC loads application.

Presented in this paper is a design and simulation of single phase inverter with wide input voltage range which is suitable for variable solar photovoltaic source. Supply voltage from the solar panel is first regulated and boosted to high DC voltage which is then subsequently converted to AC voltage for AC load supply. After filtering, the output voltage of the inverter shows that the system is suitable for local AC load and grid connection has a very low total harmonic distortion of less than 1 %.

2. SINGLE PHASE SOLAR PV SYSTEM
The block diagram of Fig. 1 shows the configuration of the single phase inverter comprising of a DC-DC boost converter and H bridge inverter. The supply voltage from the solar PV panel is subjected to variability due to the effect of environmental parameters such as temperature and solar irradiance that affects it output power. The DC-DC converter is used to regulate the supply voltage from the solar PV. The regulated voltage is then boosted to 330 V DC voltage in order to eliminate the need for transformer in the system. An H-bridge inverter was used to convert the DC voltage to chopped AC the 330 V peak voltage which gives a 230 V RMS voltage after filtering. The chopped AC voltage containing both carrier and modulating frequency was filtered using passive LC low pass filter allowing only voltage at fundamental frequency of 50 Hz at the output.

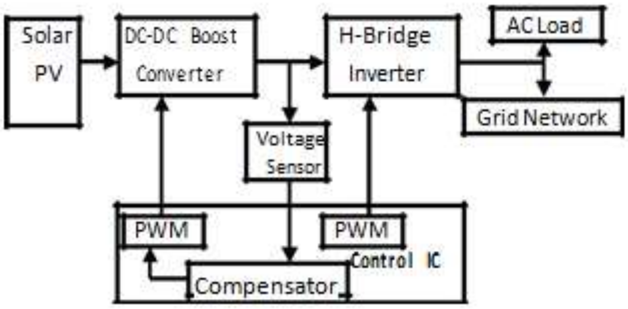

Fig. 1. Solar PV system

3. DC-DC CONVERTER DESIGN AND SIMULATION

The steady state parameters of the DC-DC boost converter were calculated using Eq. (1) to Eq. (3) [4, 5]:

The steady state input to output conversion ratio of boost converter is

$$V_{out} = \frac{V_{in}}{1-D} \qquad (1)$$

The magnitude of peak-to-peak inductor current ripple ΔI_L is given by

$$\Delta I_L = \frac{V_{in} D}{f_s L} \qquad (2)$$

The output capacitor voltage can be determined based on the desired output voltage ripple ΔV_C .

$$C_{out(min)} = \frac{I_{out(max)} D}{f_s \Delta V_{out}} \qquad (3)$$

Table I. steady state design parameter

Parameters	Symbol	Values
Rated power	P_o	1000 W
Input voltage range	V_{in}	40~60 V
Nominal voltage	V_n	48 V
Output voltage	V_{out}	330 V
Average output current	I_0	3.125 A
Inductor current ripple	ΔI_o	0.625 A
Output ripple voltage	ΔV_o	2 V
Duty cycle	D	0.855
Switching frequency	f_s	100 kHz
Inductor	L	0.656 mH
Output capacitor	C	22 µF
Load resistance	R_L	112 Ω

A. Open loop simulation of DC-DC Converter

Based on the DC-DC boost converter design parameters presented in Table I, open loop simulation was carried out in Matlab/Simulink environment as shown in Fig. 2. The supply input voltage is varied from 40 V to 60 V with steps of 40 V, 48 V, 60 V and the open loop output voltage and current are presented in Fig. 3

