



Design of Controller For Non-Isolated Three Port Buck-Boost Dc-Dc Converter

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Abstract

A new non-isolated three port buck-boost converter with simple model is given in this paper. The proposed converter work for wider positive output application. The new non-isolated three port converter has two switches both operate synchronously. The proposed converter output squared times greater than conventional buck-boost converter. In continuous conduction mode, two inductors are magnetized while two capacitors are demagnetized during switch on mode, and vice versa in switch off mode. PI and PID controllers are designed and comparative study is given in this paper. PID gives better steady state response than PI controller. Large signal averaging, small signal analysis of converter presented in detail. The simulation results are provided which validate the effectiveness of the controller.

Key Words: Buck-Boost converter, PI and PID controller, Three port converter

1 INTRODUCTION

Nowadays renewable energy have more demand and grooving interest in generating electricity from distributed renewable energy sources. Energy sources such as PV, wind, biogas, biomass etc but

these energy sources are intermittent and unpredictable so they are not highly reliable. Converter mostly used in renewable sources [11]. Converter can be defined as converting electrical energy it may be converting AC energy into DC or DC energy into AC energy. There are four types of basic converter i.e Inverter, Rectifier, Chopper and Cycloconverter. There are three chopper converter such as buck converter, boost converter, buck-boost converter, zeta converter etc these all converters are DC-DC types. Buck converter reduce output voltage than input voltage while boost converter increase output than input voltage and buck-boost converter increase or decrease depending on load. Buck converter as well as boost converter are simple and having high efficiency [9]. Here in this three port non isolated converter two input and one output. Battery is connected for excess of high energy [4]-[6]. The recent research going on multi-input and multi-output converter which improve the efficiency as well as power density by weight and power density by volume [1]

The output of solar energy is variable, during morning and evening time it generate more output while in afternoon its output less than compare to morning time and in night time it cant generate electricity. So first need to connect chopper it convert variable DC into constant DC. And after that inverter for AC application. The objective of my paper are to design PI, PID to get steady state response also to integrate battery into system to excess of energy during deficiency period. Buck-boost converter can obtain high voltage gain. The three port converter can step-up or step-down voltage, regulate the output voltage, and bucking or boosting converter [10][7]. Traditional buck-boost converter has high efficiency, it has drawback such as negative output voltage and also discontinuous output voltage and current [4]. There are other non-isolated converter such as Cuk, Sepic and Zeta converter, which also property of step-up and step-down voltage.

This paper is organized as follows. In section II, the modified buck-boost converter structure is presented in detail, the modes of operation. The large and small signal averaging presented in section III. The simulation diagram of PI and PID controller presented in section IV. In section V, it explain the experimental result and in last section explained the conclusion of this paper.

2 MODIFIED BUCK-BOOST CONVERTER

In this given Circuit two inductor and switches are used. There are two modes of operation, in mode 1 both switches are on while in Mode 2 both switches are off. The main advantages of this modified proposed converter is having less losses and high efficiency compare to traditional buck-boost converter. The modified converter is shown in fig.[12]

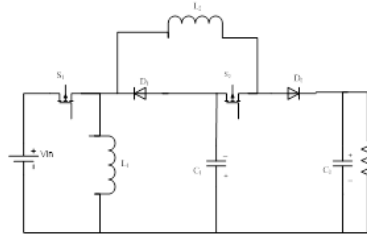


Fig.1.Proposed Buck-Boost converter

The load given in circuit is mainly resistive like DC motor. Boost converter is used for storage purpose. Boost converter is act as a battery it gives supply to load when PV is not operating While PV at peak load it store energy into battery [12]. Battery connection with converter is difficult it take time to reach steady state response. The given converter is used for the stand alone system. The modes of operation are given below.

Here, simplify the converter analyses, it assumed that the converter operate in steady state, components are ideal [2][8].

Mode 1- Switch S_1 and S_2 are ON

The switch S_1 short circuited the inductor L_1 .As a result I/P voltage is induced across it. The inductor L_2 gets magnetized through the capacitor C_1 and input source V_{in} as the switch S_2 is also conducting in this mode. The O/P voltage is maintained by the filter capacitor.

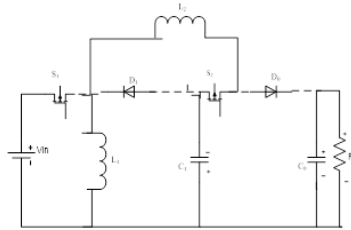


Fig.2.Mode 1

$$V_l = V_{in} \quad (1)$$

$$V_{l2} = V_{c1} + V_{in} \quad (2)$$

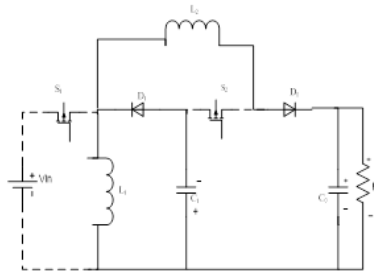


Fig.3.Mode 2

In this mode, the switch S1 and S2 are open and S3 is closed to charge battery, The capacitor C1 and C0 gets charged by inductor L1 and L2 respectively [12].

$$V_l = -V_{c1} \quad (3)$$

$$V_0 = -(V_{l2} + V_{c1}) \quad (4)$$

Mode 3

In this mode, the switch S3 is closed for boosting operation. All the other switches are in open condition. Inductor L3 is short circuited through the switch S3.

