The effect of the performance of using a boost converter on the voltage of the solar panel

E Supraptono, B P Abiyasa, R D M Putri and T Andrasto

Department of Electrical Engineering, Faculty of Engineering Universitas Negeri Semarang, Kampus UNNES Sekaran, Gunungpati, 50229 Semarang Indonesia

Abstract. In designing a grid-connected photovoltaic generator system, a DC-DC converter is needed to increase the photovoltaic output voltage. In designing this converter, a converter with high static gain is usually used in order to increase the photovoltaic output voltage and obtain high conversion efficiency. However, conventional converter has static gain with low output voltage. Conventional converter can only increase the output voltage from the input voltage when the Duty Cycle is 0.75. To meet the high standard of static gain, an output voltage of 2.93 – 3.59 times the input voltage is required. To overcome that problem, the authors propose the use of DC-DC converter topology. Modification on the conventional converter is carried out by adding capacitors and diodes. With the application of this converter, it can be concluded that the output voltage of the converter can be increased for photovoltaic application.

1. Introduction

Electrical energy which is part of everyday life is a scarce and important resource. Starting from basic needs such as for household activities to commercial needs, almost all of them use electrical energy. Most of the energy needs are borne by energy sources from fossil materials. Meanwhile, the current demand for energy is increasing [1]. The power production and transmission systems must adapt to variations in direct demand. Many European countries are still very dependent on fossil fuels and most countries present an indicator value of fossil fuel energy consumption higher than 60% which corresponds to 24 countries from 29 European countries studied. Moreover, the consumption in 10 countries is higher than 80%, which includes countries such as Germany and the United Kingdom [2].

One of the efforts to overcome the electricity crisis is to reduce dependence on fossil energy sources. Renewable energy can play an important role in reducing a country's dependence on fossil fuels and renewable energy is the fastest growing energy source among other energy sources which means the use of renewable energy will increase the most until 2040 [3]. Among the various solar energy technologies from sustainable energy sources, photovoltaic (PV) seems quite attractive for electricity generation because it is noiseless, no carbon dioxide emission during operation, scale flexibility and operation is rather simple and maintenance is not too complicated. Because the voltage generated by Solar Photovoltaic (PV) itself is fluctuating based on the intensity of sunlight received by the surface of the solar panel, a circuit such as a converter is needed. The use of a converter circuit allows an increase in the power generated. The control method is designed to stabilize the maximum power and provide the required constant voltage [4-6].
This research was conducted using data from the BMKG of North Jakarta City, where the City of Jakarta has a fairly optimal length of solar radiation and a temperature that is close to the optimal temperature to be used as data in this study. And to overcome these problems, a modified DC-DC converter is used. Modification is made by adding diodes and capacitors. The modified DC-DC converter can increase the output voltage up to 2.93 – 3.59 times the input voltage. With the implementation of this converter, it is hoped that a high converter output voltage can be obtained.

2. Research Method

In this paper, the research focus is directed at the design of the boost converter. The solar panels used in this study are solar panels that are already on the market with an input voltage of 12 V. In the boost converter circuit that is designed, there are two important parts, namely a current generation circuit or better known as Pulse Width Modulation (PWM) to produce square waves (pulse) as a regulator of the on and off switch which in this design the frequency of the PWM is determined at 40 kHz, and the generator or boost circuit as a voltage booster. The basic block diagram of a DC-DC Converter circuit with a boost converter type is illustrated in Figure 1.

![Figure 1. Boost converter block diagram](image)

In the design of the boost converter, there are several main factors that must be considered, including the initial variable in designing the boost converter circuit which will later be used as a calculation parameter to obtain the value of the magnitude of other components such as duty cycle, resistor, inductor, and capacitor. The initial variables that are determined in the design of the boost converter circuit are determined based on the components available in the market according to the desired specifications. The solar panel specification used in this study has an output voltage range of 12 – 14.4 V, while the boost converter output voltage is expected to be 48 V. The duty cycle D value for this circuit is calculated using equation (1) below.

\[
D = 1 - \frac{V_{in}}{V_{out}}
\]

\[
D = 1 - \frac{12}{48} = 0.75
\]

The next component that must be determined is the resistor at the base of the transistor. The value of the resistance used in the boost converter circuit is determined using the calculations in equation (2).

\[
R = \frac{V_o}{I}
\]

\[
R = \frac{48\, V}{4\, A} = 12\, \Omega
\]
The inductor installed in the boost converter circuit is useful as a voltage amplifier after the switching process. The minimum value of the inductor used in the boost converter circuit is determined by using the calculations in equation (3) below.

\[ L_{\text{min}} = \frac{(1-D)^2}{2 \times f} \times R \]

\[ L_{\text{min}} = \frac{(1-0.75)^2}{2 \times 40.000} \times 12 = 0.56 \]

where \( D \) represents the duty cycle, \( R \) is the resistance value at the base of the transistor, and \( f \) is the PWM frequency. From the available data, the inductance value of the inductor used is 0.56. Meanwhile, a capacitor installed in the boost converter circuit is useful as a filter to reduce noise at the output voltage. This capacitance value can be calculated using equation (4) below.

