IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE)
e-ISSN: 2278-1676, p-ISSN: 2320-3331, Volume 16, Issue 4 Ser. I (Jul. – Aug. 2021), PP 01-08
www.iosrjournals.org

Performance Analysis of Solar PV Fed Different DC-DC Converters with PI Controller

Khan Mohammad[1*], Abdul Ahad[2], Mohmmad Ahmad[3],Mohd Farman Rashid [4] and Farha Khan[5]
[1,2,4,5]Department of Electrical Engineering, Aligarh Muslim University Aligarh UP India
[3]Department of Electrical Engineering, Rajkiya Engineering College Bijnor UP India

Abstract: *In present scenario the Solar power generation has got tremendous role among renewable energy resources. In which DC-DC converter is interleaved between the Photovoltaic(PV) module and the load side because it converts unregulated DC input to regulated DC output as it works on switch mode by adjusting ON & OFF time period that is provided to switch. In order to achieve that, a proportional-integral (PI) controller is used to maintain the desired DC voltage of 110V at load side to accomplish the requirement of DC motor in general practical applications. This paper describes the analysis of a solar PV fed Boost and Buck-Boost converter regulated by a PI controller. The gain value of PI controller is obtained so, as to overcome the delay and in providing fast control to enhance the performance of the response. Initially, by calculating the values of Inductor and Capacitor for desired output, the analysis has been carried out for Boost converter with PI controller by observing output voltage, output current & output power. Later the same analysis has been done for Buck-Boost converter. Finally, the results have also been compared and described graphically. The entire simulation was obtained in SIMULINK/MATLAB environment. All the key findings have been presented in tabular form and explained graphically too.*

Keywords: *PV panel, Boost Converter, Buck-Boost converter, PI controller*

Date of Submission: 28-06-2021 Date of Acceptance: 12-07-2021

I. Introduction

Presently, the demand of electricity is expanding continuously in order to fulfill the requirement of increased population routine Life's. Although all the worldis majorly depending on conventional (fossil fuel) reserves in the production of electricity. But now the world's concern is changing toward renewable energy sources such as solar, wind, tidal, etc. Because conventional sources are finite and have a negative impact on the environment and hazardous to human health whereas renewable sources are abundant in nature and are eco-friendly[1]. Among all the renewable energy sources the solar based PV system is one of the fast-growing renewable energy systems in present scenario[2].

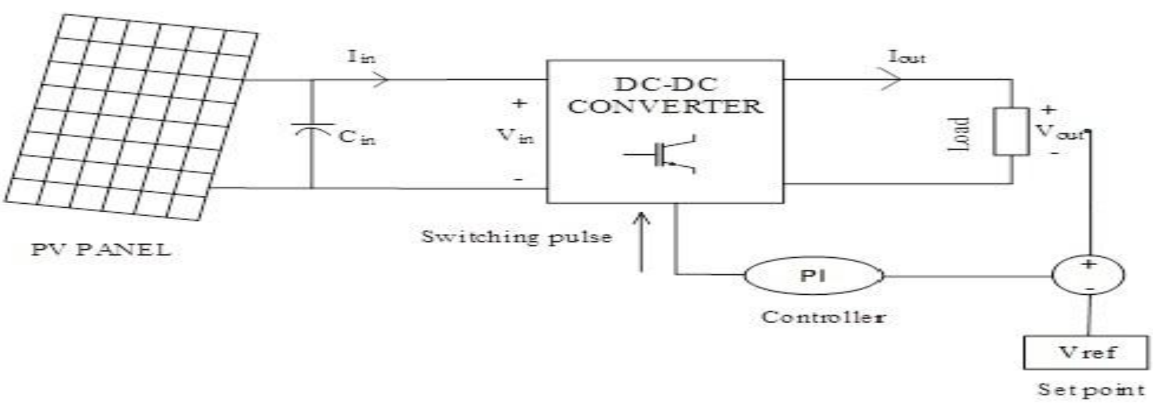


Figure 1. Schematic module of PV equipped with DC-DC converters and PI controller

Because it is easily available as compare to other renewable energy sources. In solar photovoltaic (PV) system, solar energy is converted into electrical energy. But this energy has a drawback in output such as fluctuation due to environmental conditions, temperature, and irradiance. For extracting the electrical energy from the solar PV system a dc-dc converter is introduced between PV modules to load[3-4]. In this topology, to obtain the desired response at the load side a PI controller is implemented which is used to generate the pulse that is provided to MOSFET [5-6]. The PI controller adjusts the duty ratio as the set reference at load side. A typical diagram of solar PV fed dc to dc converter having loads has been represented in Figure 1.