ISSN 2349-0292
Impact Factor (PIF): 2.365

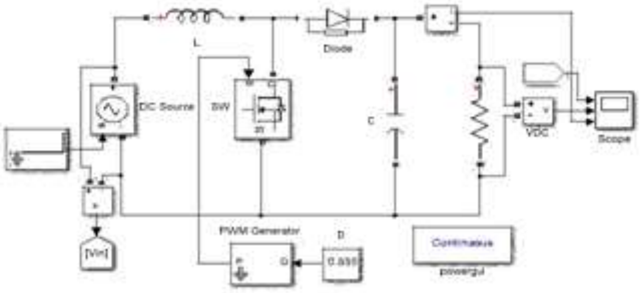

Fig. 2. Open loop DC-DC converter

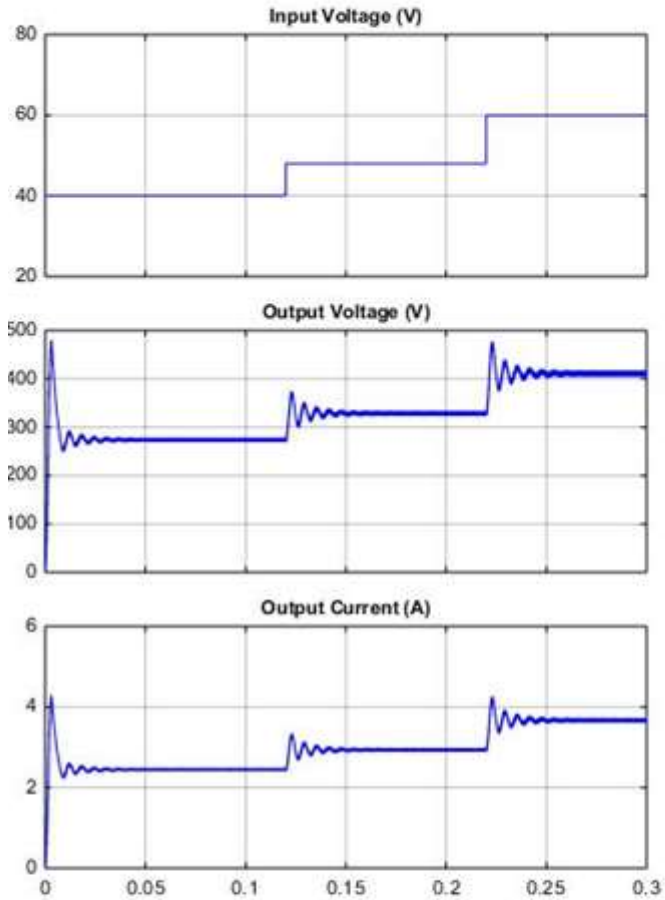

Fig. 3. DC-DC converter open loop input and output voltage

B. Closed loop simulation of DC-DC Converter

A PID auto tuning function in Matlab was used to design a PID controller for regulating the variable supply voltage from the solar PV panel [6]. With variable supply voltage of 40 V, 4 8V, 60 V, from Fig. 4, the closed loop simulation shows that the boost converter output voltage is maintained at 330 V DC voltage as presented in Fig. 5.

