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Parallel Connected Buck–Boost Converter for PV Application Using Pi Controller

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ABSTRACT: A novel synchronous double- stage buck-boost converter with PI controller is used in this project. Due to the advancement in power electronic techniques various types of renewable energy sources are have become very popular but the losses associated with the conversions are high. In order to improve efficiency the converters are implemented. Here the double stage buck-boost converter is used to increase the efficiency. Switching losses are reduced by double-stage buck-boost converters. In order to enhance the converters efficiency the soft switching schemes based on the interleaved converter is proposed. The converter units are connected to each other by an inductor as a bridge that plays an important role in the soft switching operation by maintaining the voltage applied to switches at zero switching intervals. A modified PI controller is used to control the converter to maintain a constant voltage set point for energy control applications. The circuit is simulated by MATLAB SIMULINK software and more than 93% efficiency is obtained from the simulation results.

KEYWORDS: Buck-Boost converter, interleaved inductor, soft switching.

I.INTRODUCTION

DC/DC converters are used for many purposes when the conversion between two DC voltage levels such as electrical vehicles, active filters, Power Factor Correction circuits (PFC), Distributed Generations (DG), DC/DC regulated power supplies, etc. is required [1]-[3].Normally converters are divided into several types depending on increase or decrease of the output voltage level with respect to the input voltage. So this paper focuses on the buck-boost DC/DC converters which can operate in either buck or boost modes, i.e. it can be used in both step-up and down applications. By using this converter the efficiency is an important issue, because increasing of switching loss leads to reduced efficient operation. So lot of literature dealing with analysis, control methods, topologies, efficiency issues and applications of buck- boost converters are available. The comprehensive resonance analysis and soft-switching design of the isolated boost converter with coupled inductors are presented in this paper[4]. Due to the resonance participated by the voltage doublers capacitor, clamping capacitor, and leakage inductance of coupled inductors, the reverse-recovery problem of the secondary diodes is restrained within the whole operation range. By choosing appropriate magnetic inductance of the coupled inductors, zero-voltage switching one of the main MOSFETS is obtained collectively at the same working conditions without any additional devices.

A buck/boost dc-dc converter topology based on the principle of auxiliary resonant commutated pole used snubber is fairly simple yet effective in reducing the switching losses A zero-voltage- and zero-current-switching full bridge (FB) converter with secondary resonance is presented and analyzed [6]. Soft switching techniques utilizing the features of Zero Voltage Switching (ZVS) or Zero Current Switching (ZCS) substantially reduce the switching losses [7]-[10]. Some of these approaches include active clamps [11], passive, and active snubbers [12]-[14]. In some cases a combination of ZVS and ZCS techniques has also been discussed [12], [15, 16].

Nowadays, interleaved converters are utilized in many applications and provide many advantages such as increasing efficiency, reducing the voltage and current ripple and supplying more load power [17]-[20]. The ZVS operation of the parallel boost converters has been investigated in [20]. The inductor placed between two parallel converters is called the interleaved inductor and displaces the resonating current between two converters at the

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particular time intervals in order to perform the soft switching operation of the set [21]. The operation procedure of this kind of converters is described in two sets of symmetric scenarios depending on the situation of the resonating current.

In this paper, a double-deck buck-boost converter with PI controller is proposed. It provides that the switching process can perform with the minimum losses by applying the gate signals at particular time intervals. The simulation circuit is designed and simulated to evaluate the applicability of the proposed converter. It is shown that the converter efficiency increases substantially up to 94% in all cases of the investigated load power from 100 W to 220 W. Moreover, it is also concluded that utilizing of two converters in parallel causes less ripple in the output load voltage. In addition, the fact of using only one inductor as an extra element to achieve the main goal of the paper suggests that the proposed converter is more economical than the soft switched converters by adopting coupled inductors or transformers.

