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Fractional Order PID Controlled PV Buck Boost Converter with Coupled Inductor

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ABSTRACT

Buck-boost converter is a good interface between PV and the load. This paper deals with comparison between PI and FOPID controlled PV fed Buck Boost Converter with Coupled Inductor (PVBBCCI) systems. Open loop PVBBCCI system, closed loop PI controlled PVBBCCI and FOPID based PVBBCCI systems are designed, modeled and simulated using Simulink and their results are presented. The investigations indicate the superior performance of FOPID controlled PVBBCCI system. The proposed system has advantages like reduced hardware count enhanced dynamic response and improved stability.

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1. INTRODUCTION

Fractional Order Controller has got attention of engineers because it can improve the system stability and reduce the chaoitics [1]. This article has presented the basics of some applications like robotics. This paper has presented the behavior of control system over wide range of operation. The comparison of responses with proportional integral derivative and fractional order proportional integral derivative controller for voltage regulation is given by Verma [2]. The method of selection of parameters for fractional order proportional integral derivative controller is discussed in this paper. This paper has given comparison of results using Ziglear-Nicholo's method and Coon method. A tutorial on fractional order controller is given by Chen [3]. The differentiation and integration with non integer order is presented in this paper and various numerical methods for simulating fractional order proportional integral derivative based systems are discussed. The practical applications of fractional order proportional integral derivative controller are given by Sandhya [4]. This paper deals with auto tuning of fractional order proportional integral derivative controllers. The application of fractional order proportional integral derivative controller for co-operative cell is presented in this paper. Motion control using fractional order proportional derivative controller is given in Luo [5]. A simple method for designing a fractional order proportional derivative controller is presented for second order plants and design is validated by simulation and experimental results. Tuning of fractional order proportional integral controller is given by Sheng [6]. This paper has presented the desired controlled performance robustness of the proposed fractional order proportional integral system. This paper has presented experimental step response and disturbance rejection. A soft computing technique for PV system is given by Salam [7]. The optimization using fuzzy logic and swam intelligence are presented in this paper.PID controller design and its response for DC DC converter is given by Ibrahim. This paper has discussed brief design of five methods of tuning of PID controller with mathematical analysis [8]. Modeling and Analysis of new approach of controller for boost and buck Converter is given by Roy Choudhury. This paper deals with control method for buck boost converter by keeping the switching frequency constant [9]. Comparison of sine and space vector modulated EZSI is given by Malathi. In this paper sinusoidal space vector modulation methods are compared to generate gating pulses for the switches [10].

The literatures [1] to [10] do not deal with comparison of PI & FOPID based PVBBCCI systems to improve the dynamic response. This work proposes FOPID to improve dynamic response of PVBBCI system. The organization of the paper as follows: the system description is given in section 2. Analysis is presented in section 3. Simulation results with PI and FOPID are given in section 4. Hardware results are given in section 5. Work is concluded in section 6.

2. SYSTEM DESCRIPTION

Block diagram of existing Buck-Boost Converter System (BBCS) is shown in Figure 1. Fixed DC is converted into variable DC using BBCS and its output is applied to DC load [11].

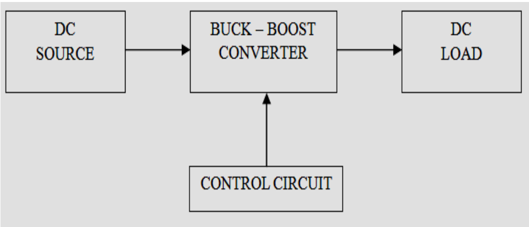

Figure 1. Block Diagram of existing BBCS

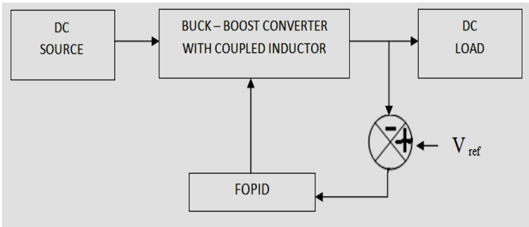

Figure 2. Block Diagram of proposed PVBBCC system

In proposed system BBC is replaced by BBCCI. Output voltage is regulated using FOPID as shown in Figure 2. The load voltage is compared with the reference voltage and the error voltage is applied to FOPID controller. The FOPID generates the updated gate pulses to regulate the output voltage of BBCCI system.