From the voltage balance equation we get,

$$V_{c1} = \frac{D}{1-D} * V_{in} \quad (5)$$

$$V_0 = [\frac{D}{1-D}]^2 * V_{in} \quad (6)$$

Equation 6, which is the O/p equation of the PV connected buck-boost converter is obtained by substituting

$$V_{l2} = -\frac{V_0}{D} \quad (7)$$

In this equation, Where D is the duty cycle;

$$D = \frac{T_{on}}{T_{on} + T_{off}} \quad (8)$$

3 LARGE AND SMALL SIGNAL AVERAGING

Large signal model is generally used for analysis of non-linear devices [3]. Hence the state variables are expressed in terms of steady state and transients

During $t = T_{on} = DT_s$

$$L_1 \frac{di_1}{dt} = v_{in} \quad (9)$$

$$L_2 \frac{di_2}{dt} = v_{in} + v_{c1} \quad (10)$$

$$C_1 \frac{dv_{c1}}{dt} = -i_{l2} \quad (11)$$

$$C_0 \frac{dv_0}{dt} = -\frac{v_0}{R} \quad (12)$$

The left hand side terms are instantaneous values which is expressed in terms of Steady state and transients

During T_{on} time, inductor charge shown in equation (8)&(9) while capacitor discharge shown in (10)&(11)

During $t = T_{off} = (1 - D)T_s$

$$L_1 \frac{di_{l1}}{dt} = V_{c1} \quad (13)$$

$$L_2 \frac{di_{l2}}{dt} = -(V_0 + v_{c1}) \quad (14)$$

$$C_1 \frac{dV_{c1}}{dt} = i_{l1} + i_{l2} \quad (15)$$

$$C_0 \frac{dV_0}{dt} = i_{l2} = -\frac{V_0}{R} \quad (16)$$

During T_{off} time, inductor discharge shown in equation (12) & (13) while capacitor charge shown in (14)&(15)

A. LARGE SIGNAL AVERAGING

$$L_1 \frac{di_{l1}}{dt} = v_{in}D - v_{c1}(1 - D) \quad (17)$$

$$\frac{di_{l2}}{dt} = (v_{in} + v_{c1})D + (v_o + v_{c1})(1 - D) \quad (18)$$

$$C_1 \frac{dv_{c1}}{dt} = -i_{l2}D + (i_{l1} + i_{l2})(1 - D) \quad (19)$$

$$C_0 \frac{dv_{c0}}{dt} = -\frac{v_0}{R}D + (i_{l2} - \frac{V_0}{R})(1 - D) \quad (20)$$

$$\dot{x} = Ax + Bu$$

Where “A” is the system property matrix “B” is the input sealing matrix “C” is the require input matrix “D” is the set of variable matrix

$$\det[A] = |A| = \frac{1-D}{L_1} \cdot (-\frac{1-D}{L_2}) \cdot \{\frac{1-D}{C_1} \frac{1-D}{C_0}\} \quad (21)$$

$$\det[A] = \frac{(1-D)^4}{L_1 L_2 C_1 C_0} \quad (22)$$

$$\det[A] = \frac{1}{|A|} \cdot \text{adj}[A] \quad (23)$$

$$\frac{V_0}{V_{in}} = \frac{L_1 L_2 C_1 C_2}{(1-D)^2} \left\{ -\frac{D(1-D)^2(1-2D)}{L_1 L_2 C_1 C_0} + -\frac{D(1-D)^3}{L_1 L_2 C_1 C_0} \right\} \quad (24)$$

$$\frac{V_0}{V_{in}} = \left[\frac{D}{1-D} \right]^2 \cdot v_{in} \quad (25)$$

B. SMALL SIGNAL AVERAGING

The perturbation are added as follows

$$i_{l1} = I_{L1} + i_{L1}^\mu \quad (26)$$

$$i_{l2} = I_{L2} + i_{L2}^\mu \quad (27)$$

$$v_0 = V_0 + v_0^\mu \quad (28)$$

$$v_{c1} = V_{c1} + v_{c1}^\mu \quad (29)$$

$$d = D + d^\mu \quad (30)$$

The small signal averaging is suitable for application of average inductor current need to control. The efficiency can be calculated by equations (23)&(24)

$$\frac{V_0^\mu}{V_{in}^\mu} = \frac{6.1414 * 10^7 (S^2 + 8.5 * 10^5)}{(S^2 + 40.74S + 6.12 * 10^5)(S^2 + 389.4S + 5.542 * 10^7)} \quad (31)$$