A. INTERLEAVING TECHNIQUE

In low power converters, the main effort is devoted to increase the switching frequency to reduce the size of reactive components and consequently the whole converter. As the switching losses are directly proportional to switching frequency, soft switching techniques are generally used in high frequency converters both at low power and at high power. One of the issues of concern in these converters is the large size of the storage capacitor on the dc link. The boost converter suffers from the disadvantage of discontinuous current injected to the load. The size of the capacitor is therefore large. Further, the ripple current in the capacitor is as much as the load current; hence the ripple current and ESR specification of the tank capacitor are quite demanding. Another problem is the way the parallel modules are controlled. Digital control is more convenient for such a topology on account of the requirement of synchronization, phase shifted operation, current balancing, etc. This thesis addresses the above issues. In addition, soft switching application to interleaved buck-boost converters is also addressed. The succeeding section deals with the current state-of-the-art in interleaved buck-boost converters. The later sections give the scope of the thesis in terms of analysis, modeling, control, new techniques and circuits. The last section gives the organization of the thesis.

B.CURRENT SHARING METHODS

Buck-Boost converter is one of the most important and widely used devices of modern power applications. Till now Buck-Boost Converters with snubber circuits are used where switching losses are dissipated in external resistors leading to higher switching losses and low overall efficiency. Modern Buck-Boost converters use IGBT switches which have the following properties such as high current and voltage rating, fast switching, low power gate drive. These properties lead to following disadvantages such as at high blocking voltage the switching frequency is reduced to low values and due to high switching speed, the rate of change of current and voltages become high. Buck-Boost converter with auxiliary resonant circuit can overcome these problems by either forcing current (ZCS) or voltage (ZVS) or both of them to zero. By adopting this topology the total efficiency of the system is improved. As Buck-boost converters are widely used these days therefore large amount of power is saved from wastages.

II.SYSTEM OVERVIEW

This section describes the block diagram of double-deck buck- boost converter using PI controller operation. The configuration of the proposed converter is composed of two identical buck-boost converters working in parallel. The source and the output capacitor *Co* are shared between two converters. The inductor *Ls* is placed in parallel with two switches as shown in below figure.

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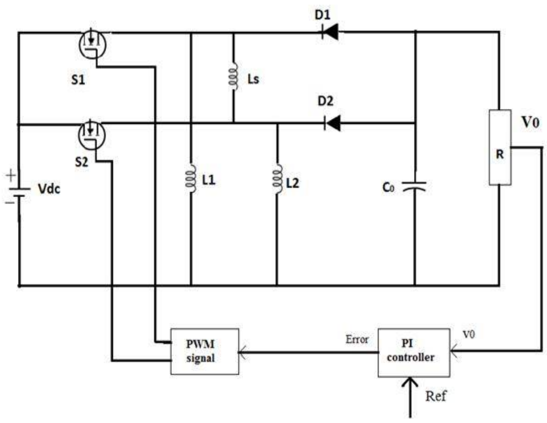


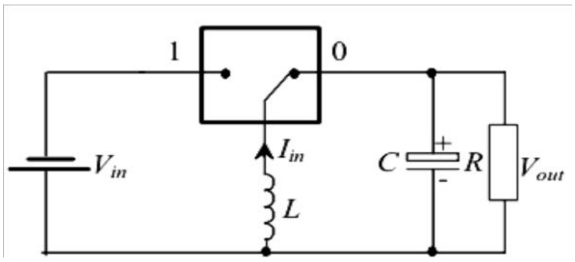
Circuit diagram of proposed converter

This element plays an important role in main plot of the soft switching manner of the converter. It discharges the intrinsic capacitances of the switches by creating a resonant circuit. Then, the switching could be done when the intrinsic anti parallel diodes of the switches conduct the negative half-cycle of this resonating current and the voltage on the switches is clamped at zero. Two power MOSFETs *S1* and *S2* are adopted for high-frequency switching with the same switching frequency. The duty ratio (*D*) for each of the switches is identical and slightly greater than 0.5 to create overlapping intervals. It is assumed that the converters operate in Continuous Current Mode (CCM).