3. ANALYSIS OF BUCK – BOOST CONVERTER

The Equations for Buck Boost converter are as follows Inductance (L) and Capacitance (C) are calculated using following formula

$$L = V_1K / f\Delta I \quad (1)$$

$$C = K/2fR \quad (2)$$

Where

V_1 = PV input voltage
K = Duty ratio
f = Switching frequency
ΔI = change in current
R = Load resistance

Output of FOPID is related to input as follows

$$V_2(S) = E(S)\,K_1 + E(S)\,K_2/S^m + E(S)\,K_3S^n \quad (3)$$

Where

V_2 = Output voltage
E(s) = Error voltage
K_1 = Proportional constant
K_2 = Integral constant

K_3 = Derivative constant

m & n are fractional values

Steady state error is

$$E_{ss} = V_{ref} - V_2 \quad (4)$$

Efficiency is calculated using

$$\eta = V_2 I_2 / V_1 I_1 \quad (5)$$

4. SIMULATION RESULTS

Open loop PVBBCCI system with change in input is shown in Figure 3.1. A change in irradiation is considered to see the variation in output [12]. The input voltage is shown in Figure 3.2 and its value is 15 V. The output voltage is shown in Figure 3.3 and its value is 75 V. The output current is shown in Figure 3.4 and its value is 1.2 A. The output voltage is shown in Figure 3.5 and its value is 100 W. The increase in output power is due to the increase in input voltage.

