Analytical Study of Combined Buck and Modified Push-Pull Converter with Efficient Step-Down Ratio

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ABSTRACT:This paper proposes a step-down conversion circuit, called an integrated buck and modified push-pull (IBMPP) converter. It can reduce the output voltage with an efficient step-down ratio. The IBMPP converter can work in duty cycle which is less than 50%.By adopting the active clamp techniques, the voltage spikes are often reduced. The benefits of the IBMPP converter are: it has a simple topology, it is easy to control, the conversion ratio is higher, low component counts for power switches, and low voltage stress on the high-voltage side switches. The control circuit is controlled using PID controller. Simulation circuits and their results are given in this paper.

KEYWORDS: MOSFET, leakage energy, IBMPP.

I.INTRODUCTION

Along with the advance in technology, the use of electronic powergenerated from non-renewable energy has increased tremendously. But people began to listen to shortage of energy and environmental pollution to beat these issues., renewable energy is taken into account to be a vital approach.Several new techniques are adopted for reducing the conversion losses [2-7].

In electronic products, switched mode power supplies are used. A high step-down conversion stage is required for transferring the high DC-bus energy to provide the low-voltage DC load [8]-[13].

The advantage of the interleaved buck converter (IBC) is that, it has low switching loss and improved step-down conversion ratio. It is suitable for the applications where the input voltage is high. It's like the traditional IBC. But two active switches are nonparallelconnected and within the power patha coupling capacitor is provided, like Cuk, Zeta, and Sepic converters [8]. The IBMPP converter features a lower voltage stress and it can provide high step-down ratio than the traditional IBC. This can be used for high-power applications like non-isolated converter with high current ripple [9]. The converter can reduce the high DC bus voltage to a low voltage output terminal [12]. The high step-down ratio can be achieved using a forward converter, flyback converter, etc... The main disadvantage with the flyback converter with airgap is that it causes higher level of leakage inductances and voltage spikes on the power switch. So, this causes the addition of snubber circuits and thus increases the complexity of the circuit and causes a decrease in efficiency. The foremost serious disadvantage of the forward converter is that it requires a magnetic field reset circuit. It leads to an increase in the number of components. Forward converters are a bit costlier than flyback converters. Some existing and new forward topologies are constructed as examples. The forward converters have features like natural-magnetizing reset, recycle of leakage energy and magnetizing energy, low voltage stress, etc [14]. Compared to forward circuits, full-bridge circuits are mostly used for high-power applications. By adding a flying capacitor, the efficiency and voltage imbalance is improved.

II.INTEGRATED BUCK AND MODIFIED PUSHPULL CONVERTER

The IBMPP converter proposed in this paper is illustrated in Fig. 1. The voltage spikes on the main switches can be reduced by adopting active-clamp techniques. The voltage spikes are equal to the voltage across the capacitor C_1 which is very much less than the input voltage. A buck converter is employed in the primary side of the transformer to stepdown the input voltage. The voltage of the primary side of the transformer is equal to the difference between the voltage across C_1 and the voltage across C_2. The driving signals for the two MOSFETs are inverted from each other and the duty ratio of each switch is less than 50%. Centre-tapped double-winding rectifier is used on the secondary side of the transformer. Though the frequency of the output inductor is twice the switching frequency, the volume of the output inductor and output capacitor can be reduced.

The output of this converter can be controlled by providing feedback. The PID controller is used for providing feedback. The closed loop circuit diagram and its output is shown in simulation results which are shown in section. The simulation of this converter are done using MATLAB/SIMULINK.

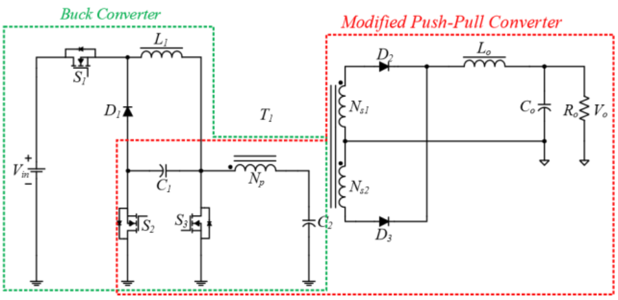

Fig.1 Equivalent circuit diagram of the IBMPP converter[1]

III.DESIGN OF IBMPP CONVERTER

The equivalent circuit of the proposed IBMPP converter is illustrated in Fig.1.The L_1 is the energy-storing inductor, and L_{lk} is the leakage inductor and The L_o is the output inductor. The S_1, S_2,and S_3 are main switches. The primary side has two switching capacitors, C_1 and C_2 and C_o is the output filtering capacitor. This converter consists of three diodes, D1 is a flywheel diode, D_2 and D_3 are rectifying diodes. The primary side of the transformer is T_1 and is defined as N_p and the secondary side of the transformer is defined as N_{s1} and N_{s2}. The turns-ratio of the transformer is defined as n $(=N_{s1} / N_p=N_{s2}/N_p)$. The operational modes for this converter are explained in[1].

