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Simulation of Buck-Boost Converter for Solar Panels using PID Controller

Farah Shabila Dinniyah[a]*, Wahidin Wahab[a], Muhammad Alif[b]

[a]*Department of Electrical Engineering, Faculty of Engineering, University of Indonesia, Depok, 16424, Indonesia*
[b]*Nano Center Indonesia, Pusat Inovasi LIPI, Cibonong, 16912, Indonesia*

Abstract

Currently, there are plenty of technological applications that utilize natural, environmental-friendly sources of energy. However, a disadvantage often found in natural energy sources is that the intensity produced is uncertain. This occurence is also found in solar panels, wherein the light intensity that enters is not always equal. Light intensity may be affected by various factors such as ones on gloomy or sunny weathers. This irregularity on light intensity leads to deviation of voltage output produced by the solar panel. With the use of buck-boost converters, the amount of output voltage may be set to higher or lower than the input voltage, enabling us to maintain the desired output voltage. The amount of output voltage produced is controlled by a microcontroller program which regulates pulse widths produced by PWM signals. This paper discusses about designing a buck-boost converter for solar panels, with a voltage input range of 10 to 50 V. The regulation of output voltage is the main aim in analyzing the success of the design created. The design is simulated with Proteus 8.4, and yields a voltage output with an efficiency of 90 to 99%.

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Keywords: buck-boost converter; PWM; duty cycle; solar panel; solar energyIntroduction

1. Introduction

Solar panels are widely used as an environmentally-friendly electricity supply. It is very popular since it simple to install and relatively cost-effective. Unfortunately, a problem is often found, wherein the voltage output produced is

* Corresponding author. Tel.: +62-8950-516-4312.
E-mail address: shabilafarah@gmail.com.

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not constant. A buck-boost converter is a component found in solar panels which is used to regulate the voltage output produced by these solar panels. This converter can be adjusted to produce voltage with a larger or smaller value than the initial voltage. This experiment aims to create a voltage output at a constant value of 12 V, with a range of voltage input of 10 to 50 V. The voltage value produced by the converter is controlled by the pulse width produced by the PWM (Pulse Width Modulation) generator. The pulse width produced by the PWM generator is controlled by a microcontroller. The microcontroller is programmed to control the pulse width and frequency produced. According to the problem stated above, the author creates a circuit architecture as well as a controller scheme for buck-boost converters which may produce a constant voltage output, which is not affected by sunlight intensity. The controller scheme used is the PID (Proportional Integral Derivative). The converter circuit is connected to the arduino microcontroller, and simulated in Proteus 8.4.

1.1 Pulse Width Modulation (PWM)

Pulse width modulation is a method used to adjust the width of a signal. This signal width is represented as a pulse width for one period of time. Commonly, a PWM signal has an equal basic amplitude and frequency, but with a varying pulse width. With the PWM technique, several *on* and *off* pulses will be formed. The percentage of *on* pulses are represented in duty cycles. A duty cycle has a range of 0 to 100%. From the calculation of duty cycle, the resulting voltage output will be known. This is herein stated

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

Wherein:

$V_{in(min)}$ = minimum voltage input
V_{out} = maximum voltage output
D = *duty cycle*

1.2 PWM buck-boost converter circuit on continous current mode (CCM)

A buck-boost converter is a type of converter which has the ability to convert a voltage output into a larger or smaller output than the voltage input. The polarity of voltage output will be the opposite of the voltage input's polarity. The PWM buck-boost converter circuit is shown in Figure 1.a. The circuit consists of a MOSFET as a controlled switch, inductor L, filter capacitor C, and load resistor R_L. The switch is turned *on* and *off* on the switching frequency (F_s) = 1/T with a duty cycle ratio (D) = t_{on}/T, wherein t_{on} is a time interval when the switch *on*. Figure 2.b. shows a buck-boost converter equivalent circuit for CCM when the switch is *on* and the diode is *off*, and when the switch is *off* and the diode is *on*.

During time interval $0 < t \leq DT$, the switch turns *on* and the diode turns *off*, as indicated in Figure 2.b. The diode voltage is $-(V_i+V_o)$ and this keeps the diode *off*. The inductor voltage is V_i and adds the linear increase on the inductor current with a steepness of V_i/L. During the $DT < t \leq T$ time interval, the switch *off* and the diode *on*, as shown in Figure 2.c. The inductor voltage is $-V_o$ and causes the inductor current to decrease linearly with a steepness of $-V_o/L$. The switch voltage is $V_i + V_o$. When t = T, the switch turns *on*, and a new cycle begins.