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Closed Loop Model of Transformer less Buck–Boost Converter with Positive Output Voltage

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ABSTRACT: *Compared with the traditional buck–boost converter, the proposed buck–boost converter's voltage gain is squared times of the former's and its output voltage polarity is positive. These Advantages enable it to work in a wider range of positive output. The two power switches of the proposed buck– boost converter operate synchronously. In the continuous conduction mode (CCM), two inductors are magnetized and two capacitors are discharged during the switch-on period, while two inductors are demagnetized and two capacitors are charged during the switch-off period*

Further we implement feedback control using PI.PI controller will eliminate forced oscillations and steady state error resulting in operation of on-off controller and P controller respectively. However, introducing integral mode has a negative effect on speed of the response and overall stability of the system.

I. INTRODUCTION

As is well known, switching-mode power supply is the core of modern power conversion technology, which is widely used in electric power, communication system, household appliance, industrial device, railway, aviation, and many other fields [1], [2]. As the basis of switching-mode power supply, converter topologies attract a great deal of attention and many converter topologies have been proposed. Buck converter and boost converter have the simple structure and high efficiency.

However, due to the limited voltage gain, their applications are restricted when the low or high output voltage are needed [3]. Luo converters can obtain high voltage gain by employing the voltage lift technique, but the topological complexity, cost, volume, and losses increase at the same time. [4]–[6]. Interleaved converters can achieve high step-up or stepdown conversion ratio with low-voltage stress, while their operating mode, converter structure, and control strategy are complicated [7]–[10]. Quadratic converters can achieve the voltage gain of cascade converters with fewer switches; however, the efficiency of these converters are low . Additionally, some switched networks are added into the basic converters to obtain the high-voltage step-up or step-down gain, at the price of complicating construction and increasing cost . Compared with the above-mentioned converter topologies which can only step-up or step-down voltage, the voltage bucking/boosting converters, which can regulate output voltage under wider range of input voltage or load variations, are popular with the applications such as portable electronic devices, car electronic devices, and so on.

The traditional buck–boost converter with simple structure and high efficiency, as we all known, has the drawbacks such as limited voltage gain, negative output voltage, and floating power switch, meanwhile discontinuous input and output currents. The other three basic non-isolated converters: 1) Cuk converter; 2) Sepic converter; and 3) Zeta converter, which also have the peculiarity of step-up and step-down voltage, have been provided. However, the limits of the voltage gain along with other disadvantages in Cuk, Sepic, and Zeta converters are also non-ignorable. The quadratic buck–boost converter, proposed by Mak simovic and Cuk in [24], has one common-ground power switch; meanwhile, it can achieve the voltage gain D2/(1 − D)2. However, due to the diodes D1 and D2 clamp the output voltage to the input voltage while the duty cycle is bigger than 0.5, so that this converter can only work in step-down mode. By combining KY converter and the traditional synchronously rectified buck converter, Hwu and Peng proposed a new buck–boost converter which can realize the continuous output current, positive output voltage, continuous conduction mode (CCM) operation all the time, and no right-half plane zero. Unfortunately, its voltage gain of two multiplies the duty cycle (2D) is not sufficiently high or low in the situation where the converter needs to operate in a wide range of output voltage. Moreover, based on the Cuk converter, a new buck–boost converter, which has the low output voltage ripple, minimal radio frequency interference, and one common-ground power switch. However, as a seventh-order circuit, the converter has complex construction, and both its input terminal and output terminal do not share the same ground. Besides, the voltage gain is still limited. A boost–buck cascade converter, aggregating two separated converters with current source and current sink, is applied for the thermoelectric generator. Nevertheless,

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the voltage gain of this cascade converter is also constrained.

1.1 Existing system:

1 Switching mode power supply is the core of modern power conversion technology, which is widely used in electric power, communication system, household appliance, industrial device, railway, aviation and many other fields.