IV.PARAMETERS DESIGN

In this section, the parameters of the proposed converter will be discussed according to the analyses above on the operation of the proposed converter in CCM. Firstly, the output voltage Vo will be deduced as follows.

Output voltage and voltage stress of the components:

1. The capacitor voltage and inductor currents are considered to be constant due to large capacitances and inductances.
2. The proposed converter works in continuous conduction mode. The duty cycle is below 50%.
3. D: Duty Cycle.

The voltage across the capacitors C_1 and C_2 can be obtained as follows:

$$V_{C1}=DV_{in} \qquad (1)$$

$$V_{C2}=\frac{1}{2}DV_{in} \qquad (2)$$

The voltage gain of the converter can be determined as:

$$\frac{Vo}{Vin}= n.D^2 \qquad (3)$$

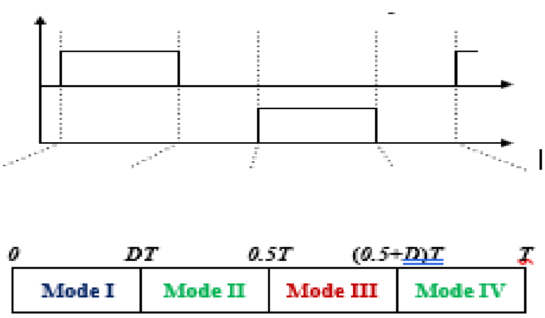

Fig 2. Equivalent simplified CCM operation state of the proposed IBMPP converter [1].

The voltage stress of elements used in the converter are as follows:

$$V_{DS1}= (1+D)V_{in} \qquad (4)$$

$$V_{DS2} = DV_{in} \qquad (5)$$

$V_{DS3} = DV_{in}$ (6)

$V_{D1} = V_{in}$ (7)

$V_{D2} = n.D.V_{in}$ (8)

$V_{D3} = n.D.V_{in}$ (9)

Parameters of capacitors:

1) *Rated Capacitance*: The ripples of the capacitors have great influence on the stability of the converter, whose permitted fluctuation range can be used to design the capacitance. In order to get high bucking, it requires capacitive components that can store electrical energy. Capacitance design are explained in[1].

Parameters design of switching devices

Normally, the design of the diodes is to determine the rated voltage and rated current to keep the diodes operating safely for a long time.

V.SIMULATION RESULTS

To verify the feasibility and validity of the proposed converter, MATLAB software is applied for the simulation. The pre-assigned parameters are as follows, V_s = 220V,
V_o = 5V and T = 20 μs. Further, assume the parameters of the converter as: $C_1=C_2=C_3=100μF$, L_1= 1.37mH
L_2=1.5mH.

The simulation diagram and the simulation results are given below.

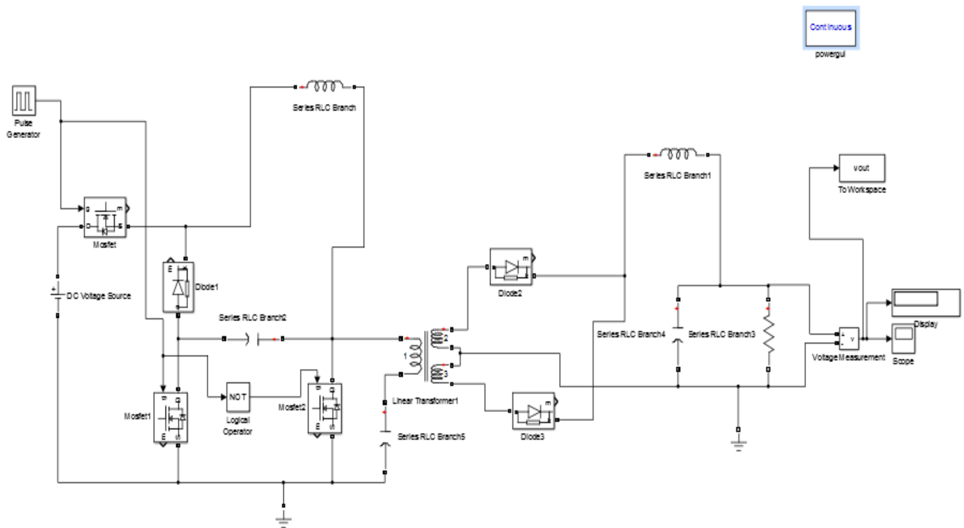

Fig .3 MATLAB simulation circuit of open loop IBMPP converter.

