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PI and Fuzzy Logic Control of Photovoltaic Panel Powered Synchronous Boost Converter

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Abstract

In this paper, control of DC/DC synchronous boost converter for photovoltaic panels with different controllers is simulated in the Matlab/SIMULINK software. Firstly, synchronous boost converter is simulated, and then regarding to the changes in reference and source voltages traditional PI and Fuzzy Logic control is achieved. Results obtained are analyzed and compared.

Keywords : Synchronous; Boost Converter; PI; Fuzzy Logic

Fotovoltaik Panel Beslemeli Senkron Artıran Çeviricinin PI ve Bulanık Mantık Denetimi

Özet

Bu çalışmada fotovoltaik paneller için DC/DC senkron artıran çeviricinin farklı denetleyicilerle denetimi Matlab/SİMULİNK ortamında benzetim yapılarak yapılmıştır. İlk olarak senkron artıran çevirici benzetimi yapılmıştır ve sonrasında çeviricinin referans gerilim değişimi ve kaynak gerilim değişim durumları altında, geleneksel PI ve Bulanık Mantıkla denetimi yapılmıştır. Denetim sonuçları analiz edilerek sonuçlar karşılaştırılmıştır.

Anahtar Kelimeler: Senkron; Artıran Çevirici; PI; Bulanık Mantık

1. Introduction

As the usage of electrical energy continuously increasing this also brings so many problems in together. Problems in providing fossil energy resources, environmental disasters, increasing in energy consumption, in order to stay away from nuclear energy disputes are being the reason of global disagreements and even the wars. Therefore in recent years financial losses as the result of not to providing energy demand properly, regional electricity cut-offs directed people to the renewable energy sources for their clean and reliable energy needs [1].

Approximately 20 % of the energy needs is being provided from renewable energy sources in the world, in Turkey this figure is almost in the rate of 9 % only [2-3]. Electrical energy generated from sun as one of those energy sources is usually obtained by using photovoltaic (PV) panels. While total generated energy from this type of energy was 177 GW in 2014, at the beginning of 2016 this figure reached 227 GW. As in January 2017 in Turkey, this figure has exceeded 860 MW [3]. With regard to the installed power, respectively China, Germany and Japan are the leader countries in this sector [2]. According to the load or systems energy to be provided, whether they are DC or AC, power electronic circuits differ from one to another[4-5].

In order to meet the needs of DC sources, PV systems are in need of boost, buck or buck-boost converters. According to their circuit structures these converters increase or decrease input voltages, at the same time if they include a diode in their circuit, they are called asynchronous converter, or if they include a switch instead of a diode are called synchronous converters (Figure 1-a and -b).

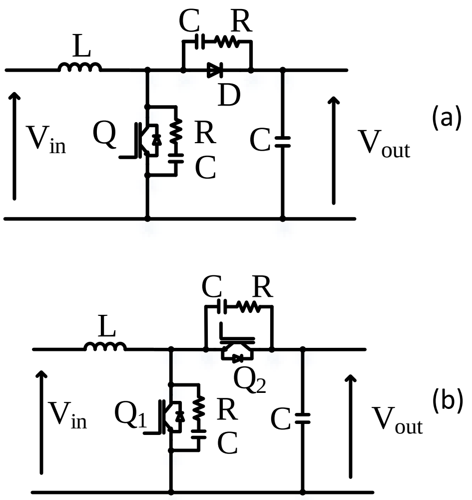

Figure 1. (a) Asynchronous Boost Converter
(b) Synchronous Boost Converter

In the synchronous converters using a switch instead of diode , as there will not be a voltage drop in forward direction their efficiencies are higher than asynchronous converters[5,6]. Another advantage of synchronous converters output voltage is constant when it is controlled even in no load case. Output voltage in both converter types will be changed with the solar irradiance, temperature and load. In order to fix this output voltage it must be controlled. In the literature there are papers in controlling of synchronous converter [6,7]. Beside these works, in [8] maximum power point tracking in distributed grids, cost and efficiency analysis are verified for asynchronous and synchronous converters. Efficiency of synchronous type converters reached up to 98 %.

In the controlling of converters are implemented in different ways based on current or voltage. Aims of controlling can be sequenced as maximum power transfer, reactive power control, bus voltage stability and providing load with the quality power supply[9,10]. In [11] fuzzy logic control of buck converter is done for water electrolysis. Beside this in [12], radiant control of synchronous converter is done in case of changing LEDs' status ON or OFF.

In this study, design of a PV panel powered synchronous boost converter is made and then fuzzy logic and PI control under varying source and reference voltage cases, the results obtained are compared and proper control method is proposed.