2 Buck converter and boost converter have the simple structure and high efficiency. However, due to the limited voltage gain, their applications are restricted when the low or high output voltage are needed.

1.2 Proposed system:

1 In this proposed system, An additional switched network is inserted into the traditional buck-boost converter, a new transformer less buck-boost converter is proposed.

2 The main part of the proposed buck-boost converter is that its voltage gain is quadratic of the traditional buck-boost converter so that it can operate in a wide range of output voltage, that is, the proposed buck-boost converter can achieve high or low voltage gain without extreme duty cycle.

3 Moreover, the output voltage of this new transformer less buck-boost converter is common-ground with the input voltage, and its polarity is positive.

II. DC-DC CONVERTER

The application of solid state electronics in which the electric power is controlled and converted is called power electronics. As it deals with designing, computation, control, and integration of electronic systems where energy is processed with fast dynamics which is non linear time varying,it is referred in electrical and electronic engineering as a research subject. Mercury arc valves are the first electronic devices with high power. The conversion is performed in modern systems with tryistors,diodes,transistors which are the semiconductor switching devices, pioneered in the 1950s by R.D.Middle Brook and others. In power electronics processing of substantial amounts of electrical energy is done in contrast to electronic systems concerned with transmission and processing of signals and data. The most typical power electronics device found in many consumer electronic devices,such as battery chargers,peronal computers,,television sets,etc is an AC/DC converter. Its power ranges from tens of watts to several hundred watts. The variable speed drive which is used to control an induction motor is the common application in industry.VSDs power ranges from few hundred watts to tens of mega watts.

2.1 Buck converter/stepdown converter:

In this circuit the transistor turning ON will put voltage V_{in} on one end of the inductor. This voltage will tend to cause the inductor current to rise. When the transistor is OFF, the current will continue flowing through the inductor but now flowing through the diode.

We initially assume that the current through the inductor does not reach zero, thus the voltage at V_x will now be only the voltage across the conducting diode during the full OFF time. The average voltage at V_x will depend on the average ON time of the transistor provided the inductor current is continuous.

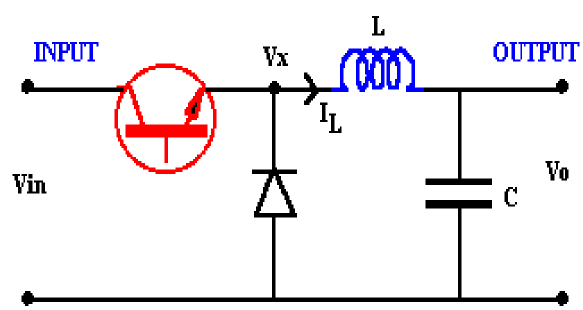

Fig 2.1 Buck Converter

2.2 Boost converter/stepup converter:

The schematic in Fig.2.5 shows the basic boost converter. This circuit is used when a higher output voltage than input is required.

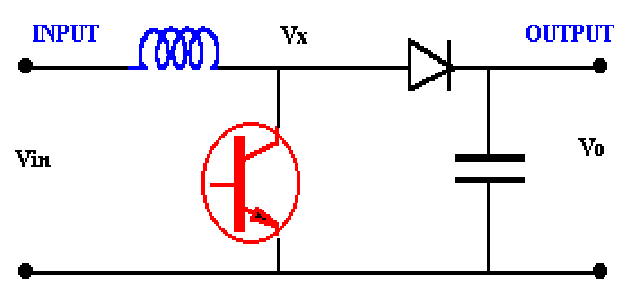

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Fig 2.2 Boost Converter Circuit

While the transistor is ON $V_x = V_{in}$, and the OFF state the inductor current flows through the diode giving $V_x = V_o$. For this analysis it is assumed that the inductor current always remains flowing (continuous conduction). The voltage across the inductor is shown in Fig. 7 and the average must be zero for the average current to remain in steady state.