ISSN 2349-0292
Impact Factor (PIF): 2.365

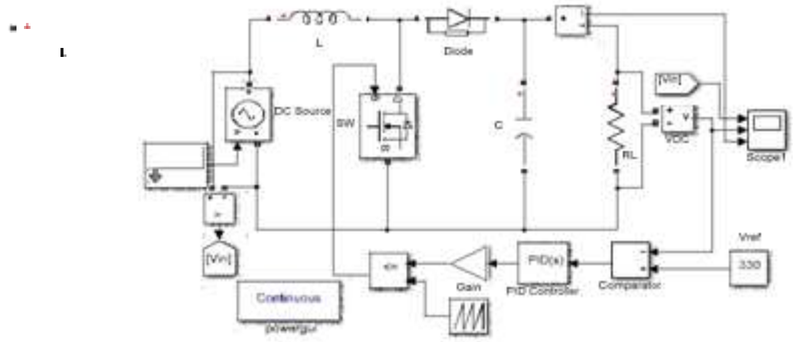

Fig. 4. Closed loop DC-DC converter

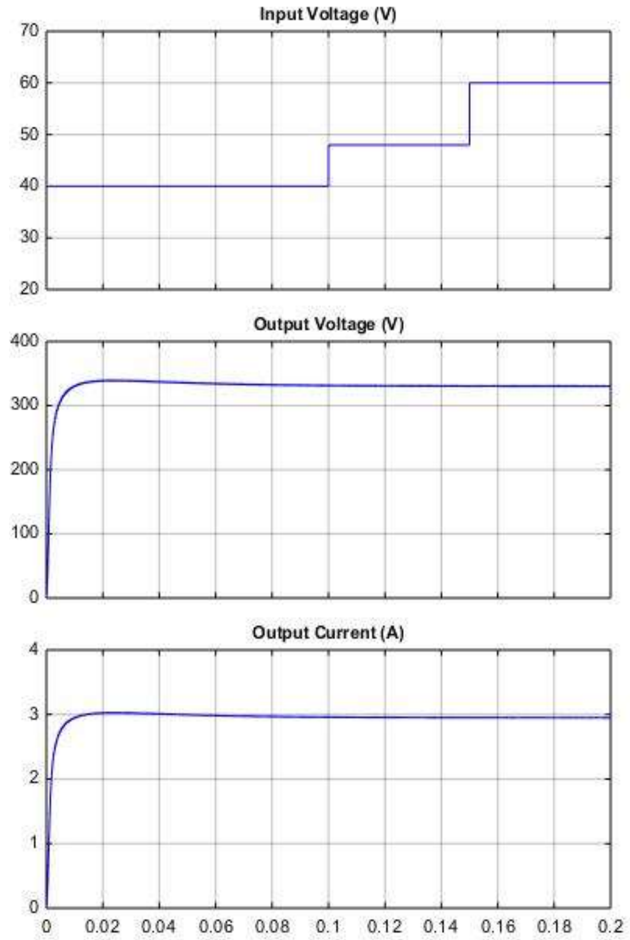

Fig. 5. DC-DC converter closed loop input and output voltage

4. INVERTER SIMULATION

The main function of the inverter in the solar PV system is to convert the DC voltage from DC-DC boost converter to alternating current (AC). The H-Bridge inverter consisting of four switched MOSFET was employed with two switches per leg as shown in Fig. 6. The switches are turned on and off diagonally with S1, S4 turning on the same time and then S2, S3 in succession.

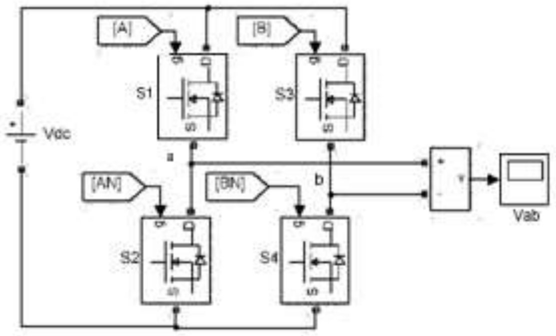

Fig. 6. Single phase H-Bridge inverter

Fig. 7(a) shows the unipolar PWM switching control scheme using Simulink blocks. The unipolar PWM switching was employed because it exerts less switching stress on the switching device. The gating signal was generated by comparing triangular carrier signal with a sinusoidal reference (modulating) signal. A triangular carrier signal of 5 kHz frequency is compared with two reference signals of 50 Hz frequency on both positive and negative signal planes as shown in Fig. 7(b) resulting in two switching signal for each leg of the inverter. The inverter output voltage switches between 0 and V_{dc} making the voltage stress experienced by

the switch device the same with supply voltage unlike bipolar switching strategy that has output voltage swing between V_{dc} and $-V_{dc}$ exerting double voltage stress on the switch.