In this paper, I-V and P-V characteristics of solar PV module has discussed under section II and two DC-DC converters i.e. boost, buck-boost have been designed[7] to obtain the output voltage of 110 volts at the load side from 1650 watts PV panel. Subsequently, the control technique of PI controller is defined in section III. The topologies of DC-DC converter with mathematical modeling & designing of converter is described in section IV. The comparative analysis of passive element with output response is presented in the tabular and graphical form under section V.

II. PV MODULE

PV module is fabrication of PV cell which is p-n junction semiconductor arranged in structure of installation and the function of PV cell is conversion of irradiated energy to electrical energy which is based on particle theory of irradiation energy. PV cellgenerates dc current which varies according to light of irradiance. The equivalent circuit of PV cell consists of diode in anti-parallel with current source and parallel resistance Rsh and series resistance Rs as shown in figure 2.

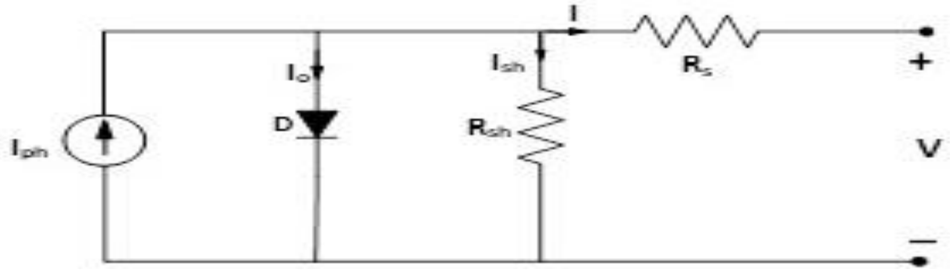


Figure 2: Equivalent circuit of a solar cell

2.1 Specifications of Solar PV module

A solar module can be made up of a series parallel combination of various solar cells. Further the series and parallel combination of solar modules are formed as a solar panel or array. A solar model has been used as an input dc source feeding into a dc-dc converter. The specification of solar PV module used for simulation purpose has been depicted in Table 1

.TABLE 1: Specifications of solar module used

Maximum Power of PV module, P_m	213.15 W
Open circuit voltage of PV module, V_{oc}	32.2 V
Short circuit current of PV module, I_{SC}	7.54 A
Current at Maximum Power, I_M	7.35 A
Voltage at Maximum Power, V_M	29 V
Coefficient of Current temperature, K_T	0.102
Coefficient of Voltage temperature, K_V	-0.36099

The mathematical modeling of solar cell, shown in Figure 2, can be represented in the following set of equations. The mathematical equation for output current of an ideal cell is shown in equation (1).

$$I = Iph - Io - Ish \qquad (1)$$

Where, I_{ph} light generated current and Io is Shockley equation.
The Shockley equation can be expressed as

$$Io = Is\left\{\exp\left(\frac{q}{AKtc}\right) - 1\right\} \qquad (2)$$

Where,Is = saturation or leakage current of diode, q= Electron charge [1.60×10^{-19}C], Tc=module temperature,K=Boltzmann Constant [1.38×10^{-23}J/k] and A=diode ideality factor

$$Ish = \frac{V + IRs}{Rsh} \quad (3)$$

From equation (1), (2) & (3), output current can be calculated as:

$$I = Iph - Is\left\{\exp\left(\frac{q}{AKTcNs} * V + IRse\right) - 1\right\}\frac{V + IRs}{Rsh} \quad (4)$$

Where I_{ph}=light generated current ,I_o= diode reverse saturation current, I_{sh}= current in parallel resistance, R_S= series resistance, R_{sh}= parallel resistance, I= module output current, V= module output voltage, N_s= no. of series connected cell in module

Here power matching algorithm is used to find the value of series resistance, shunt resistance. While the diode ideality factor is arbitrarily chosen. The value of I_{ph} & I_o is calculated by using equations (1) and (2)respectively.