III. PROPOSED CONVERTER STRUCURE & OPERATION

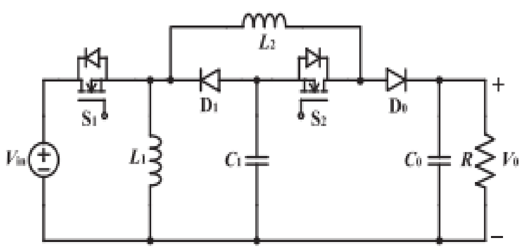

Fig.3.1. Proposed transformer less buck–boost converter

Fig. 3.1 shows the circuit configuration of the new transformer less buck–boost converter, which consists of two power switches (S1 and S2), two diodes (D1 and D0), two inductors (L1 and L2), two capacitors (C1 and C0), and one resistive load R. Power switches S1 and S2 are controlled synchronously.

According to the state of the power switches and diodes, some typical time-domain waveforms for this new transformer less buck–boost converter operating in CCM are displayed in Fig.3.2, and the possible operation states for the proposed buck–boost converter are shown in Fig.3 3. For Fig.5 3(a), it denotes that the power switches S1 and S2 are turned on, whereas the diodes D1 and D0 do not conduct. Consequently, both the inductor L1 and the inductor L2 are magnetized, and both the charge pump capacitor C1 and the output capacitor C0 are discharged. For Fig.3 3(b), it describes that the power switches S1 and S2 are turned off while the diodes D1 and D0 conduct for its forward biased voltage. Hence, both the inductor L1 and the inductor L2 are demagnetized, and both the charge pump capacitor C1 and the output capacitor C0 are charged. Here, in order to simplify the circuit analyses and deduction, we assumed that the converter operates in steady state, all components are ideal, and all capacitors are large enough to keep the voltage across them constant.

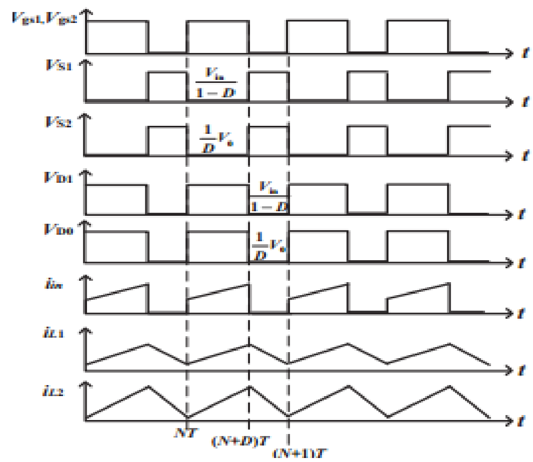

Fig 3.2 Typical time-domain waveforms for the proposed buck–boost converter operating in CCM

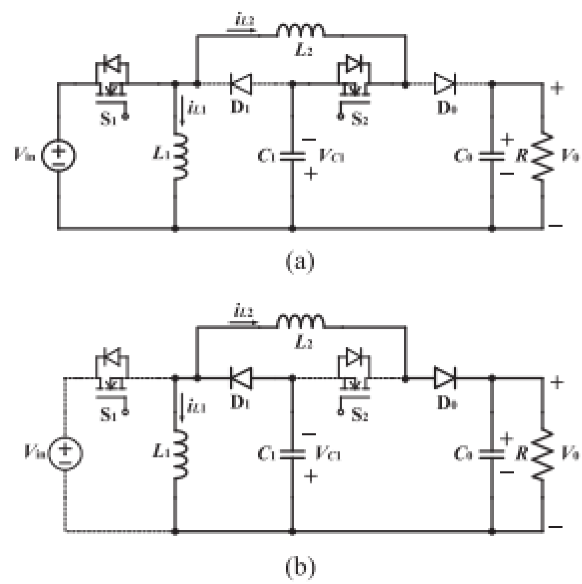

Fig.3 3. Equivalent circuits of the proposed buck–boost converter in two possible states. (a)State 1. (b) State