\[ \Delta V_o = \frac{V_o \times D}{R \times C \times f} \]

\[ \Delta V_o = \frac{48 \times 0.75}{12 \times 31.25 \times 40.000} = 0.024 \]

\[ C = \frac{V_o \times D}{R \times \Delta V_o \times f} \]

\[ C = \frac{48 \times 0.75}{21 \times 0.024 \times 40.000} = 3.125 \]

In designing a photovoltaic, an equation is needed to define the output value of the photovoltaic. The module used in this study is the KSM235M-96 type with table 1 as the parameter.

| Parameter               | Variable | Value     |
|-------------------------|----------|-----------|
| Power Rating            | \( P_{\text{MPP}} \) | 235 Watt  |
| Optimal Working Voltage | \( V_{\text{MPP}} \) | 48 Volt   |
| Optimal Working Flow    | \( I_{\text{MPP}} \) | 4.89 Ampere |
| Open Circuit Voltage    | \( V_{\text{OC}} \) | 57.8 Volt |
| Short Circuit Current   | \( I_{\text{SC}} \) | 5.28 Ampere |
| Series Connected Module | \( N_s \) | 96        |
| Parallel Connected Module | \( N_p \) | 1         |
Temperature coefficient $I_{SC}$  

| Model Series Resistor | Rs  | 0.0111 Ω |
|-----------------------|-----|----------|
| Model Shunt Resistor  | Rsh | 1000 Ω   |

3. Results

The test result of this boost converter circuit is the final result of the design that has been realized. Measurement data of the boost converter circuit data includes the boost converter circuit voltage ($V_{in}$), PWM circuit voltage ($V_{PWM}$), and boost converter circuit output voltage ($V_{out}$). Meanwhile, the form of the signal $V_{in}$ is given in Figure 2.

![Figure 2. Vin signal form](image)

With an input of 12 Volts, it produces an output voltage of 49.34 Volts. As well as the photovoltaic results with an input of 883 W/m² and a temperature of 29.8°C. From the measurement results, the output voltage data that has been connected to the Boost Converter is also discovered, as shown in table 2 and in Figure 3 as follows.

| No | Photovoltaic | Photovoltaic Connected Boost Converter |
|----|--------------|---------------------------------------|
| 1  | 253.6        | 910.9                                 |
| 2  | 253.3        | 911.2                                 |
| 3  | 229.7        | 796.2                                 |
| 4  | 190.9        | 654.7                                 |
| 5  | 140          | 478.5                                 |
| 6  | 209.9        | 721.8                                 |
| 7  | 227.9        | 789.1                                 |
| 8  | 240.1        | 841                                   |
| 9  | 184.7        | 633.3                                 |
| 10 | 197.6        | 678                                   |
| 11 | 111.8        | 327.7                                 |
| 12 | 142          | 485.3                                 |
5. Discussion
The circuit made in this research is a DC to DC step-up voltage based voltage booster. This circuit is widely known as boost converter. Because this circuit is a voltage booster, the output voltage is up to 4 times the input voltage. The addition of inductors and switching of transistors can generate voltage with switching modes. In this circuit there are two important parts, namely a current generator circuit or better known as PWM and a voltage generator circuit or boost. In connecting photovoltaic with a boost converter, we must also use an ideal boost converter component in accordance with the boost converter parameters that have been calculated using the above formulas in order to get the ideal input value for the boost converter itself so that the resulting output voltage gets the ideal value [7-8].

5. Conclusion and Suggestion
This study has described the design of a boost converter to be applied in a voltage amplifier scheme from photovoltaic. From the results of the study, it was found that the circuit that was built showed good performance as indicated by the strengthening value of 2.93 - 3.59 times in accordance with the design objectives. In addition, the very small output voltage ripple value shows that the filter components used are relatively successful in suppressing the non-DC signal components that enter the system. To improve the results obtained, further research is needed so that the designed circuit can be
applied in real systems. One of the alternative is by increasing the accuracy to a very high level so that the resulting voltage can be more relevant.

References

[1] Akdi Y, Gölveren E and Okkaoğlu Y 2020 Energy 191 116524
[2] Ali M 2004 Jurnal Edukasi Elektro 1 1-8
[3] Diner F 2011 Renewable and Sustainable Energy Reviews 15 713–720
[4] Bamati N and Raoofi A 2020 Renewable Energy 151 946–955
[5] Bahadori A, Nwaoha C, Zendehboudi S and Zahedi G 2013 Renewable and Sustainable Energy Reviews 21 582–589
[6] Benli H 2013 Renewable Energy 50 33-46
[7] Luque A and Hegedus S 2011 Handbook of Photovoltaic Science and Engineering (West Sussex: John Wiley & Sons)
[8] Rahman Z and Premadi A 2014 Seminar Nasional PIMIMD 2014 p 33–35

Acknowledgement

Thank you to those who have given supports in this research from preparation, process to completion of research, especially managers and administrators in the department and colleagues in the TE FT UNNES laboratory.