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Implementation of a fuzzy controlled buck-boost converter for photovoltaic systems

Gerard Ang[a,*], Paul Jerome Arcibal[a], Llorien Marie R. Crisostomo[a], Conrado F. Ostia, Jr.[a], Peter Joshua Cornelius S. Joaquin[a], Jose Emmanuel C. Tabuton[a]

Mapua University, Intramuros, Manila 1002, Philippines

Abstract

Man's growing demand for energy calls for an increase in energy supply. Since burning of fossil fuels produces harmful chemicals, finding new sources of power such as renewable energy is encouraged. This study aims to implement a DC/DC Buck-Boost converter with fuzzy logic controller for photovoltaic systems. In this study, use of a solar panel was integrated in the design of a buck-boost converter with a fuzzy logic controller was considered. The researchers used a microcontroller which measures the input and output voltages of the system and conducted experiments in which it was determined that when the voltage reading of the solar panel is 20 V, buck mode is operated and when the voltage reading of the panel is at least 3 V – 10 V, boost mode is operated. In the actual application of the buck-boost converter, the researchers verified that at a particular time of operation, the converter was not able to boost the voltage higher due to very small input current. For the 6 V, 9 V and 12 V batteries, the recorded voltage ranges for state of charge from 0% - 100% are 6.03 V – 7.2 V, 8.4 V – 9.54 V and 11.9 V – 12.92 V, respectively.

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Keywords: Buck-boost converter; fuzzy logic control; solar cell

* Corresponding author. Tel.: +63-915-701-2925
E-mail address: gang@mapua.edu.ph

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1. Introduction

Energy is one of the major needs of humanity. For centuries, fossil fuels have been the main source of energy in the world. Since burning of fossil fuels produce carbon emissions that contribute to global warming and other pollutions, the need to find new sources of energy preferably renewable sources of energy becomes inevitable. Alternative sources of energy such as renewable and sustainable energy like solar, wind, geothermal, hydro and biomass are being considered. Today's challenge is to design and build devices to harness solar energy effectively. Fossil fuels which at present are the primary source of energy are slowly being depleted; thus, energy shortage will take place when all fossil fuels have been completely depleted. Scientists, engineers and other researchers tend to find ways to address this problem and create efficient ways to harness energy from the sun. This paper suggests that a buck-boost converter can be controlled by a fuzzy logic controller. The main focus of the study is to integrate buck-boost converter with a fuzzy logic controller and be implemented in a solar charging system.

The main objective of the study is to design and implement a DC/DC Buck-Boost converter with fuzzy logic controller for harnessing solar energy. The specific objectives of this research are to design and construct a buck-boost converter for PV cell, create a fuzzy logic controller for the charging circuit and to integrate a microcontroller to observe the state of charge of the battery.

The significance of the study is that it will serve as a basis of any study regarding DC-DC converter applied to renewable energies more specifically solar energy. This research will also serve as benchmark of any further study on buck-boost DC-DC Converter and lastly this research will be an additional knowledge on applications of DC-DC converters and fuzzy logic controller.

The scope of the study is that buck-boost converter and fuzzy logic controller are to be integrated to create a solar charging system. The solar panel has a rating of 10 W and the battery ratings used were 6 V, 9 V and 12 V so that buck and boost of input voltage can be applied. Triangular membership function was used for the fuzzy logic controller. However, overcurrent protection, overvoltage protection, over temperature protection and maximum power tracking were not included in the design of the circuit.

2. Methodology

Figure 1 shows the conceptual framework of the whole system. The prototype was mainly tasked to charge batteries with different voltage ratings of 6 V, 9 V and 12 V. The design was composed of two main systems: the fuzzy controller and DC converter system. These systems were activated in sequential order starting from the detection of system voltages done by the fuzzy controller. The system works by comparing the solar panel voltage to a reference voltage to produce an error signal which is analyzed by the fuzzy controller to determine the required PWM duty cycle.

As shown in Figure 2, the beginning of the procedure was to design and construct a buck-boost converter for photovoltaic cells. The design of buck-boost converter includes sizing of components that will be used. After testing the converter, the fuzzy logic controller was developed using MATLAB software. The MATLAB fuzzy inference system (.fis) file was then converted to Gizduino code. After a successful program compilation, the whole system was integrated by connecting the microcontroller to the buck-boost converter together with the solar panel and the batteries to be charged. The voltage method was used in this research in determining the state of charge of the battery. By knowing the minimum and maximum voltage of each battery, the percentage state of charge of the battery was computed using the formula below.

$$\%SOC = \frac{V_{bat} - V_{\min}}{V_{\max} - V_{\min}} \times 100\% \quad (1)$$

Lastly, data has been gathered and analyzed when the whole system is already functioning.