2. General Description of The System

General block diagram of a PV panel powered converter is in Figure 2. System structure includes a PV panel, a synchronous converter, a filter and a control unit.

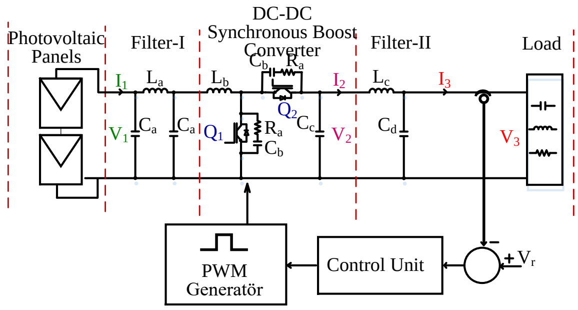

Figure.2. Systems' General Diagram

2.1. Synchronous Boost Converter

Synchronous boost converter transfer D.C. voltages applied to their inputs by boosting to their outputs according to duty-cycle of switches (Figure 1-b). DC voltage that is generated PV panel will be boosted by synchronous boost converter. Then filtering output filter, this voltage will supply to load

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

Where, V_{out}: output voltage, V_{in} : input voltage and D is the duty-cycle.

Output voltage of a synchronous boost converter is basically determined by the duty-cycle of Q_1 switch. Q_1 and Q_2 are opposite switches. When one is ON, the other is OFF. Switching frequencies are 100-1000 times higher than asynchronous converter. Despite in such higher frequencies switching causes to be smaller passive circuit components in greater power systems causes more losses. Therefore faster semiconductor materials and better switching actions are needed.

2.2. Controller Structure

System controlling depends on synchronous converter control. Classical PI controller and fuzzy logic controllers will be used to stabilize the voltage at the output of converter. Output voltage readings will be compared with reference voltage, the difference between those is the error. In both controllers to decrease the error, to the Q_1 and Q_2 switches of converter, Pulse Width Modulation (PWM) signal will be produced.

$$e(k) = r(k) - y(k) \quad (2)$$

Where, e(k): error signal, r(k): reference signal and y(k): output signal.

2.2.1. Fuzzy Logic

Fuzzy logic controller without being in need of a mathematical model adjusts the input signal according to the output signal. System variables is designed for system control. Output voltage of boost converter can be controlled by changing the duty-cycle of the switch used. The error in equation (2) and the changing error in equation (3) are inputs of fuzzy logic controller

$$de(k) = e(k) - e(k-1) \quad (3)$$

Where, de(k) change in error is obtained from subtracting previous value of error.

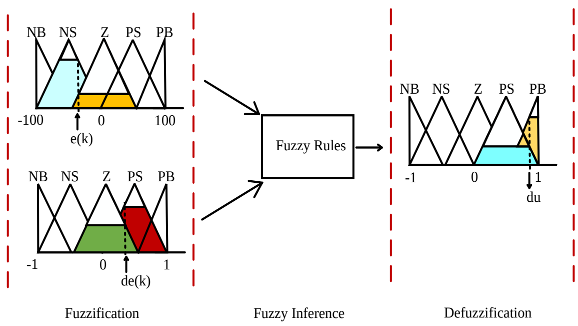

Figure.3. Fuzzy Main Diagram

Fuzzy Logic Controller as it is seen in Figure 3 becomes combination of three parts as fuzzification, rule base and defuzzification. Input and output membership functions chosen as a triangle. Two inputs signals, five membership functions converted fuzzy membership by using Positive Greater (PG), Positive Smaller (PS), Zero (Z), Negative Smaller (NS) and Negative Greater (NG).

After the fuzzification process, rules in Table.1 is applied to determine fuzzy memberships of equalized output signal. Finally, by using the max-min method definite results is obtained. In order to confirm Fuzzy Logic Parameters a better control can be provided by the trial and error method.

Table.1. Rule Base

		de				
		NB	NS	ZZ	PS	PB
e	NB	NB	NB	NS	NS	ZZ
	NS	NB	NS	NS	ZZ	PS
	ZZ	NS	NS	ZZ	PS	PS
	PS	NS	ZZ	PS	ZZ	NS
	PB	ZZ	PS	PS	PB	PB

These definite values will be given PWM generator, and according to the duty cycle values PWM will generate two signals inverse of each other, at high frequencies that will be applied to the switches by this mean error will approach to zero.

Fuzzy Logic can be applied to different control systems with fundamental alterations, for detailed information refer to [13,14].

2.2.1. PI Controller

A PI controller is designed to approach to zero the error between the output voltage and the reference voltage such as fuzzy logic controller. In figure 4, a PI controller block diagram is seen.