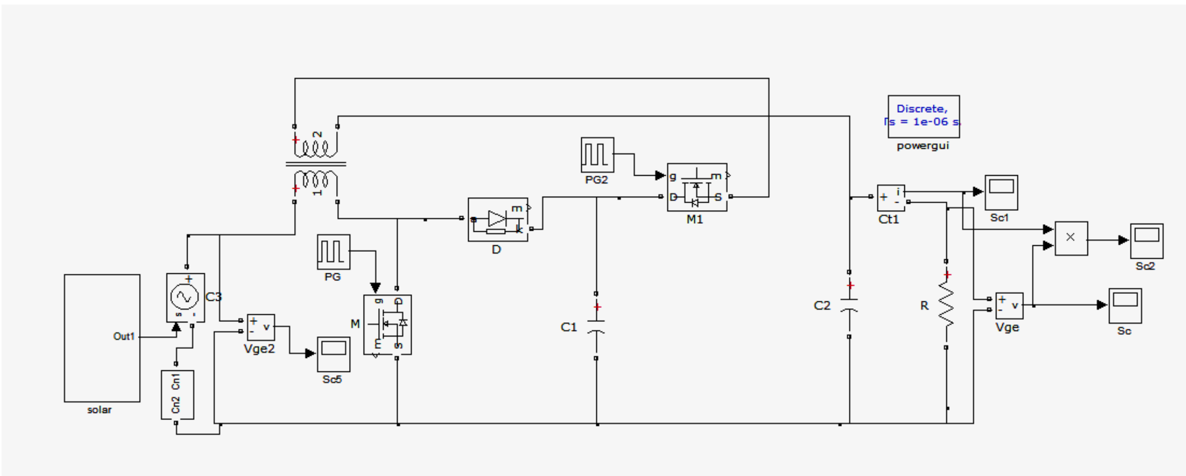

Figure 3.1. Open loop BBCCI system with change in input

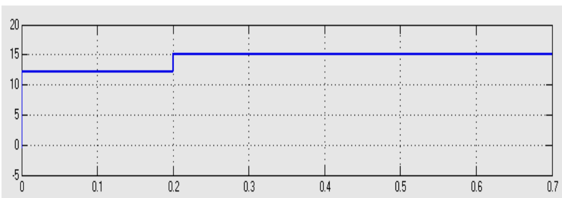

Figure 3.2. Input voltage

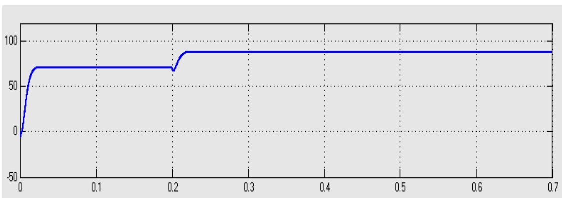

Figure 3.3. Output voltage of PVBBCCI

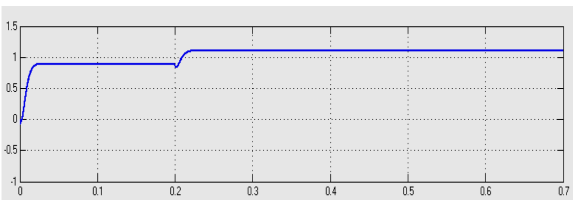

Figure 3.4. Output current of PVBBCCI

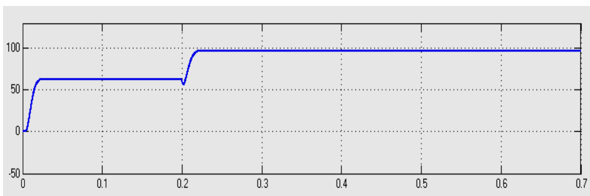

Figure 3.5. Output power of PVBBCCI

Closed loop PVBBCCI system with PI controller is shown in Figure 4.1. The input voltage is shown in Figure 4.2 and its value is 15 V. The output voltage is shown in Figure 4.3 and its value is 75 V. The output current is shown in Figure 4.4 and its value is 1 A. The output power is shown in Figure 4.5 and its value is 75 W. The output voltage is compared with reference voltage. The error is applied to the PI controller. The output of PI applied to the comparators. The comparators produce updated pulses for the two MOSFETs. The output parameters are regulated by using PI controller. The summary of simulation parameters are given in the Table 1.