2.2 Solar PV module Characteristic

To understand the behavior of PV module, there are mainly two characteristic curves which perceived for study i.e. I-V and P-V curves. The P-V curve is a plot between power and voltage where power is calculated by multiplying the voltage across cell with corresponding current through cell. The I-V curve is drawn between cell current and voltage in which current is desired to have its value near to the maximum power point. This current is called current at maximum power point. There are two factors which affect PV characteristic are irradiance and temperature level. P-V characteristic must change the value of current and voltage at each moment to obtain maximum output from the panel. So, in this way tracking speed and accuracy is required for PV module. A typical I-V and P-V characteristics

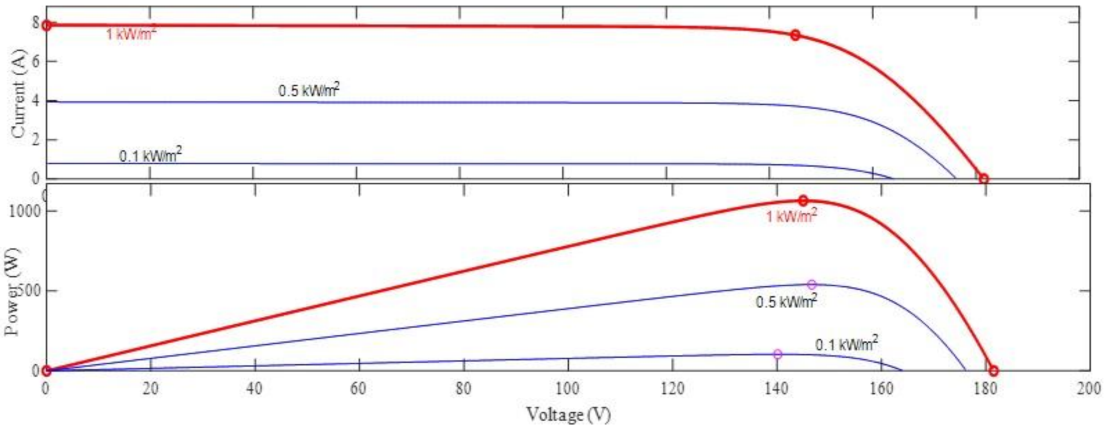


Figure 3. I-V and P-V characteristics of solar cell

have been represented by the in Figure 3. Ideally, the value of FF is 1.To improve the efficiency of PV module solar cell are connected in series or parallel combination. So, when cell connected in series short circuit current would remain same and during parallel current will become twice if the cell is identical. From fig 4, a constant irradiance of 1000 $W/m^2$is provided to PV panels. Another parameter which is used to determine the performance of solar cell is Fill factor which can be calculated as given in equation (5).

$FF = (Vmpp * Impp)/(Voc * Ish)$ (5)

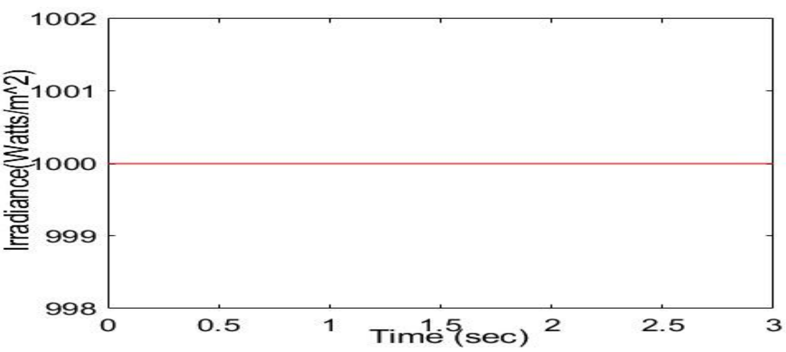


Figure 4. Solar Irradiance graph of p-v panel

III. DC-DC CONVERTER TOPOLOGIES

A DC-DC converter is a power electronic device that is based on switching mode (on & off) time period, it transforms unregulated dc input to regulated dcoutput. For obtaining the constant voltage irrespective of load condition, a PI controller is used its control the switching pulse that is provided to Mosfet at 5 kilohertz through the repeating sequence. There are two types of dc-dc converter are discussed below such as(1) Boost (2) buck-boost

3.1 BOOST CONVERTER

It is also named as step-up converter because it provides the output voltage greater than the input voltage when switch is in ON condition. The diode becomes reverse biased and hence output gets isolate from input. The input energy is supplied only across the inductor. During the switch off condition, the output is obtained through the input as well as from the inductor stored energy [8-9]. A typical boost converter has shown in Figure 5.