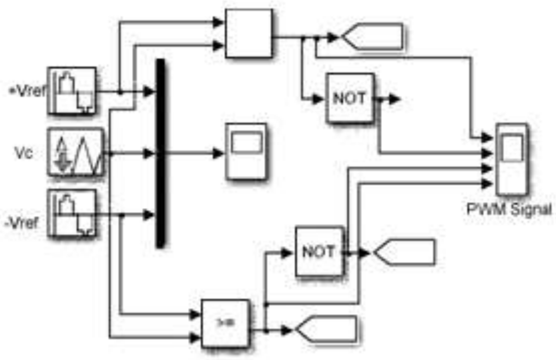

Fig. 7 (a). PWM Simulink block

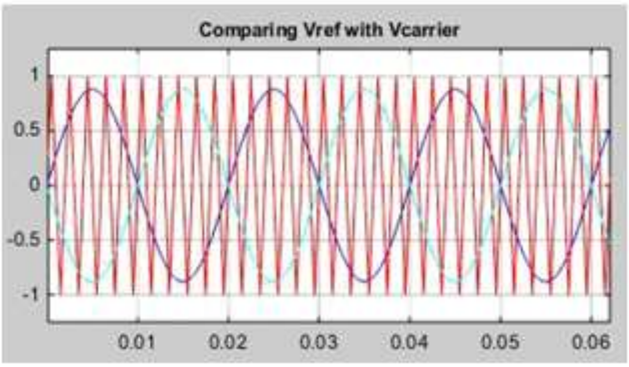

Fig. 7 (b). Carrier and reference signal for PWM generation

The output voltage of the inverter is a chopped AC voltage of 330 V peak with component of carrier frequency which was then filtered using a passive LC low pass filter to obtain pure sinusoidal AC output at 50 Hz frequency. The cut off frequency of the low pass filter f_c is chosen below $1/25^{th}$ of the inverter switching frequency. The filter inductor value L_f is calculated such that the voltage drop across the inductor is less than 5 % of the inverter output RMS voltage [7, 8] by using Eq. (4).

$$I_{L\max} 2\pi f L_f \leq 0.05 V_{RMS} \qquad (4)$$

Where,

$I_{L\max}$=Maximum RMS load current

V_{RMS}= Inverter RMS output voltage RMS

F = Output voltage frequency

At resonant, the resonant frequency of LC circuit is given by Eq. (5), used to calculate the filter capacitor.

$$2\pi f_C = \frac{1}{\sqrt{L_f C_f}} \qquad (5)$$

The complete Simulink model of the single phase inverter is shown in Fig. 8 with closed loop DC-DC converter. The variable supply voltage (40 V~60 V) from the solar PV is regulated and boosted to 330 V by the DC-DC boost converter. Before filtering as illustrated in Fig. 9, the inverter transforms the regulated DC voltage to chopped AC voltage of 330 V peak which was then filtered by LC low pass filter to give pure sinusoidal AC output voltage. The inverter output voltage presented in Fig. 10 has root mean square voltage
(V_{rms}) of 230 V with total harmonic distortion (THD) of 0.94 % as shown in Fig. 11

