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A High Step up Boost Converter Using Coupled Inductor with PI Control

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ABSTRACT: The paper proposes a high step up boost converter. The proposed converter has used a coupled inductor with switched capacitors. The capacitors were made to get charged in parallel and were made to get discharged in series by the configuration to achieve high step up voltage gain. And the voltage across the load is maintained constant by using a closed loop control.

The operation and steady state analysis of the configuration has been shown in detail. Finally, a circuit with 24-V input, 400-V output, and power of 200W has been implemented in MATLAB software to verify the proper working and performance of the proposed configuration.

KEYWORDS: High step-up Boost Converter, Coupled Inductor, Switched Capacitor, PI Controller.

I.INTRODUCTION

Boost converter is one of the most important and widely used devices of modern power applications. These converters are electronic devices used to change DC electrical power efficiently from one voltage level to another. They provide smooth acceleration control, high efficiency, and fast dynamic response. There are FOUR main types of converter usually called the buck, boost, buck-boost and Boost converters. The buck converter is used for voltage step-down/reduction, while the boost converter is used for voltage step-up. The buck-boost and Cuk converters can be used for either step-down or step-up.

Basically, the DC-DC converter consists of the power semiconductor devices which are operated as electronic switches and classified as switched-mode DC-DC converters. Operation of the switching devices causes the inherently nonlinear characteristic of the DC-DC converters. Due to this unwanted nonlinear characteristics, the converters requires a controller with a high degree of dynamic response. Pulse Width Modulation (PWM) is the most frequently consider method among the various switching control method. In DC-DC voltage regulators, it is important to supply a constant output voltage, regardless of disturbances on the input voltage.

Nowadays, the control systems for many power electronic appliances have been increasing widely. Crucial with these demands, many researchers or designers have been struggling to find the most economic and reliable controller to meet these demands. The idea to have a control system in dc-dc converter is to ensure desired voltage output can be produced efficiently as compared to open loop system. Controller for the PWM switching control is done by Proportional-Integral (PI) controller.

Many different methods have been proposed to improve the efficiency of the converter and to achieve high voltage gain, which can be done by using a switched capacitor and a coupled inductor is used for high gain by adjusting its turns ratio. Voltage spikes may occur due to the coupled inductor. For which we have used an active clamp circuit with coupled inductor which avoids voltage spikes.

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Figure 1 shows the block diagram of the proposed converter with closed loop control such that the voltage drift problem is minimized and the desired output is maintained. The output voltage was then taken as feedback and compared with desired value of output voltage and the difference is then fed to PI control which then produces the PWM signal to the switch of the converter.

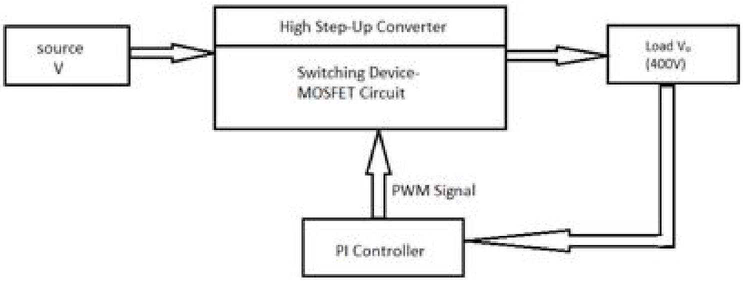

Figure 1 Proposed block diagram

II.SYSTEM MODEL AND ASSUMPTIONS

Figure 2 shows the configuration of the proposed circuit. The circuit has a boost converter with coupled inductor, switched capacitor and a clamp circuit. The equivalent circuit of the coupled inductor consists of a magnetizing inductor L_m, leakage L_k, and an ideal transformer. The leakage inductor energy of the coupled inductor is recycled to capacitor C_1, and thus the voltage across the switch S can be clamped. The voltage across the capacitors C_2, and C_3 can be adjusted by the turns ratio of the coupled inductor. For these reasons the voltage of switch is reduced significantly and low conducting resistance $R_{ds(on)}$ of the switch can be used. Thus high step-up voltage gain can be achieved.