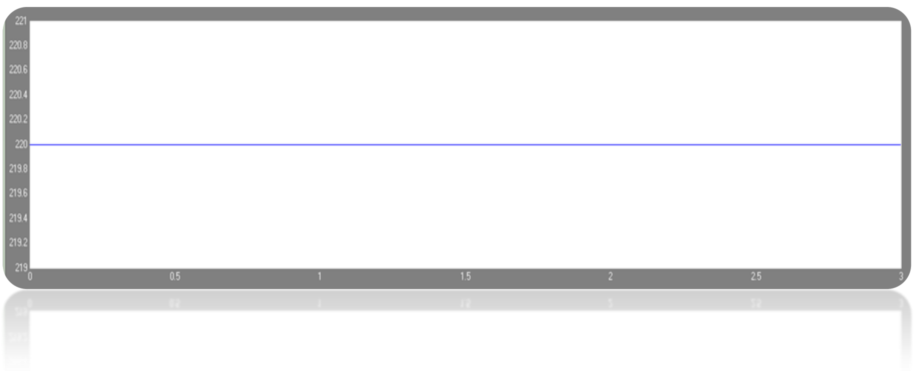

Fig. 4 Input voltage waveform Vs=220V

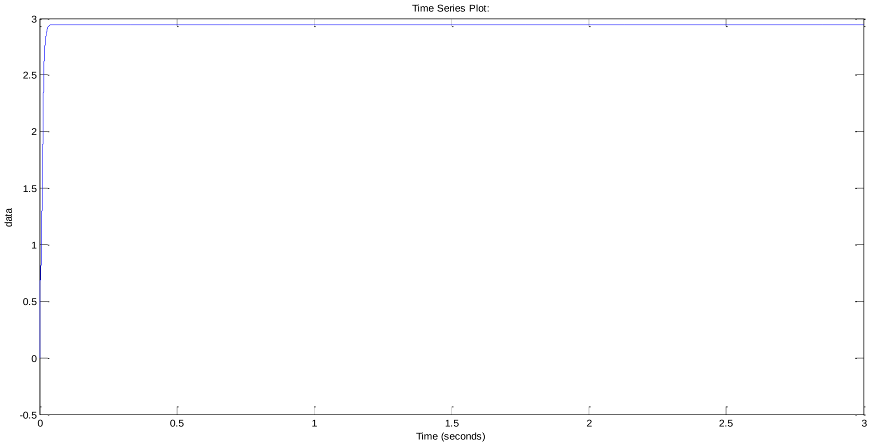

Fig.5. Output voltage waveform Vo=5V.

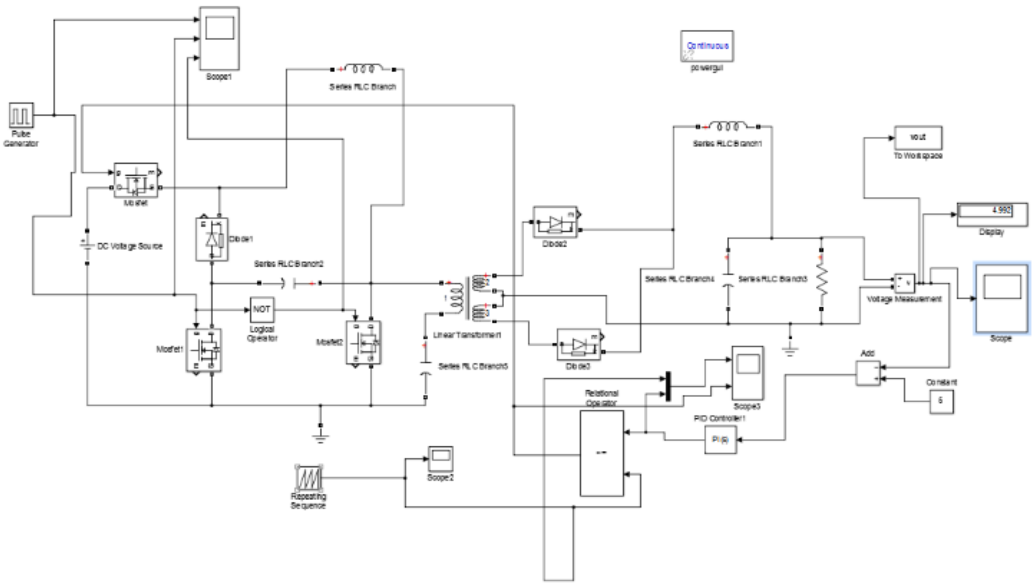

Fig.6. MATLAB simulation circuit of closed loop IBMPP converter.