During the design of the PI controller for the buck and boost converter, a closed loop operation is performed. The open loop operation is insensitive to load and line disturbances. So this operation is ineffective. Therefore the closed loop operation is selected. The closed loop control uses a feedback signal from the process, a desired value or set point (output voltage) and a control system that compares the two and derives an error signal. The error signal is then processed and used to control the converter to try to reduce the error. The error signal processing can be very complex because of delays in the system. The error signal is usually processed using a Proportional -Integral (PI) controller whose parameters can be adjusted to optimize the performance and stability of the system. Once a system is set up and is stable, very efficient and accurate control can be achieved.

III.DESIGN PROCEDURE FOR THE BUCK- BOOST CONVERTER

The duty ratio of the switches must be considered slightly greater than 0.5. Therefore, it causes a small overlap between the gating signals of the switches. But, the effective duty ratio is larger than that of the duty ratio (D) of each of switches *S1* and *S2*. A mathematical model of buck- boost converter is shown below.



and *iL2* are decreased due to voltage *-VO* which is clamped at the inductances *L1* and *L2*. Therefore, the value of inductances *L1* and *L2* should meet the following constraint.

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Duty ratio *DE* can be represented as:

$$\frac{V_0}{V_S} = D = \frac{I_S}{I_0} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots 2.1$$

where *TS* and *TC* are the switching and commutation times, respectively. The voltage across the inductor *LS* is clamped at input and output voltage, commutation time can be represented as follows:

$$V_L = V_S - V_0 = L\frac{di_L}{dt} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots 2.2$$

$$\frac{di_L}{dt} = \frac{V_S - V_0}{L} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots 2.3$$

The voltage across the inductor when the switch is open is determined by:

$$V_L = -V_0 = L\frac{di_L}{dt} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots 2.4$$

$$\frac{di_L}{dt} = \frac{-V_0}{L} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots 2.5$$

Selecting Ls;

The voltage ratio of the converter can be obtained from the switching frequency, load resistance,.

Therefore, it can be concluded that the control over the output voltage could be possible by modifying the switching frequency *fs* while not changing the duty ratio of the switches like conventional buck-boost converters.

Selecting L1&L2;

Inductances *L1* and *L2* are obtained by considerations the magnitude of the *iL1* and *iL2* current ripples. The maximum permissible current ripple should not exceed the rated output current, so the converter could operate in the CCM and *iL1*

SELECTING Co;

To determine the value of the output capacitor, it is considered that the ripple and the average value of the converter output current flow to the output capacitor *Co* and the load, respectively. Because the two conversion units work in parallel, the average current of each diode can be assumed to be half of the average current of the load.

Where *ΔVO/VO* is the relative output voltage ripple usually considered to be less than 1 % of the output nominal voltage. Finally, to achieve the efficiency of the proposed converter.

IV.SIMULATION RESULTS

In order to improve the performance of the converter, the PI controller is proposed. PI control is needed for non-integrating processes, meaning any process that eventually returns to the same output given the same set of inputs and disturbances. It provides a method to design a controller for a system so that the controlled system is to be insensitive to parameter variations and external load disturbances.

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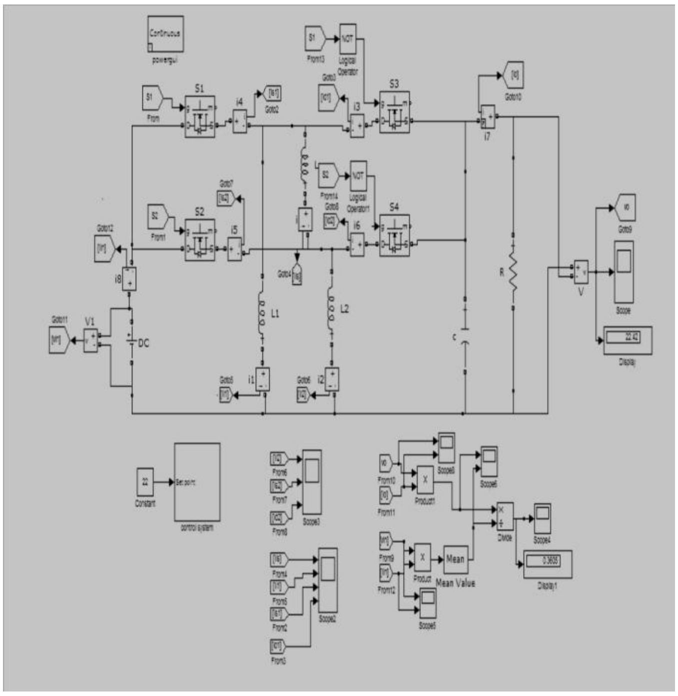