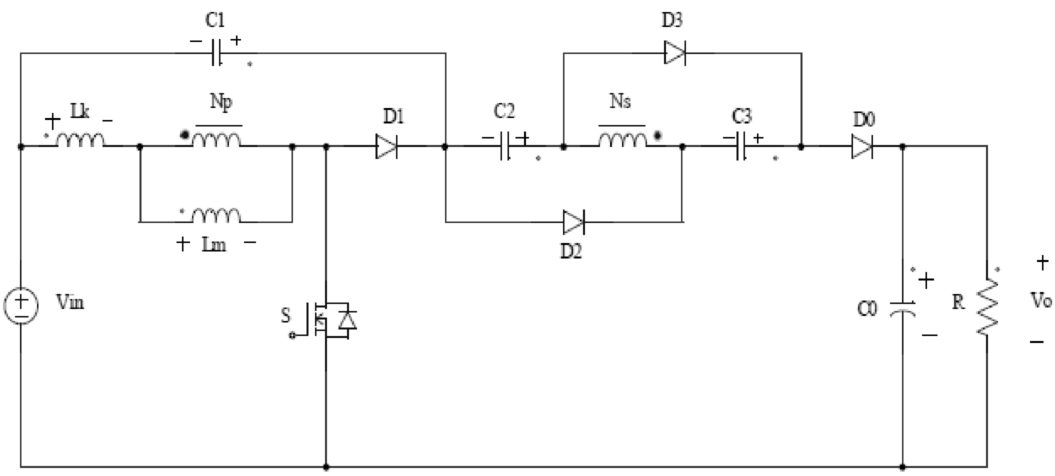

Figure 2 Circuit configuration of the proposed converter

To simplify the circuit analysis, these conditions have been assumed.

A. Capacitors $C_{1,}$ $C_{2,}$ C_3 and C_0 are very large which makes voltages V_{C1}, $V_{C2,}$ V_{C3} and V_O to be constant in one switching period.

B. The power devices used are ideal, but the parasitic capacitance of the power switch was considered.

C. The coupling coefficient of the coupled inductor k is equal to $L_m/(L_s+L_k)$ and the turns ratio of the coupled inductor n is equal to N_s/N_p .

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III.MODES OF OPERATION AND ANALYSIS

There are five operating modes in one switching period.

1) Mode I (t_0, t_1): Mode will start when the switch S is turned ON. Diodes D_1 and D_0 are off, and D_2 and D_3 are on. The current through L_k starts increasing linearly. The inductor L_m starts storing energy from the source voltage. Voltages V_{C2} and V_{C3} being connected in series to charge the output capacitor C_O which will then provide energy to the load. When current through D_0 becomes zero, operating mode ends.

2) Mode II (t_1, t_2): Here S will be kept ON. Diodes D_1, D_2 and D_3 are off and D_0 is on. The L_m starts getting charged due to the source voltage. Capacitors C_2 and C_3 are also get charged due to the source via the coupled inductor. Capacitor C_0 discharges to the load to maintain the desired output voltage. Switch S turns off to end the mode.

3) Mode III (t_2, t_3): S is turned OFF in this mode. Diodes D_1, D_2 and D_3 are off, and D_0 is on. Inductors L_k and L_m are discharged to the parasitic capacitor of the switch C_{ds}. Capacitor C_O continues to discharge and to provide energy to the load. Now the voltage across C_1 is equal to $V_{in}+V_{ds}$, diode D_1 now turned on and the mode ends.

4) Mode IV (t_3, t_4): S is kept OFF. Diodes D_1 and D_0 are turned on and D_2 and D_3 are off. Inductors L_k and L_m are discharged to charge capacitor C_1. L_k gets discharged quickly. No current flows through the secondary side and L_2 charges capacitor C_0 and maintains the voltage across the load, which makes D_0 to switch off and mode ends.

5) Mode V (t_4, t_5): S is kept OFF. Diodes D_1, D_2 and D_3 are turned on and D_0 is turned off. Inductors L_k and L_m are discharged to charge capacitor C_1. Making the voltage across the switch equals $V_{in}+V_{C1}$. And L_2 is charging both the capacitors C_2 and C_3. The mode ends when the switch is turned ON and makes the next switching period.

IV.SIMULATION RESULTS AND DISCUSSIONS

Figure 3 shows the MATLAB Simulation diagram of a high step-up boost converter using coupled inductor with PI control. The duty ratio of the switch is adjusted by PI Controller to obtain the require output.