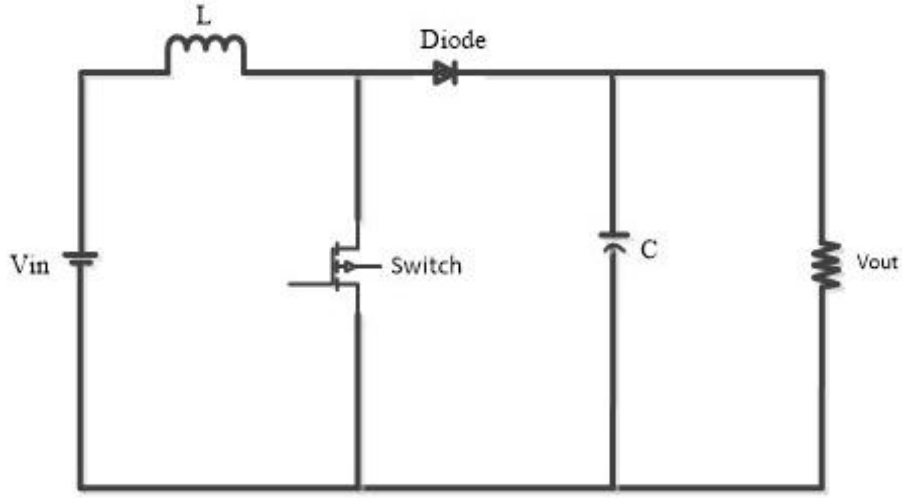


Figure 5. DC-DC BOOST CONVERTER

Duty ratio, $D = \left(\frac{Vin}{Vout}\right)$ (6)

Ripple current in inductor, $\Delta Il = \left(\frac{D.Vs}{f.L}\right)$ (7)

So, inductor $L = \left(\frac{D.Vs}{f.\Delta Il}\right)$ (8)

Voltage ripple in capacitor, $\Delta Vc = \left(\frac{D.Vin}{R(1-D).\Delta Vc.f}\right)$ (9)

And capacitor, $C = \left(\frac{D.Vin}{R(1-D).\Delta Vc.f}\right)$ (10)

Where, D= duty ratio
ΔI_L= ripple in inductor current taken as 5% of output current
C= capacitor in (μf)
ΔV_c= ripple in output voltage taken as 1% of output voltage
Vin= input voltageL= inductor in Henry
Vout= output voltage across load

3.2 BUCK-BOOST CONVERTER

It works both as step up or step down dc-dc converter depends on the duty cycle that is provided to MOSFET. When the D> 0.5, it behaves as a step up otherwise step down. When the switch is in ON position diode gets reversed biased and the input energy is supplied to inductor on the other hand in switch off condition the output voltage is obtained from input and the stored energy in inductor [10-11]. A typical boost converter has shown in Figure 6.

Duty ratio, $D = \left(\frac{Vout}{Vout + Vin} \right)$ (11)

Inductor, $L = \left(\frac{D.Vin}{f.\Delta Il} \right)$ (12)

Capacitor, $C = \left(\frac{D.Io}{f.\Delta Vc} \right)$ (13)