3.1 OPERATING PRINCIPLES:

As shown in Fig. 3.3, there are two states, i.e., state 1 and state 2, in the new transformer less buck–boost converter when it operates in CCM operation

State 1 ($NT < t < (N + D)T$):

During this time interval, the switches S1 and S2 are turned on, while D1 and D0 are reverse biased. From

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Fig.5.3(a), it is seen that L1 is magnetized from the input voltage Vin while L2 is magnetized from the input voltage Vin and the charge pump capacitor C1. Moreover, the output energy is supplied from the output capacitor C0. Thus, the corresponding equations can be established as

$$V_{L1} = V_{in} \ldots\ldots\ldots\ldots\ldots.(1)$$

$$V_{L2} = V_{in} + V_{c1} \ldots\ldots\ldots.(2)$$

State 2 ((N + D)T <t< (N + 1)T):

During this time interval, the switches S1 and S2 are turned off, while D1 and D0 are forward biased. From Fig. 5.3(b), it is seen that the energy stored in the inductor L1 is released to the charge pump capacitor C1 via the diode D1. At the same time, the energy stored in the inductor L2 is released to the charge pump capacitor C1, the output capacitor C0, and the resistive load R via the diodes D0 and D1. The equations of the state 2 are described as follows:

$$V_{L1} = -V_{C1} \ldots\ldots\ldots\ldots\ldots (3)$$

$$V_{L2} = -(V_{C1} + V_o) \ldots..(4)$$

If applying the voltage-second balance principle on the inductor L1, then the voltage across the charge pump capacitor C1 is readily obtained from (1) and (3) as

$$V_{C1} = \frac{D}{1-D} V_{in} \ldots\ldots\ldots\ldots.(5)$$

Here, D is the duty cycle, which represents the proportion of the power switches turn-on time to the whole switching cycle. Similarly, by using the voltage-second balance principle on the inductor L2, the voltage gain of the proposed buck–boost converter can be obtained from (2), (4), and (5) as M = V0 Vin = D 1 − D 2 . (6) From (6), it is apparent that the proposed buck–boost converter can step-up the input voltage when the duty cycle is bigger than 0.5, and step-down the input voltage when the duty cycle is smaller than 0.5.

IV. OPEN LOOP&CLOSED LOOP SYSTEM

When a number of elements are combined together to form a system to produce desired output then the system is referred as control system. As this system controls the output, it is so referred. Each element connected to the system has its own effect on the output

4.1 DEFINITION OF CONTROL SYSTEM:

A control system is a system of devices or set of devices, that manages, commands, directs or regulates the behavior of other device(s) or system(s) to achieve desire results. In other words the definition of control system can be rewritten as A control system is a system, which controls other system. As the human civilization is being modernized day by day the demand of automation is increasing accordingly. Automation highly requires control of devices

In recent years, control systems plays main role in the development and advancement of modern technology and civilization. Practically every aspects of our day-to-day life is affected less or more by some control system. A bathroom toilet tank, a refrigerator, an air conditioner, a geezer, an automatic iron, an automobile all are control system. These systems are also used in industrial process for more output. We find control system in quality control of products, weapons system, transportation systems, power system, space technology, robotics and many more. The principles of control theory is applicable to engineering and non engineering field both.

4.1.1 Open loop control system:

A control system in which the control action is totally independent of output of the system then it is called open loop control system. Manual control system is also an open loop control system. Fig - 1 shows the block diagram of open loop control system in which process output is totally independent of controller action.

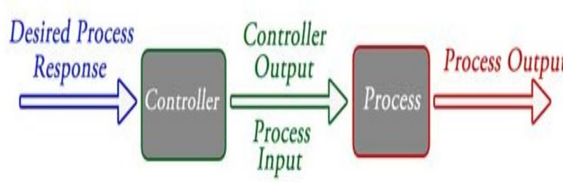

Fig 4.1 Block diagram of open loop system

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4.1.2 Closed loop control system:

Control system in which the output has an effect on the input quantity in such a manner that the input quantity will adjust itself based on the output generated is called closed loop control system. Open loop control system can be converted in to closed loop control system by providing a feedback. This feedback automatically makes the suitable changes in the output due to external disturbance. In this way closed loop control system is called automatic control system. Figure below shows the block diagram of closed loop control system in which feedback is taken from output and fed in to input.