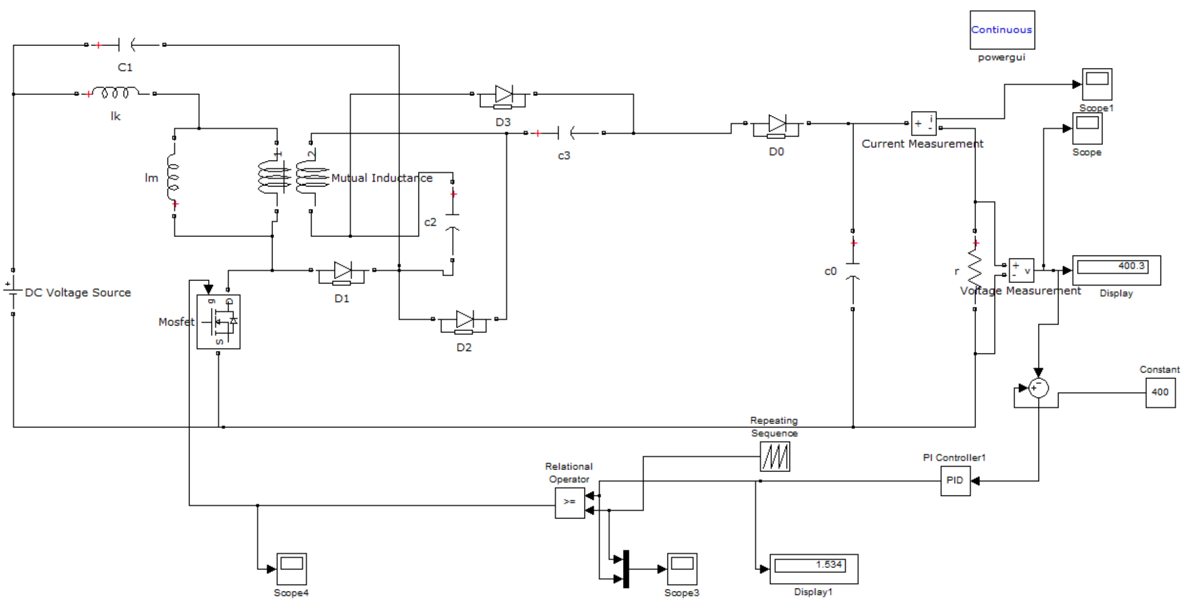

Figure 3 MATLAB Simulation Diagram of proposed converter with PI controller.

Figure 4 shows the output voltage V_0=400.3V with 18.75% maximum peak overshoot and the output voltage is well controlled by PI controller feedback.

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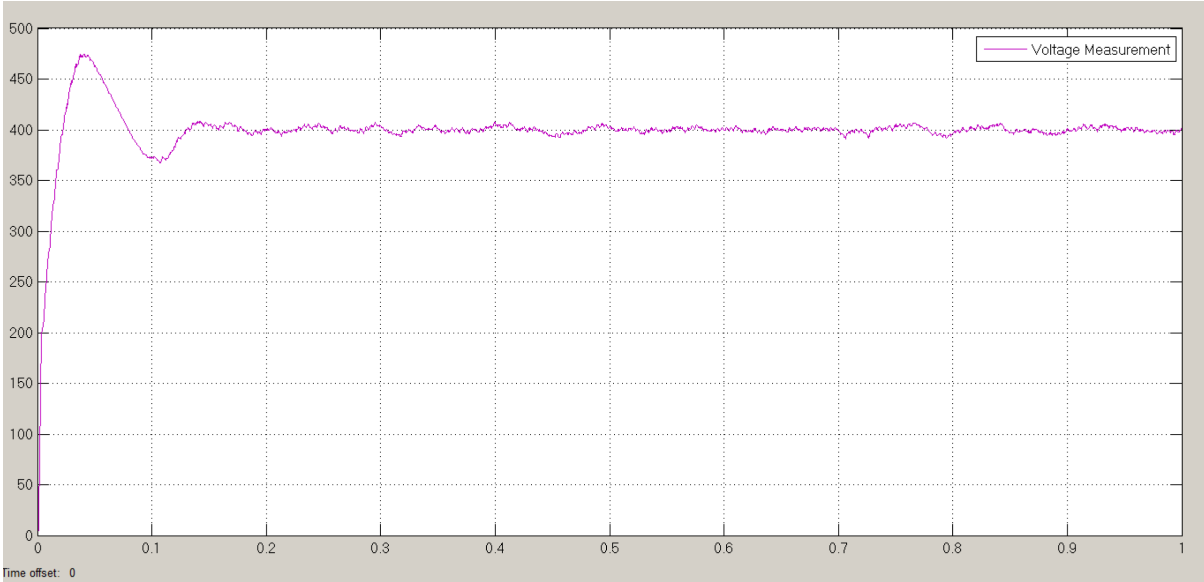

Figure 4 Output voltage (V_0=400.3V).