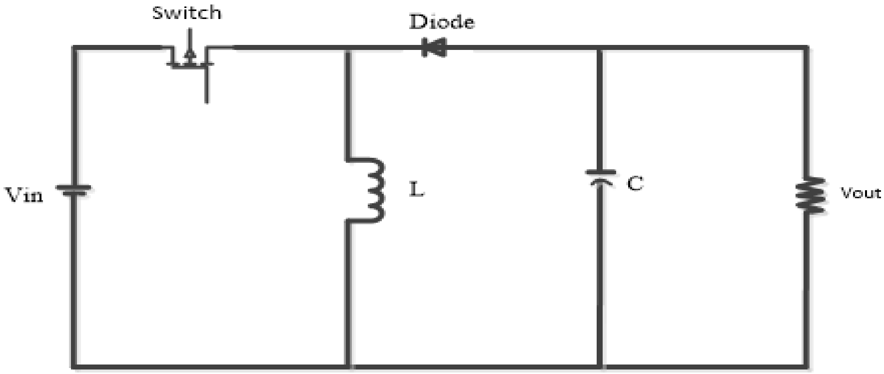


Figure 6. Buck-boost converter circuit

IV. PI CONTROLLER

Proportional-integral (PI) is a closed loop controller that is implemented with DC-DC converter in this article to obtain the constant condition. It is based on feedback control mechanism. So an error signal is producing due to reference. This error signal is provided to PI controller with repeating sequence at 5 kHz to obtain the constant voltage across the load side. The PI controller adjusts the duty cycle which is provided to IGBT for getting the appropriate response [12]. The mathematical structure of PI controller is depicted below. A typical PI controller is depicted in figure 7.

$$u(t) = K_P(t) + K_i \int_0^t e(\tau) d\tau \qquad (14)$$

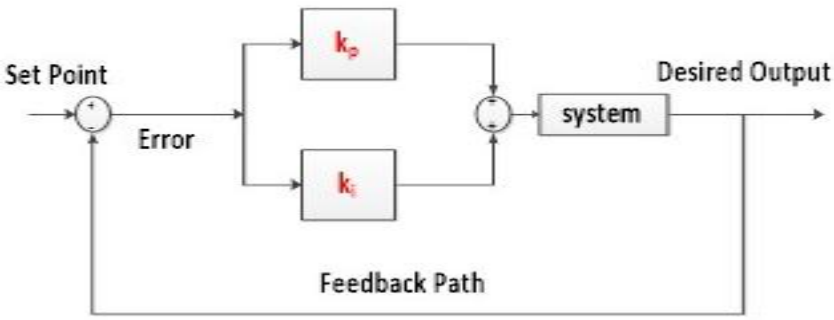


Figure 7. A schematic diagram of PI Controller

V. Simulation Result

The simulation is accomplished in MATLAB software to represent the comparative analysis of both Boost & Buck-boost converter. In Both the configurations two series and four parallel PV panels are implemented as input with these converters. This PV module provided 58volt dc as input to the converters, which is boosted to 110 volt across the load through the converter boosting mechanism. The switching pulse is provided to the converter through PI controller to obtain the constant voltage across the load. The calculation of passive elements of both the converters are obtained by using mathematical analysis from equation (6) - (13), that are presented in Table 2. The response of both the converters in the form of waveform and simulation results are depicted in figure 8 to figure 12 and in table 3 respectively, carried out through MATLAB software.

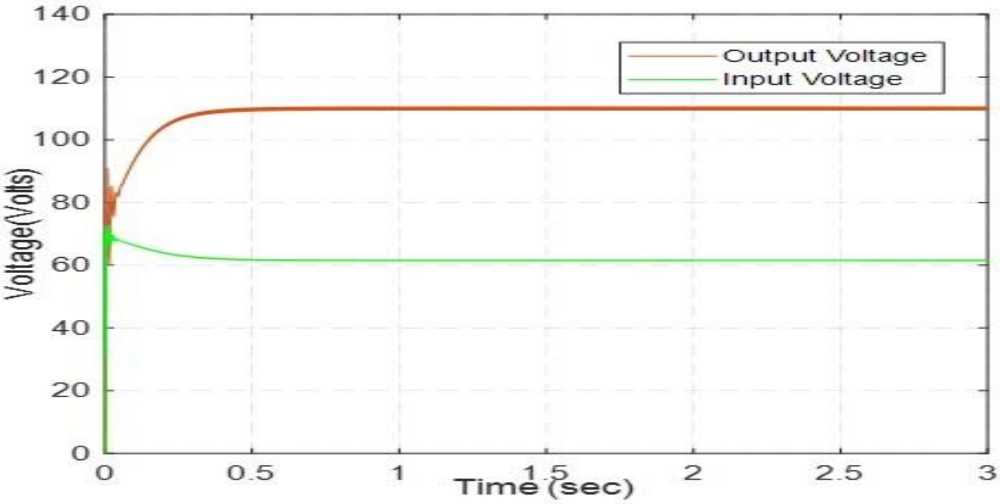
TABLE 2. Specification of passive elements

DC-DC CONVERTER	Resistance R_L (Ω)	Inductor L (mH)	Capacitor C (mF)
Boost	7.50	3.86	1290
Buck-Boost	7.50	10.12	1783