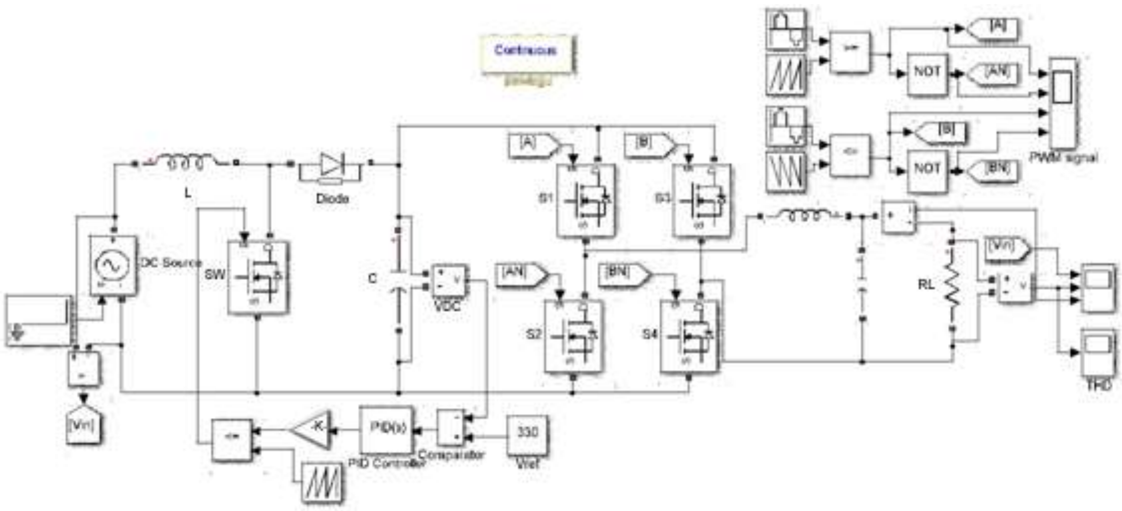

Fig. 8. Complete signgle-phase inverter with DC/DC converter

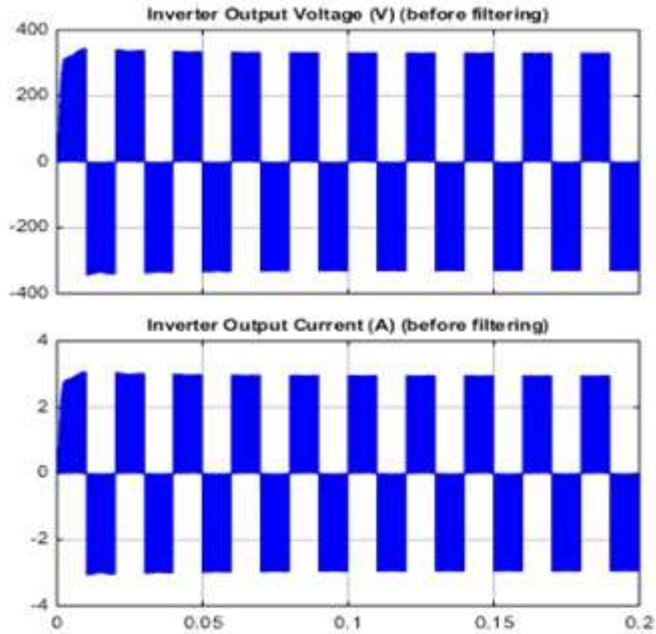

Fig. 9. Inverter output before filtering

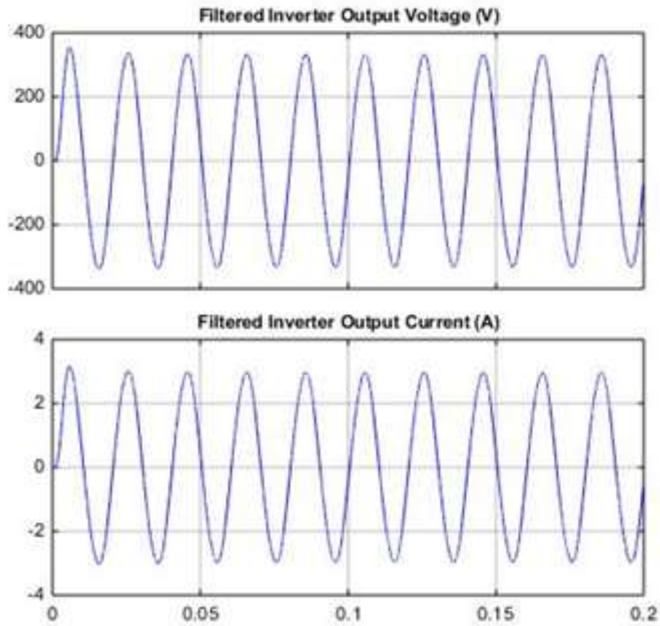

Fig. 10. Inverter output after filtering

5. CONCLUSION

A single phase inverter with DC-DC boost converter for solar PV system with wide input voltage range is designed and modelled in Matlab/Simulink environment. The simulation result shows that the DC-DC boost converter was able to regulate the variable supply DC input voltage (40~60 V) from the solar PV and maintain it at 330 V DC voltage regardless of supply voltage variations. The inverter stage successfully converts the DC voltage to 330 V peak AC voltage. The inverter output voltage has 230 V RMS AC value with very low THD of 0.94 % making the system suitable for AC local load supply and grid network application.

REFERENCES

1. http://www.worldenergyoutlook.org/media/weowebsite/2012/WEO201 2_Renewables.pdf [Retrieved December, 2013]
2. E. F. Camacho, T. Samad, M. Garcia-Sanz, and I. Hiskens, "Control for renewable energy and smart grids," The Impact of Control Technology, Control Systems Society, pp. 69-88, 2011.

3. REN21. (2012). Renewables 2012 Global Status Report. Available: Available at: http://www.map.ren21.net/GSR/GSR2012_low.pdf [Retrieved December, 2013]
4. S. Ang and A. Oliva, Power-switching converters: CRC press, 2005.
5. B. Hauke, "Basic calculation of a boost converter's power stage," Texas Instruments, Application Report November, pp. 1-9, 2009.
6. A. Turevskiy, "PID Controller Tuning for a Model with Discontinuities," ed: MathWorks.
7. K. H. Ahmed, S. J. Finney, and B. W. Williams, "Passive filter design for three-phase inverter interfacing in distributed generation," in Compatibility in Power Electronics, 2007. CPE'07, 2007, pp. 1-9.
8. A. E.-S. A. Nafeh and M. A. El-Sayed, "Modeling and Simulation of a Single Phase Grid Connected Photovoltaic System.".