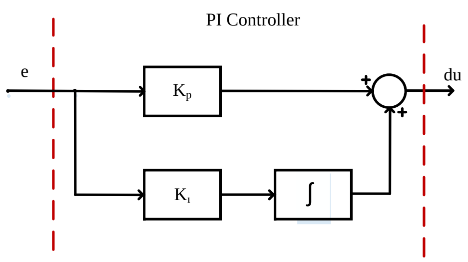

Figure.4. PI Controller Block Diagram

Output of the PI controller like fuzzy logic controller generates PWM signal according to du signal at its output, so the error becomes zero.

3. Simulation Work

In this section, system simulation of a PV panel powered synchronous boost converter with DC loads is done in Matlab/SIMULINK software. Simulation works are accomplished under variable reference and source voltages. Output voltage is controlled by PI and Fuzzy Logic Controllers. Used system parameters are given in Table.II.

Table.2. Parameters of the System

Photovoltaic Panel		Synchronous Boost Converter	
$V_{open-circuit}$	37.6 V	L_b	2.55 uH
$I_{short-circuit}$	8.55 A	R_a	33 Ohm
N_{serial}	1	C_b	300 pF
$N_{parallel}$	2	C_c	1 mF
$T_{ambient}$	25 °C	f_s	100 kHz
$S_{ambient}$	1000W/m^2		
Filter-I		**Filter-II**	
L_a	16.2 uH	L_c	0.338 uH
C_a	33 uF	C_d	10 mF
Load			
P	0.5kW		

Control results of a PV powered high frequency switching synchronous boost converters' PI and Fuzzy Logic controls are shown in Figure 5 and 6 respectively. In the case of synchronous boost converter output voltage changes with a defined reference voltage and changing of source voltage with the light intensity. Therefore, indirectly changing in the source voltage, output voltage did not change are shown. In Figure 6 similar situations for Fuzzy Logic controller are valid.

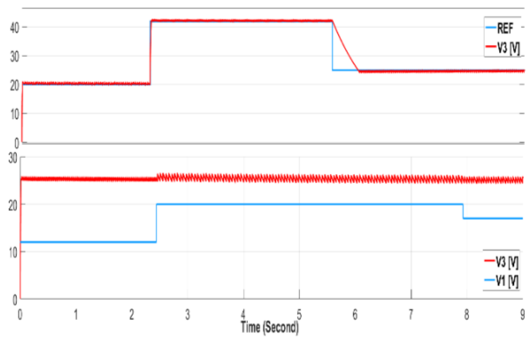

Figure.5. PI Control Results of the System

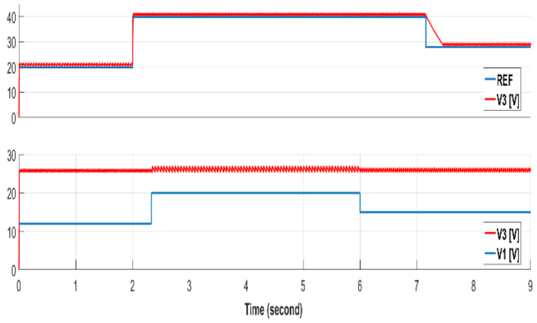

Figure.6. Results of Fuzzy Logic Control of the System

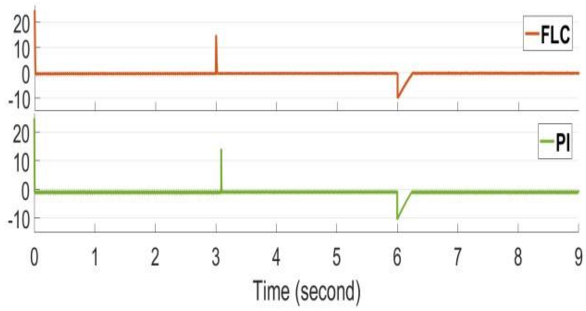

Figure.7. the Change of the Error in Variable Reference Voltage for Both Controller

Where, V1: PV output voltage, V3: Synchronous boost converter output voltage, REF: Reference Voltage. FLC: Fuzzy Logic Controller.

4. Results

In this study, output voltage of a PV panel powered synchronous boost converter PI and Fuzzy logic control is done. In the simulation work, in case of changing in source voltage and reference voltage, PI and Fuzzy Logic control of output voltage show that it is precisely stabilized. When Fuzzy Logic controller gives faster response to the changings in reference voltage, lesser overshoot rate with respect to PI controller are observed. Both control methods give faster response to any increases in reference voltage but in case of any decreases in reference voltage both methods give slow response. In accordance with these results it is observed that fuzzy logic control is better than PI control.

Because of the developments in power electronics in recent years when switches working at high frequencies will be commercially available, it is expected that usage of high power synchronous converters will increase, also their efficiencies are higher.

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