.TABLE 3. Summary of DC-DC converters

DC-DC Converters	Vin (Volts)	Vout (Volts)	Iin (Amps)	Iout (Amps)	Pin (Watts)	Pout (Watts)	Efficiency (%)
Boost	61.49	110.5	26.58	14.73	1704	1628	95.53
Buck-Boost	61.39	110.5	26.77	14.74	1704	1639	96.18

From Table 3, it has shown that 61.50 volts dc is provided to Boost Converter as input that is transferred to 110 volts dc, obtained across the load.Similarly a voltage of 61.40 volts dc is provided to Buck-Boost Converter as input that is transferred to 110 volts dc, obtained across the load. These two waveforms of boost and buck-boost converter have been represented in Figure 8 and 9 respectively.



.

Figure 8. The voltage waveform of Boost converter

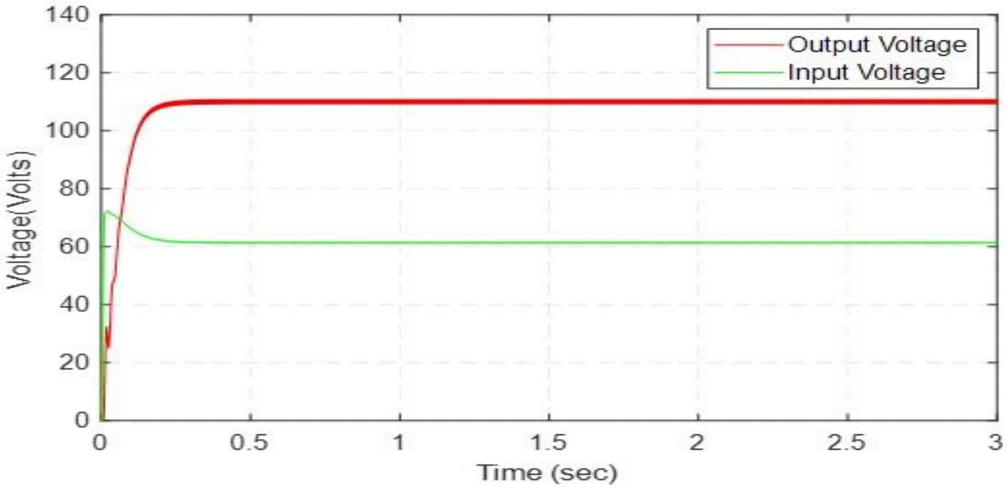