Figure 5 shows the output current of 0.5A which shows the proposed controller was well able to control the output current as desired.

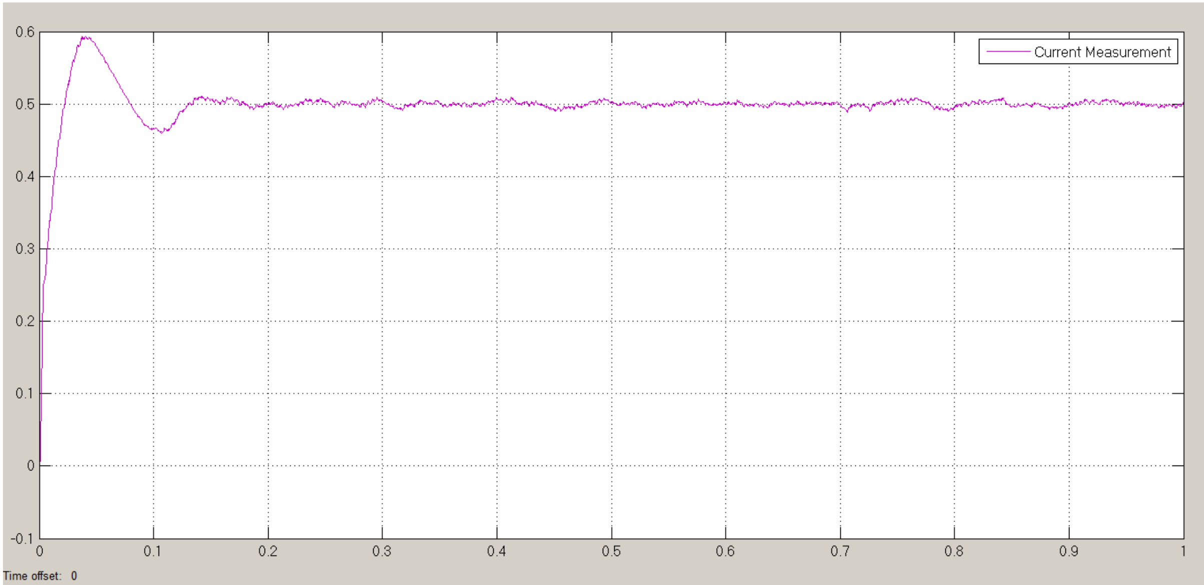

Figure 5 Output Current (I_0=0.5A).

Figure 6 shows the pulse generated and given to the switch for its proper working and the maintenance of the desired output.

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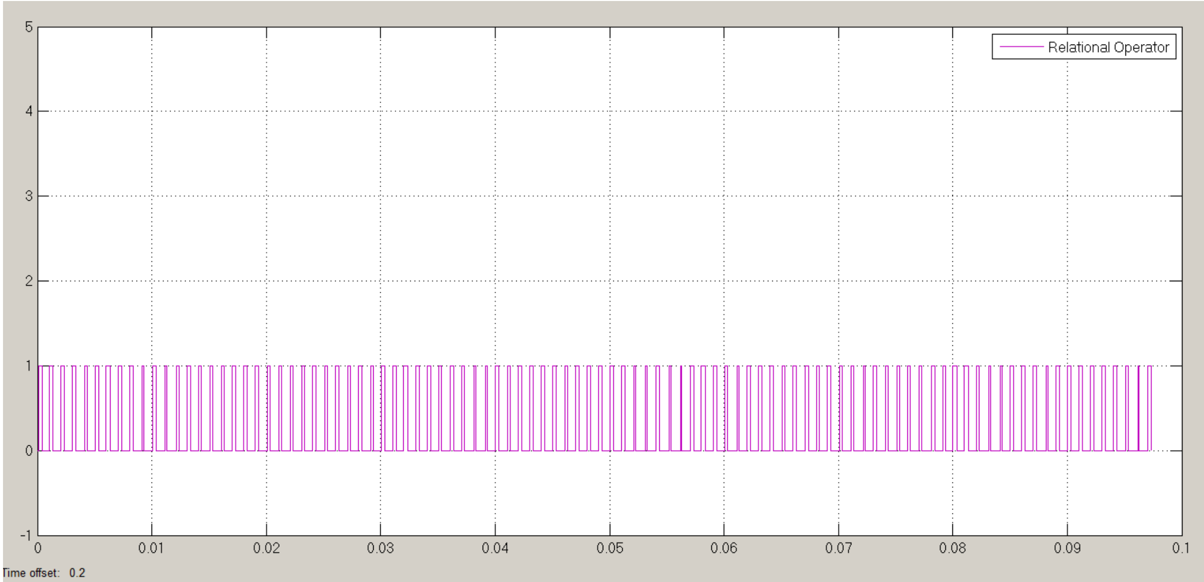