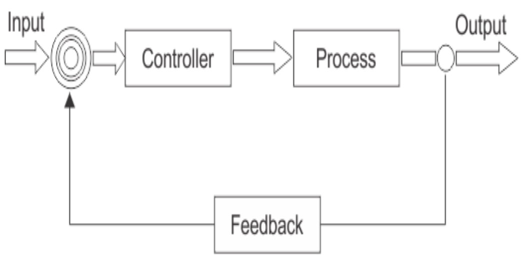

Fig 4.2 Block diagram of closed loop system

4.2 Proportional and Integral Controller:

As the name suggests it is a combination of proportional and an integral controller the output (also called the actuating signal) is equal to the summation of proportional and integral of the error signal. Now let us analyze proportional and integral controller mathematically. As we know in a proportional and integral controller output is directly proportional to the summation of proportional of error and integration of the error signal. writing this mathematically we have,

$$A(t) \propto \int_0^t e(t)\,dt + A(t) \propto e(t)$$

Removing the sign of proportionality we have,

$$A(t) = K_I \int_0^t e(t)\,dt + K_p e(t)$$

Where, K_i and k_p proportional constant and integral constant respectively. Advantages and disadvantages are the combinations of the advantages and disadvantages of proportional and integral controllers.

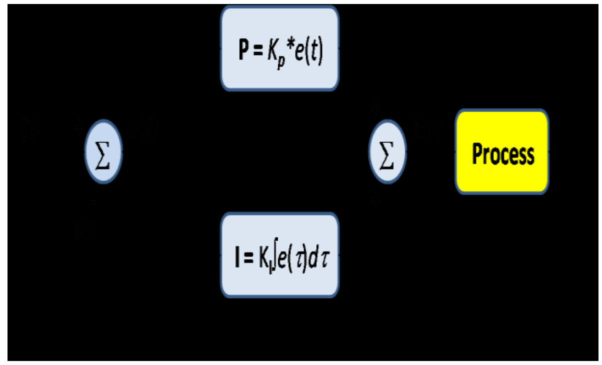

Fig 4.3 PI controller

V. SIMULINK MODEL OF PROPOSED SYSTEM:

5.1 Step down mode:

The Theoretical results are VC1 = 27 V, V0 = 40.5 V, IL1 = 0.34 A, IL2 = 0.68 A, ΔiL1 = 0.54 A, ΔiL2 = 0.45 A, ΔvC1 = 2 V, ΔvC0 = 0.4 V, respectively. For the proposed buck–boost converter operating in stepdown mode when the duty cycle is choosing as 0.4, Fig.5.3.2 displays the time-domain waveforms of the output voltage v0, the charge pump capacitor voltage vC1, the currents of the two inductors L1 and L2, and the driving signal vg. It is clearly seen that the charge pump capacitor voltage vC1, the output voltage v0, the inductor current iL1, and the inductor current iL2 are within (11.44 V, 12.32 V), (7.77 V, 8.04 V), (−0.33 A, 0.03 A) and (0.34 A, 0.54 A), respectively.

Moreover, the ripples of the inductor current ΔiL1 and the inductor current ΔiL2 are 0.36 and 0.2 A, respectively. The ripples of the two capacitors ΔvC1 and ΔvC0 are 0.88 and 0.27 V, respectively. Similarly, the theoretical calculations from (5), (6), (17), (18), and (23)–(26) are VC1 = 12 V, V0 = 8 V, IL1 = −0.15 A, IL2 = 0.44 A, ΔiL1 = 0.36 A, ΔiL2 = 0.2 A, ΔvC1 = 0.89 V, ΔvC0 = 0.27 V, separately.