Figure 9. The voltage waveform of Buck-Boost converter

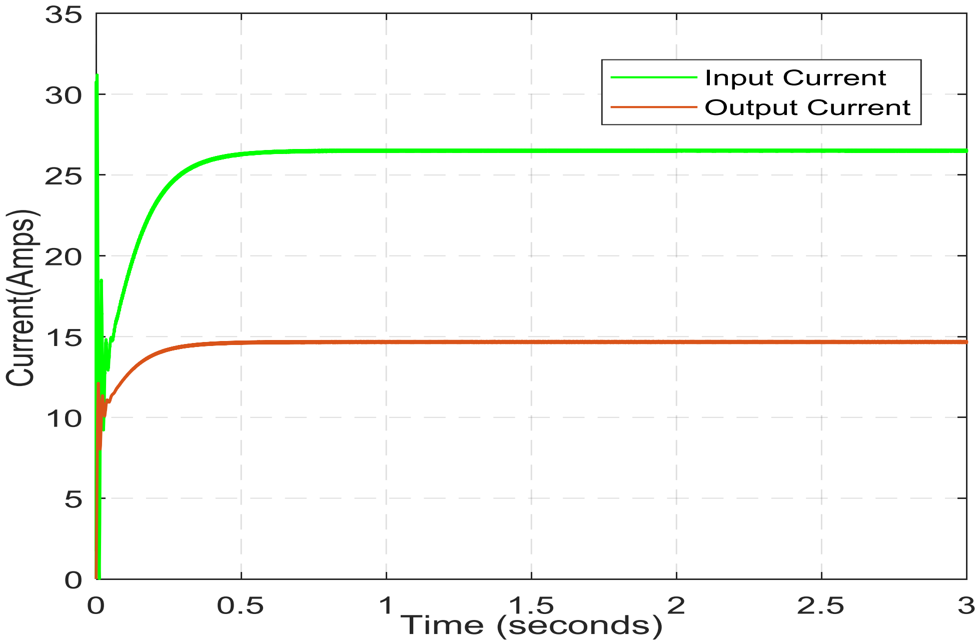


Figure 10. The current waveform of Boost converter

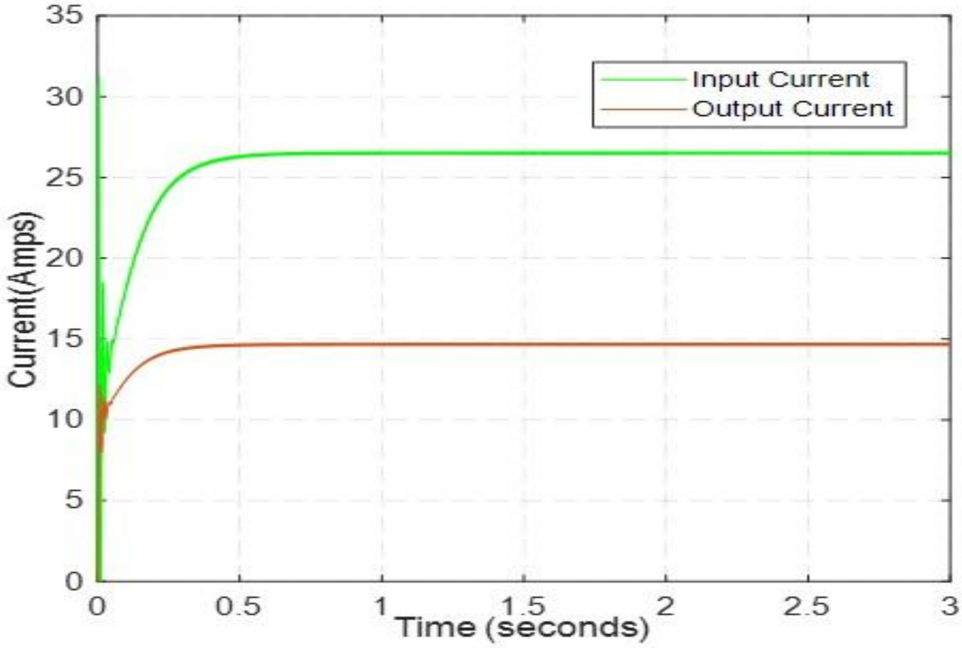


Figure 11. The current waveform of Buck-Boost converter

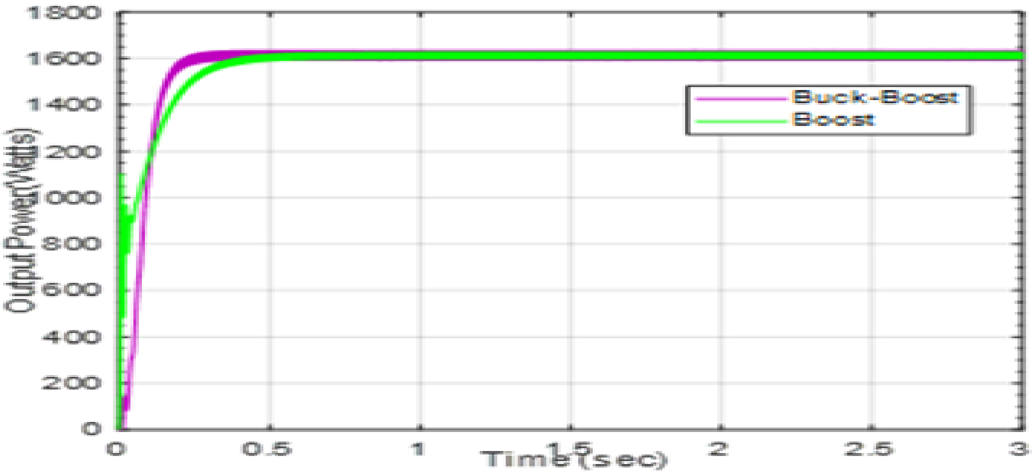


Figure 12. Output power waveforms of converters

The output current of 14.73 Amp was obtained across the load which is shown in Figure 10. Further, as shown from figure 11, the output current of 14.74 Amp has been obtained across the load. The output power obtained from both the converters have also been examined and it is depicted in Figure 12, stating that 1628 Watts & 1639 Watts are observed as output power through the Boost, Buck-Boost converters respectively.