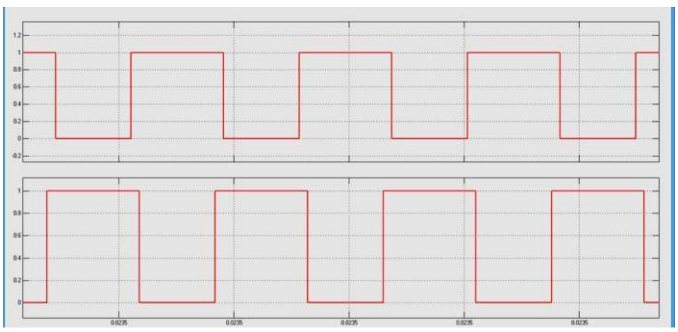
Simulation circuit diagram for double- deck buck- boost converter with PI controller.

Components Selection:

Components	Values
Vin	20V
Ls	30
L1	180
L2	180□F
R	35

A.SIMULATION RESULTS FOR BOOST MODE

The below simulation result shows that the output of PWM signal is applied to the two switches.



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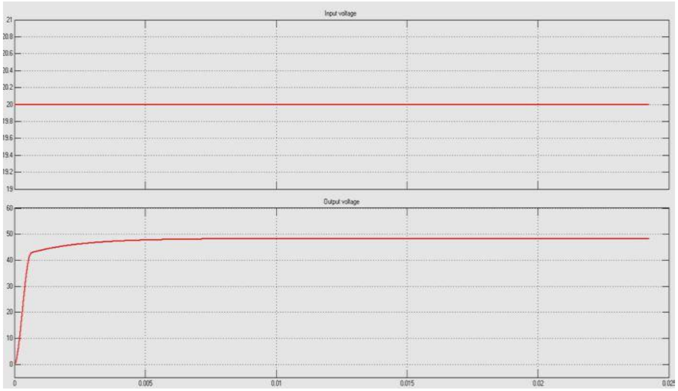
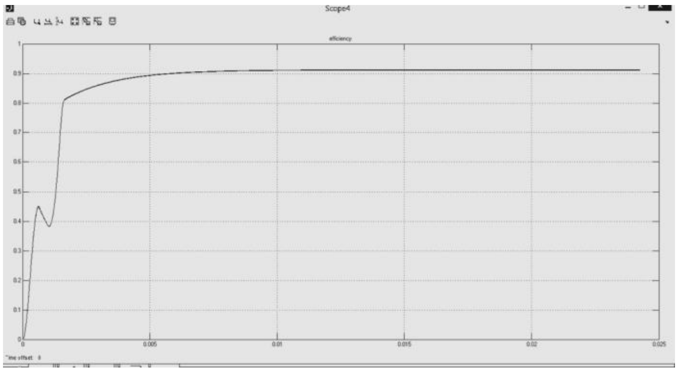
The below simulation result shows that the output of boost mode input and output voltage.

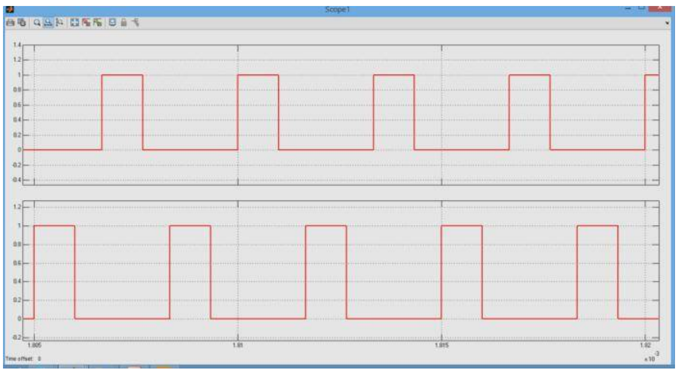


The below simulation results shows that the efficiency of the boost mode got increased up to 94%.