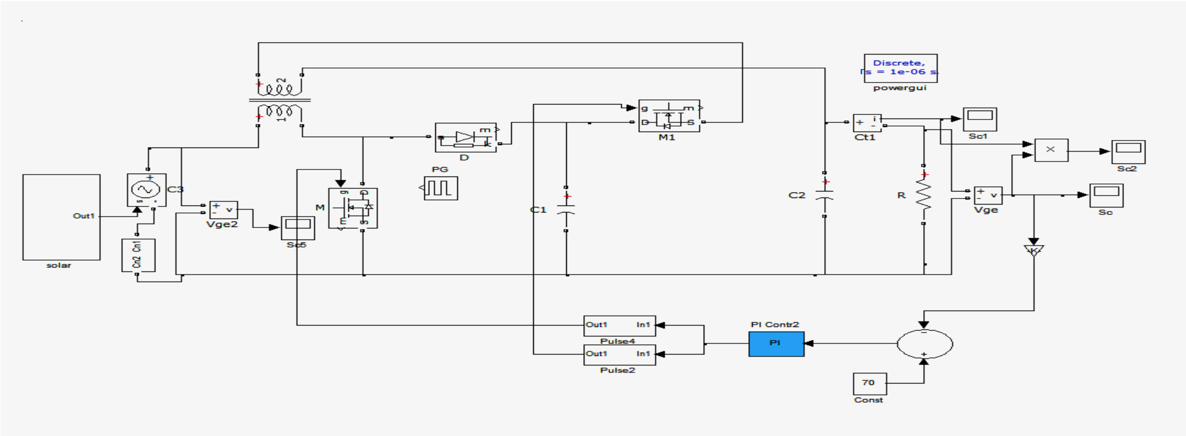

Figure 4.1. Closed loop PVBBCCI system with PI controller

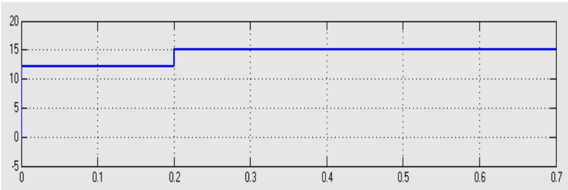

Figure 4.2. Input voltage

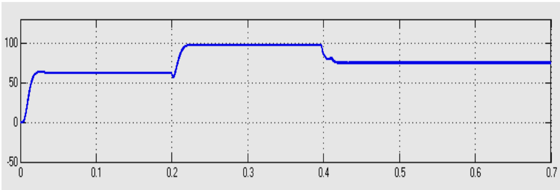

Figure 4.3. Output voltage of PVBBCCI

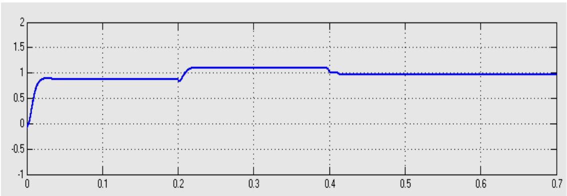

Figure 4.4. Output current of PVBBCCI

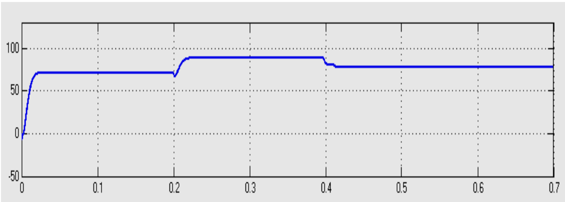

Figure 4.5. Output power of PVBBCCI

The Buck-Boost converter small signal model having non linear function across the duty cycle is presented in this section. FOPID uses fractional values for the powers of s in differentiator and integrator. The closed loop FOPID controlled system is shown in Figure 5.1. The input voltage is shown in Figure 5.2 and its value is 15V. The output voltage is shown in Figure 5.3 and its value is 75 V. The output current is shown in Figure 5.4 and its value is 1A. The output power is shown in Figure 5.5. The comparison of time domain parameters is shown in Table 2. The settling time is reduced from 0.42 to 0.28 second and steady state error is reduced from 1.3 V to 1.1 V using FOPID controller.

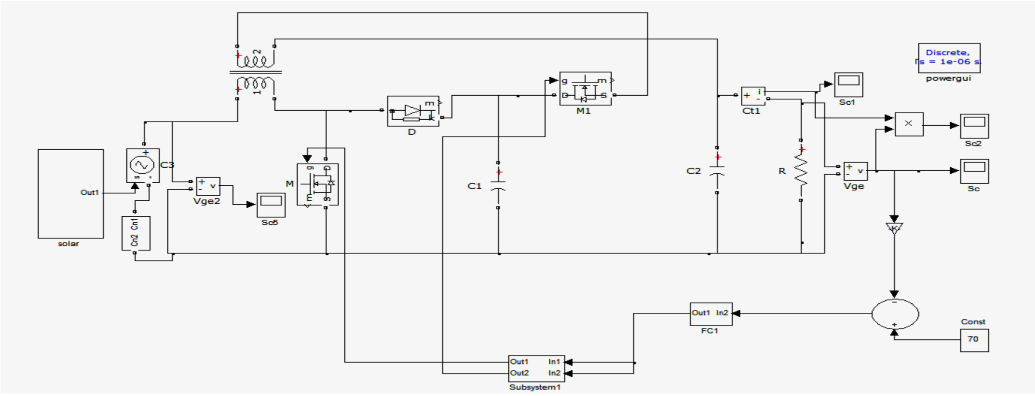

Figure 5.1. Closed loop PVBBCCI system with FOPID controller

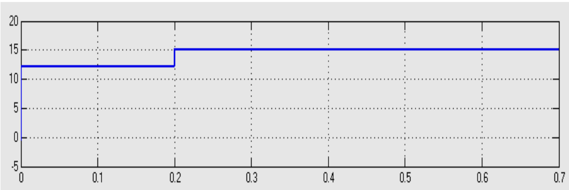

Figure 5.2. Input voltage

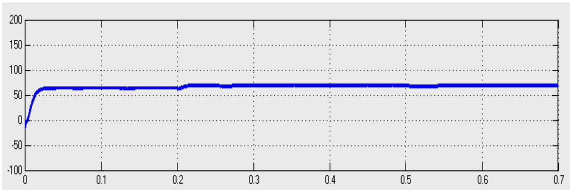

Figure 5.3. Output voltage of closed loop PVBBCCI

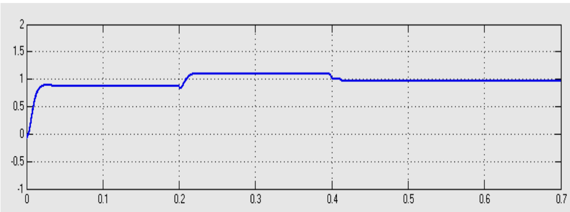

Figure 5.4. Output current of closed loop PVBBCCI

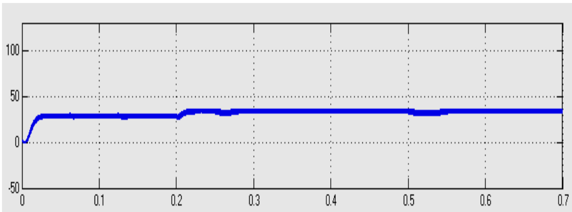

Figure 5.5. Output power of closed loop PVBBCCI

Table 1. Summary of Simulation Parameters

Specifications	Parameters Value
V_{IN}	12V
L_1	0.1mH
C_1	6.6µF
C_o	50µF
K_p	0.018
K_i	0.65
K_f	0.32
K_d	0.9
MOSFET (IRF840)	500V/8A
Diode	230V/1A
R_{Load}	80Ω