VI. Conclusion

In this paper, the performance of two types of DC-DC converters such as boost and Buck-Boost are compared in boosting mode that is fed from solar PV energy. The comparative analysis of both the converters are consists of output response along with required passive elements. The switching pulse is provided to MOSFET switches by using the PI controller to maintain the constant 110 volts dc across the load. As it is discussed in simulation results that the output power of 1628 watts and 1639 watts are extracted through the boost and buck-boost converter respectively at 7.50 Ω resistive load. Hence, it has been found that the Buck-Boost converter is more efficient than Boost converter in form of output power, But the required size of passive elements are reduced in Boost converter. Various results and key findings have been tabulated and explained in a graphical manner.

References

[1]. N. H. A.W., S. S.F. and M. Z. Ab Muin, "Modeling of DC-DC converter for solar energy system applications," 2012 IEEE Symposium on Computers & Informatics (ISCI), 2012, pp. 125-129.

[2]. Baharudin, N.H., Mansur, T.M.N.T., Hamid, F.A., Ali, R. and Misrun, M.I. (2017) Topologies of DC-DC Converter in Solar PV Applications. Indonesian Journal of Electrical Engineering and Computer Science, 8, 368-374

[3]. S. Jayaprakash, "Comparison of solar based closed loop DC-DC converter using PID and fuzzy logic control for shunt motor drive," 2014 IEEE National Conference on Emerging Trends In New & Renewable Energy Sources And Energy Management (NCET NRES EM), 2014, pp. 115-117.

[4]. Saravanan S., Ramesh Babu N., Sanjeevikumar P.,"Comparative Analysis of DC/DC Converters with MPPT Techniques Based PV System", Advances in Power Systems and Energy Management, Lecture Notes in Electrical Engineering, Vol. 436, 2018, pp. 275-284, Singapore.

[5]. R. Nagarajan et al, "Implementation of PI Controller for Boost Converter in PV System", International Journal of Advanced Research in Management Architecture, Technology Engineering (IJARMATE) vol. 2, no. 12, pp. 6–10, Dec 2016

[6]. A. A. Bakar, W. M. Utomo, T. Taufik, S. Aizam, and Jumadril, "DC/DC boost converter with pi controller using real time interface," ARPN Journal of Engineering and Applied Sciences, vol. 10, no. 19, pp. 9078–9082, October 2015

[7]. R. F. Rajakumari and M. Deshpande, "Comparative Analysis of DC-DC Converters," 2019 2nd International Conference on Power and Embedded Drive Control (ICPEDC), 2019, pp. 504-509

[8]. V. Sharma and C. Panwar, "Comparative analysis of PV FED DC-DC converters", 2014 International Conference on Green Computing Communication and Electrical Engineering (ICGCCEE), 2014, pp. 1-4.

[9]. M. Errouha, S. Motahhir, Q. Combe, A. Derouich and A. E. Ghzizal, "Fuzzy-PI Controller for Photovoltaic Water Pumping Systems," 2019 7th International Renewable and Sustainable Energy Conference (IRSEC), 2019, pp. 1-6,

[10]. A. M. Abdul Hussain and H. M. D. Habbi, "Maximum Power Point Tracking Photovoltaic Fed Pumping System Based on PI Controller," 2018 Third Scientific Conference of Electrical Engineering (SCEE), 2018, pp. 78-83,

[11]. O. K. Islam, M. S. Ahmed, K. Rahman and T. Tahsin, "A Comprehensive Comparison between Boost and Buck-Boost Converters in Solar MPPT with ANN," 2020 Emerging Technology in Computing, Communication and Electronics (ETCCE),2020pp. 1-6,

[12]. S. Kumar and P. R. Thakura, "Closed loop PI control of DC-DC Cascode Buck-Boost converter," 2017 International Conference on Innovations in Information, Embedded and Communication Systems (ICIIECS), 2017, pp. 1-6.

Khan Mohammad, et. al. "Performance Analysis of Solar PV Fed Different DC-DC Converters with PI Controller." *IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE)*, 16(4), (2021): pp. 01-08.