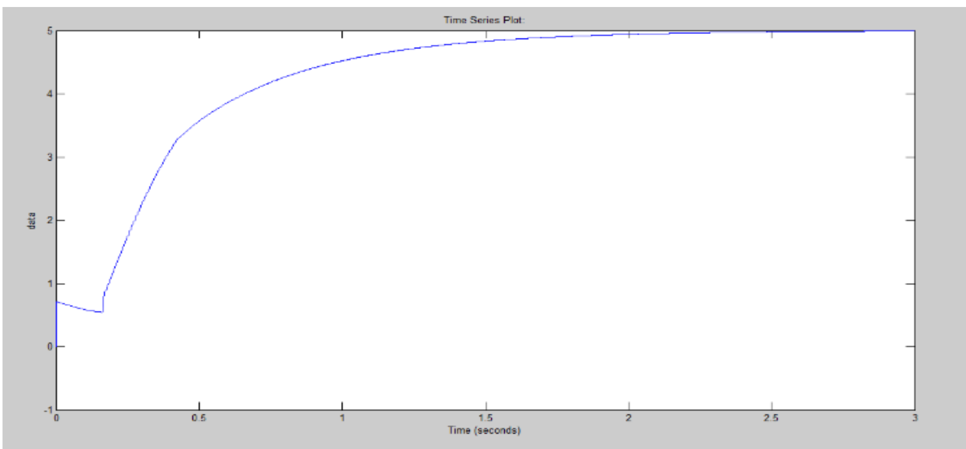

Fig.7. Output voltage waveform Vo=5V.

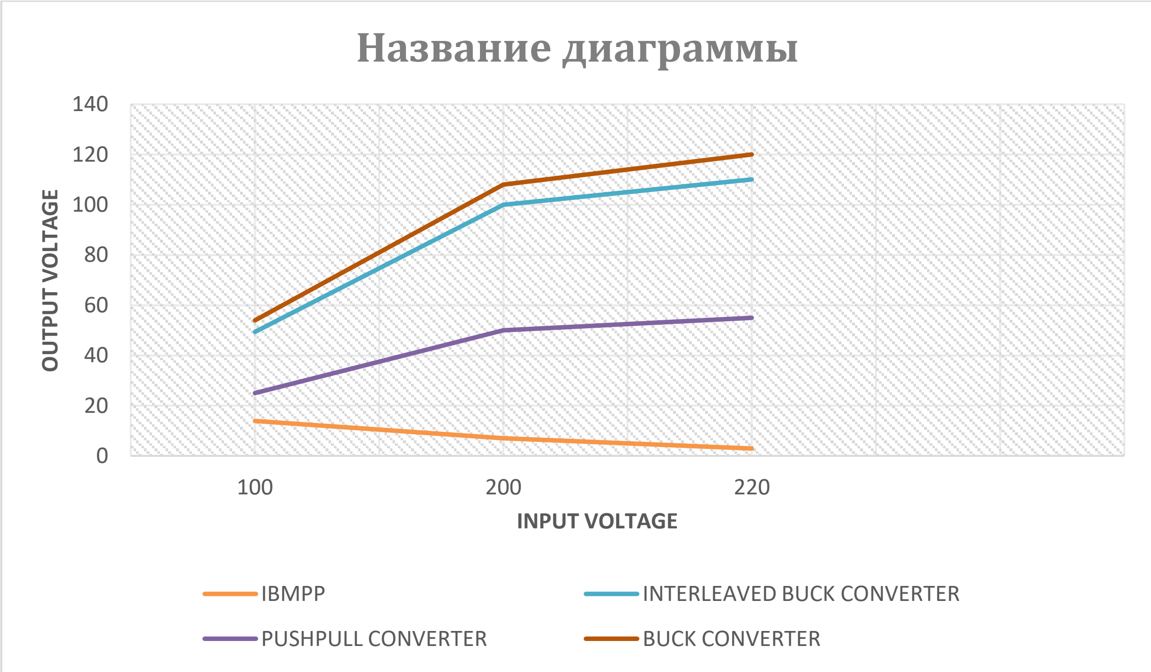

Fig. 8 Output voltage v/s input voltage of different converters.

High step-down ratio is achieved using our IBMPP converter than other buck converters for high input voltage values.

VI. CONCLUSION

An IBMPP converter is described in this paper. The advantages of the IBMPP converters are as follows:

1) A buck converter and modified push pull converter are combined in this paper so that high step-down ratio can be achieved.
2) For recycling the energy of the leakage inductor, an active clamping technique is employed.
3) The paired switches are driven by two inverted signals.

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