Table 2. Summary of Time Domain Parameters

Type of Controller	t_r (sec)	t_p (sec)	t_s (sec)	E_{ss}(Volts)
PI	0.23	0.3	0.42	1.3
FOPID	0.22	0.27	0.28	1.1

5. EXPERIMENTAL RESULTS

Hardware snap shot for PVBBCCI with FOPID is shown in Figure 5.1. The hardware consists of PV panel, control board, rectifier board and BBCCI board. The input voltage is shown in Figure 5.2. The

Switching pulses for M_1 and M_2 are shown in Figure 5.3. The Output voltage of PVBBCCI is shown in Figure 5.4. The display of output voltage is shown in Figure 5.5. The simulation results of previous section match with the experimental results.

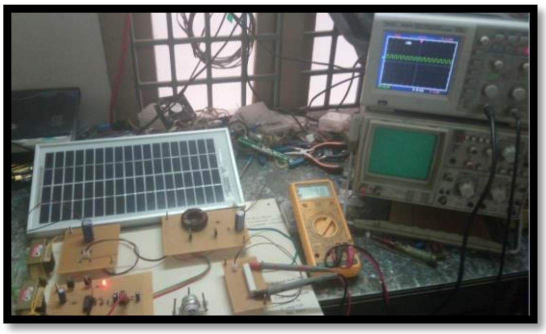

Figure 5.1. Hardware snap shot

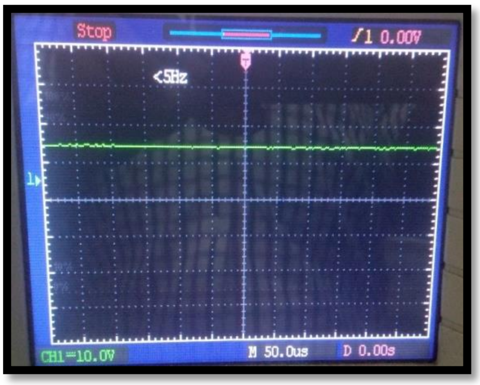

Figure 5.2. Input voltage

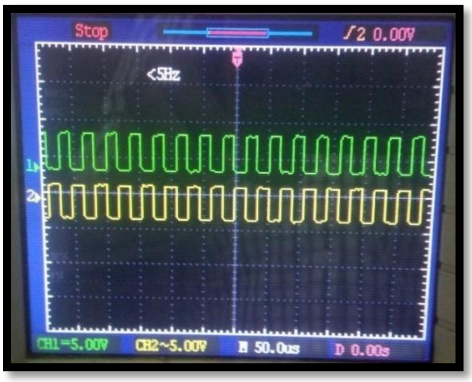

Figure 5.3. Switching pulses for M_1 & M_2

Figure 5.4. Output voltage of PVBBCCI

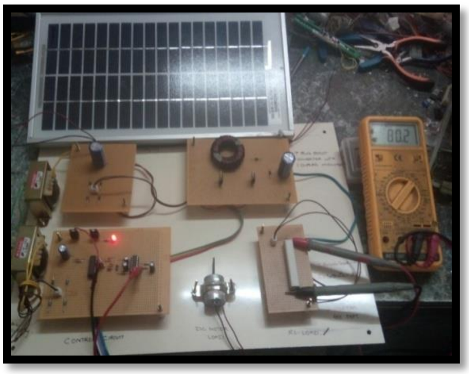

Figure 5.4. Display of hardware output voltage

6. CONCLUSION

PV based BBCCI system is investigated with a step change in solar irradiation. The output voltage is regulated using PI & FOPID controllers. The responses are compared in terms of rise time, peak time, settling time and steady state error in output voltage. The settling time with FL controller is reduced to 0.03 sec and steady error is reduced to 1.1V. Therefore FOPID based PVBBCCI system is superior to PI based

PVBBCCI system**.** The hardware is constructed and the hardware results are presented. The hardware results are similar to simulation results. The scope of the present work is to compare PI controlled PVBBCCI with FOPID controlled PVBBCCI system. The comparison with hysteretic controlled PVBBCCI system will be done in near future. The PVBBCI can be extended to handle high power.

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