Figure 6 Pulse generated by PI controller for the switch.

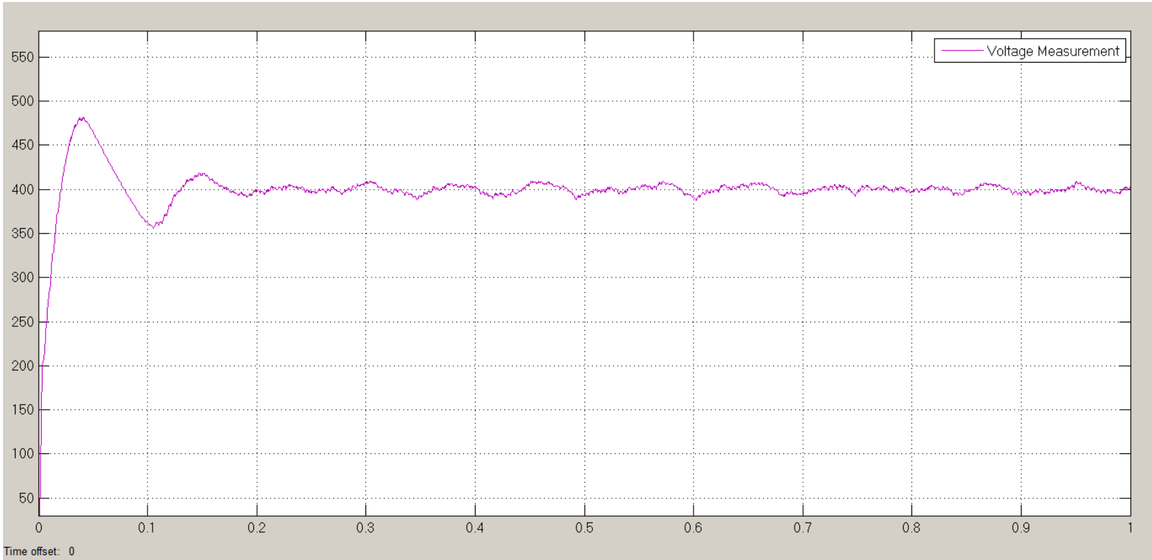

Figure 7 voltage waveform for the values K_P=0.009 and K_I=1.5.

S.I No.	K_P	K_I	V_I	V_O
1	0.009	1.1	24	402.7
2	0.009	1.2	24	406.3
3	0.009	1.3	24	404.3
4	0.009	1.4	24	400.2
5	0.009	1.5	24	404.1

Table showing different output values with varying values of K_P and K_I.

From Figure 7 it is very much clear and can be calculated that the output voltage V_O is not much stable with K_P=0.009 and K_I=1.1, 1.2, 1.3, 1.5 and the maximum peak overshoot, rise time is also more than the output in Figure 4. The output voltage waveform shown in Figure 4 has less settling time. Hence, we have chosen the values for K_P and K_I as in serial number 4 from the table i.e. K_P=0.009 and K_I=1.4. While the converter specifications were kept same.

V.CONCLUSION

Here a high step-up boost converter using coupled inductor with proportional integral control is simulated. By the capacitor charged in parallel and discharged in series by the coupled inductor, high step-up voltage gain of 400V is achieved. As the output voltage of the converter with PI Control has minimum overshoot and produces a constant output current shown. These studies could solve many types of problems regardless on stability because as we know that proportional integral controller is an intelligent controller to their appliances.

Further it can be simulated with different types of feedback control like fuzzy logic control, artificial neural network, genetic algorithm and others can be used for advanced tuning and to check the constant output voltage with least ripple and to support different appliances with different voltage ratings.

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BIOGRAPHY

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