B.SIMULATION RESULTS FOR BUCK MODE

The below simulation result shows that the output of PWM signal is applied to the two switches in buck mode.



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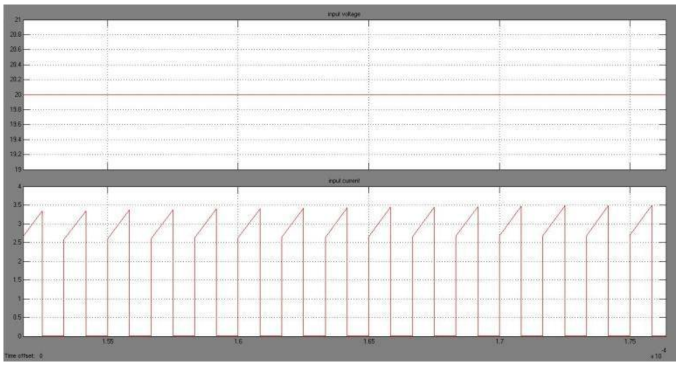
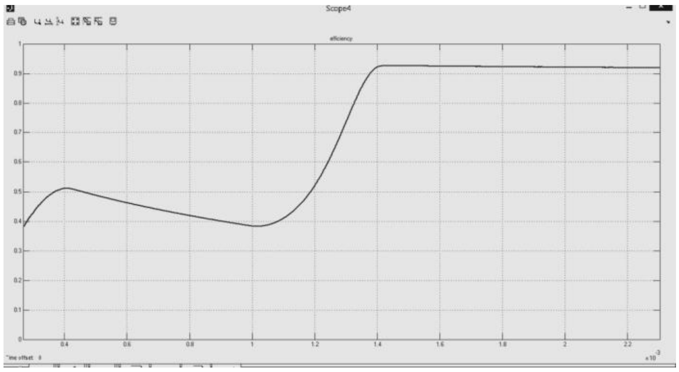
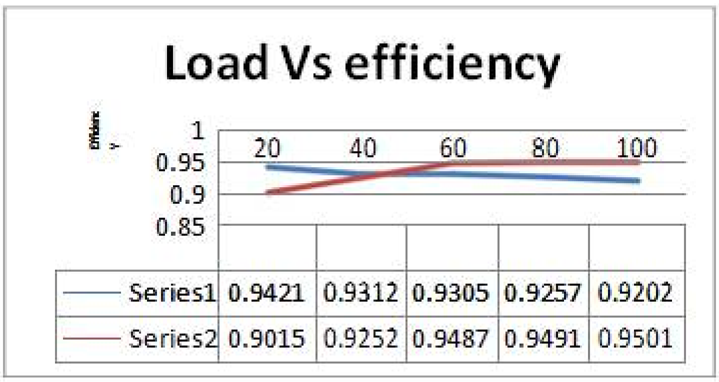
The below simulation result shows that the buck mode input voltage and input current.



The below simulation result shows that the efficiency of the buck mode got increased up to 94%



Comparison between load and efficiency



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V.CONCLUSION

This paper has discussed a double deck converter with a PI controller provides a decent efficiency under both buck and boost modes. The converter topology which naturally switched with the zero voltage switching PWM generates a better control over current provides a load voltage control. The theoretical analysis and design equations are described to achieve the soft switching operation of the proposed converter. This goal could be obtained by just an extra inductor placed between two units as a bridge. Therefore, the reliability of the proposed converter increases due to the simplicity of the proposed structure. It is demonstrated that the output voltage of the converter could be regulated by changing the switching frequency instead of the duty ratio. Therefore, the converter efficiency improved significantly so that it remained greater than 93% in all of the investigated loads. Moreover, it could be concluded that the proposed converter can provide less ripple in the voltage and current of the load and input supply due to the operation of two converters in parallel. This concept can be accomplished in the similar DC/DC converters such as cuk converter or etc.

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