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Design and Analysis of Hybrid Flyback Converter with Coupled Inductor and SC Network

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ABSTRACT: In recent years, DC-DC converters have become increasingly important in a variety of applications, including electric vehicles and photovoltaic systems. As a result, the converter should have a high voltage gain ratio and a high efficiency. As a result, this research presented a new DC-DC converter topology with soft switching. This suggested converter is built using a coupled inductor and includes both a boost and a switching capacitor-based flyback converter. The Switched Capacitor (SC) network is used in the flyback arrangement to increase the voltage gain. Because there is only one switch in this converter, switching losses are reduced. To improve the dynamic performance of the converter, PID controller is implemented and its performance is validated in MATLAB simulation. From the results, it is observed that the proposed converter exhibits a higher voltage gain.

KEYWORDS: Flyback Converter, SC (Switched Capacitor Network),PID Controller.

I. INTRODUCTION

The rapid advancement of technology is increasing the need for energy at the same time. Because of air pollution and other environmental concerns caused by fossil fuels, the world is migrating to renewable energy sources for power generation. Solar energy is the most extensively used of the many renewable energy sources since it is more readily available. However, because of the practical shadowing condition, the power generated by PV can be lowered. As a result, conversion efficiency suffers, and the system becomes more expensive.

Many classical converters are used to overcome these disadvantages. To convert low voltage to high voltage for needed applications, a boost converter with a larger step up are used [1-5]. The efficiency of this converter, however, is lowered due to the high inrush current. Aside from that, when used in high gain applications, it causes input current ripple/voltage or current stress on the switching devices, as well as significant switching loss as the duty cycle is increased. It also causes reverse recovery loss in diodes. As a result, the converter's efficiency will deteriorate. To overcome this, a couple inductor based converters have been proposed [6-12]. However, while shutting off switches, a voltage spike is formed due to the presence of leakage inductance. As a result, the efficiency suffers and there is a lot of Electromagnetic Interference [EMI]. Active/passive clamping approaches can be used to overcome this. However, it increases the cost. As a result, non-isolated boost converters were offered as a solution to the above-discussed problems [12-17].

However, it may have several drawbacks, including decreased reliability, increased complexity, and increased expense. Aside from that, diode recovery remains a significant issue in high gain applications [18-20]. With the help of a transformer, isolated Boost converters can also achieve high voltage gain. However, leakage inductance will play an important role and cause issues such as voltage stress on switching devices, EMI issues, and so on. At the same time, transformer losses will result in higher costs, lower efficiency, and increased control plan complexity. Boost convert with flyback converters architecture can also be constructed to get a high transform ratio. When compared to other converters, this design is conceivably simple. Maintaining voltage balance among the capacitors, on the other hand, is time-consuming.

Hence, this work proposed a novel converter topology using a conventional boost and flyback converter.

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II. MODELLING OF PROPOSED CONVERTER

Figure 1 shows a developed converter that combines a flyback converter with a typical boost converter. An additional step-up SC topology is added to the secondary side of the flyback converter to boost the output voltage of the proposed converter. It reduces the di/dt stress on diodes in addition to increasing the voltage output.

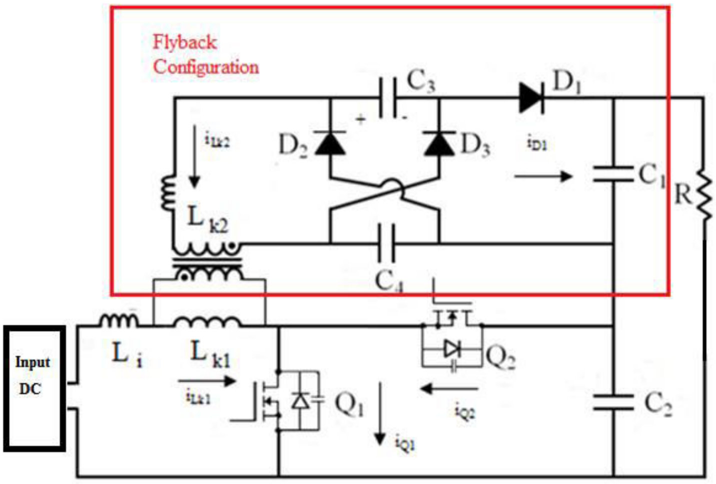

Figure 1. Schematic representation of the converter

III.DESIGN AND AC ANALYSIS OF THE PROPOSED CONVERTER

3.1Derivation of Voltage Gain

The gain (voltage) of the proposed Soft Switched Converter with Coupled Inductor circuit depends on two stages and it can be stated as

$V_{out} = V_{c1} + V_{c2}$ (1)

From the mode two operations, the inductors L_i and L_{k1} as

$V_{in}D = (V_{c1} - V_{in})(1 - D)$

$V_{in}D = (V_{c1} - V_{c2} + V_{c3} - V_{in})(1 - D)$ (2)

The voltage across capacitor as

$V_{c3} = V_{c4} = \frac{2V_{in}}{1-D}$ (3)

$V_{c1} = \frac{V_{in}}{1-D}$ (4)

$V_{c2} = \frac{6V_{in}}{1-D}$ (5)

The output capacitor is given as given in equation (6), D denotes as duty ratio, T as topology and N is the Turns ratio.