$$a_1, a_2 = 54.05 \pm 847.86i \quad (32)$$

$$b_1, b_2 = -20.37 \pm 782.039i \quad (33)$$

$$c_1, c_2 = -194.7 \pm 744.9i \quad (34)$$

where,

$$x = 3.79 * 10^5$$

$$a=847.86$$

$$b=54.05$$

$$c=782.039$$

$$d=20.37$$

$$e=7441.915$$

$$f=194.7$$

$$180 = \tan^{-1} A + \tan^{-1} B \quad (35)$$

By solving above equation we get the values of A&B

$$A = \frac{7158.4W + W^2}{2.2044 * 10^{11} + 308008.1W^2} \quad (36)$$

$$B = \frac{2W(567713314.1 + 976.73W^2)}{3.3824 * 10^{18} + W^2(55346308.86 + W^2)} \quad (37)$$

$$180 = \tan^{-1} A + \tan^{-1} B = \frac{A - B}{1 - AB}$$

By putting above values we get,

$$W = -2.3386R + 2.3386$$

$$-M = 168.40$$

$$K_c = \frac{1}{M} = 0.0059382$$

$$P_C = \frac{2\pi}{W} = 2.6867$$

Proportional Controller:

$$K_p = 0.45, K_c = 0.00267, K_i = 2.23$$

Proportional Integral and Derivative Controller

$$K_p = 0.00356$$

$$K_i = 1.3433$$

$$K_d=0.33583$$

Where, K_p = Ultimate gain

T_u = It is oscillation period

Mostly Trial and error method and Zigler-Nichols methods are used in tuning of PID controller. This is acceptable method for some result but not for all application[13][14]. Given table gives the tuning values by Zigler-Nichols method.

TABLE 1 Zigler-Nichols Method

Controller	K_p	K_i	K_d	V_{ref}	Error
PI	0.0251	0.12		27	0.1%
PI	0.009	0.12		35	0.5%
PID	0.0052	0.12	5×10^{-6}	35	0.2%
PID	0.0052	0.12	5×10^{-6}	40	0.1%

4 CONTROLLER

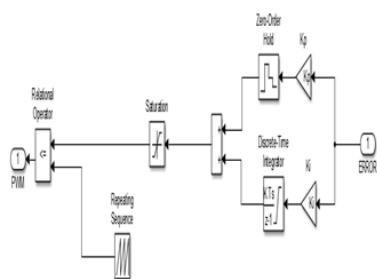


Fig.4. Simulation of PI controller

5 EXPERIMENTAL RESULT

PI Controller-

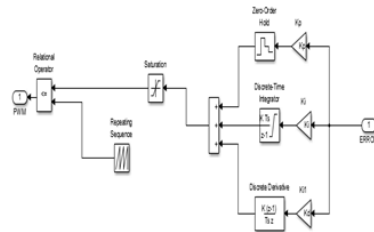


Fig.6. Output voltage and current with battery at 27Vref

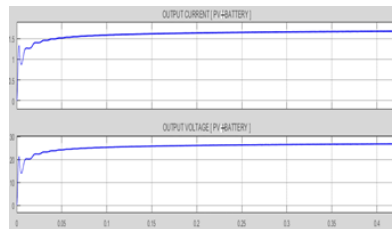


Fig.7. Output voltage and current with battery at $27V_{ref}$

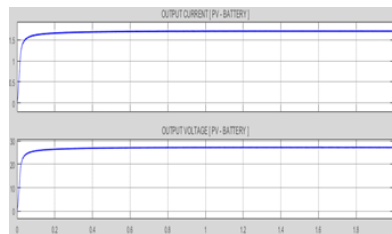


Fig.8. Output voltage with battery at $27V_{ref}$

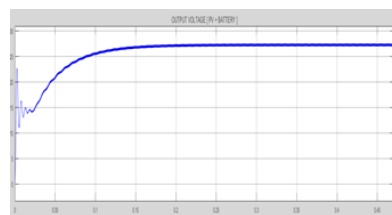


Fig.8. Output current with battery at $27V_{ref}$

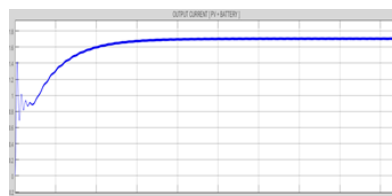
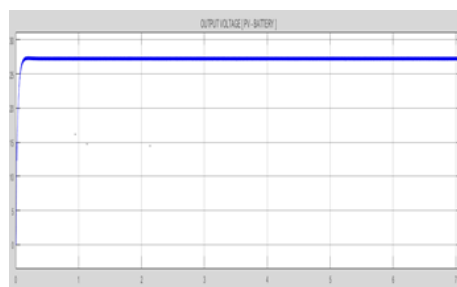


Fig.10. Output voltage without battery at $27V_{ref}$ Fig.11. Output current without battery at $27V_{ref}$

6 Conclusion

This paper has proposed a new non-isolated three port buck-boost converter as a fourth order circuit, which minimize drawback of traditional buck-boost converter. The operating principles of proposed converter, small signal modelling presented. The proposed converter has been simulated with satisfactory output result in Mat-Lab Simulink environment. The DC gain of the proposed converter has been found to be higher than traditional buck-boost converter. The design and analyses of PI and PID controller has been simulated with satisfactory result. The output voltage and current of controller shown in result. Hence, the new non-isolated three port buck-boost converter is use for industrial application requiring high step up and step down voltage gain

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