5.2 Closed loop model of proposed system:

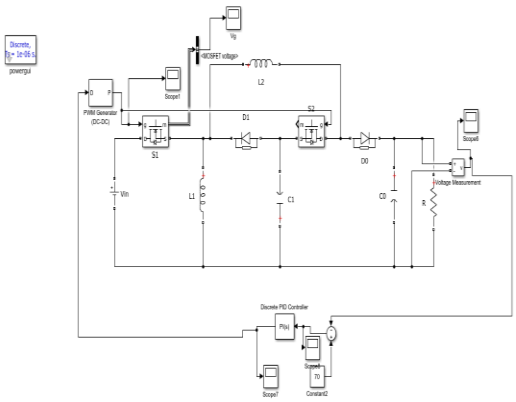

Fig 5.1 closed loop model of proposed system

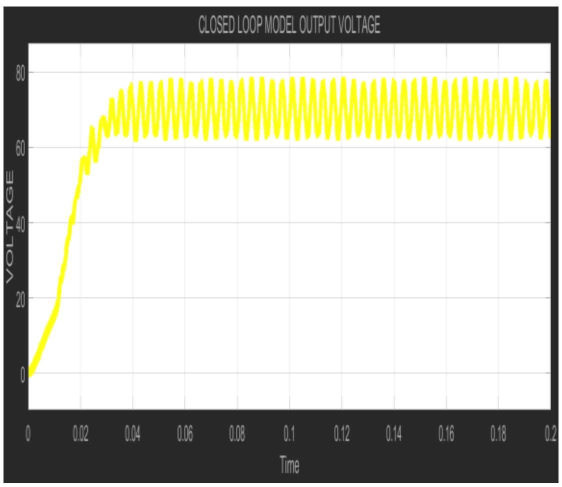

Fig 5.2.closed loop model output voltage

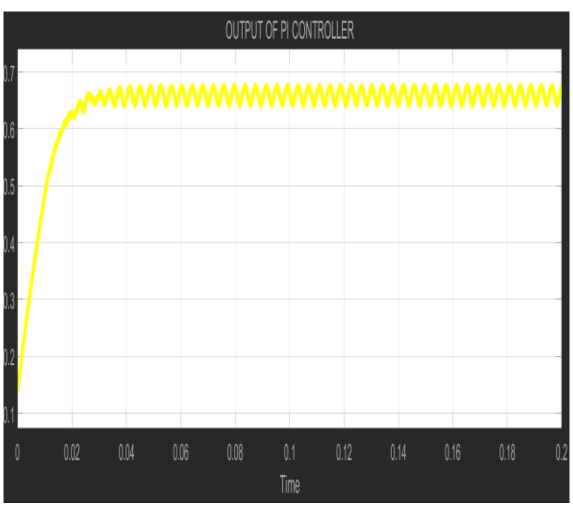

Fig.5.3 output of pi controller

VI. CONCLUSION

DC-DC converters and their design remain an interesting topic and new control schemes to achieve better regulation and fast transient response are continually developed. Step up switching regulators are the backbone of power electronic equipments. A key challenge to design switching regulators is to maintain almost constant output voltage within acceptable regulation. Performance and applicability of this converter is presented on the basis of simulation in MATLAB SIMULINK. The design concepts are validated through simulation and results obtained show that a closed loop system using buck-boost converter will be highly stable with high efficiency. Buck-Boost converter can be used for universal input voltage and wide output power range. The design of DC-DC converter capable of having low rise time, quick settling time and stable output.

6.1 FUTURE SCOPE:

DC motor has been successfully controlled by using Chopper as a converter and Proportional Integral as the controller for closed loop control system. Initially a simplified closed loop model for control of DC motor is considered and requirement of PI controller is studied. Then a generalized modeling of separately & self excited DC motor is done. The MATLAB/SIMULINK model shows good results under below the rated voltage during simulation.

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