$V_{c1} = \frac{(1+T)V_{in}}{1-D}$ (6)

Mode of operation :(Stage II)

At this mode, the switch Q_2 is ONand the inductor L_{k1} as

$V_{L_{k1}} = V_{in}$ (7)

The voltage across inductor L_{k2} as

$V_{L_{k2}} = NV_{L_{k1}} = NV_{in}$ (8)

The output capacitor is given as

$V_{c2} = V_{L_{k2}} + V_{c3}$ (9)

The switch Q_2 is OFF, the inductor voltage L_i as

$V_{L_i} = \frac{DV_{in}}{1-D}$ (10)

The capacitor voltage C_3 is

$V_{c_3} = NV_{L_i} = \frac{NDV_{in}}{1-D}$ (11)

The equation (8) and (11) sub in (9) and we get the capacitor $V_{c2}$is

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$$V_{c_2} = \frac{NV_{in}}{1-D} \quad (12)$$

The equation V_{c1} and V_{c2} can be expressed the output voltage for the proposed Soft Switched Converter with Coupled Inductor is derived as

$$V_{out} = V_{c1} + V_{c2} = \frac{(1+T+N)V_{in}}{1-D} \quad (13)$$

The overall gain M of the proposed converter is given in (14), and k is the inductor coefficient

$$M = \frac{V_{out}}{V_{in}} = \frac{(1+T+kN)}{1-D} \quad (14)$$

3.2 Design of Energy Storage elements

The proposed Soft Switched Converter with Coupled Inductor operated in CCM (continuous condition mode). The output capacitor and inductor values are

$$L_i = L_{k_1} = \frac{V_{in}D}{S_f \Delta I \emptyset} \quad (15)$$

$$C_1 = C_2 = \frac{V_{out}D}{S_f \Delta V_c} \quad (16)$$

$$f_s = \frac{1}{2\pi\sqrt{LC}} \quad (17)$$

Where

ΔI -Current ripple present in the inductor,

ΔV_c-Ripple across the voltage of the capacitor, φ is the no of phases,

f_s-resonant frequency and

S_f is the switching frequency

3.3. Design of controllers

PID Controller

PID controllers have lately been employed in a variety of industrial applications to improve system control. Figure 2 depicts the PID controller.

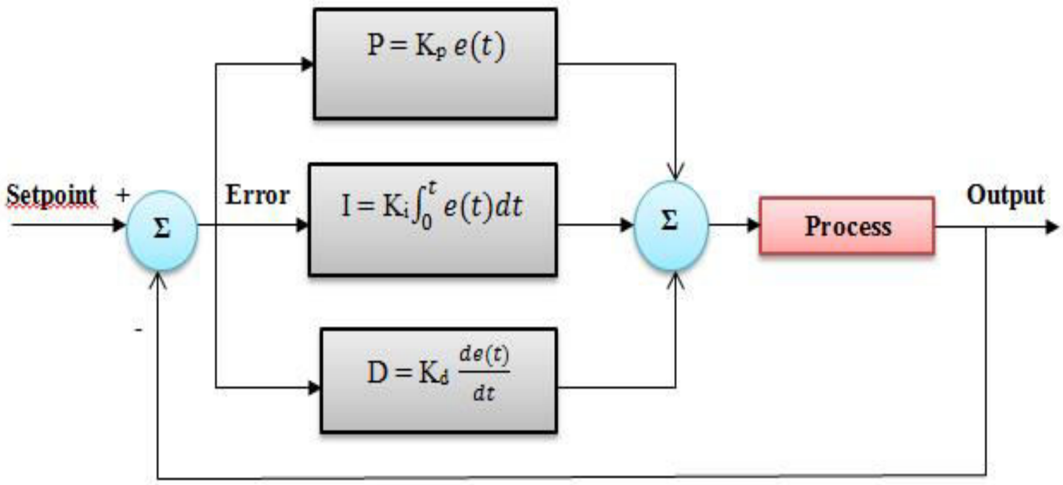

Figure 2. Block diagram of a PID controller

IV. RESULTS AND DISCUSSION

To demonstrate the effectiveness of the proposed converter, it is simulated in MATLAB 2015a. As a result, its efficacy has been demonstrated in both open and closed-loop operations.

Thus, the design limits of the components incorporated during simulation are tabulated in table 1.

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Table 1. Design parameters and their values

Parameter	Values
V_1	18 V
V_o	220 V
C_1, C_2 (SC network)	36μF
C_3, C_4(Output Capacitor)	57 μF
n	3.8
L_m	617μH
L_{k2}	17.1μH
fs	16 kHz
D	0.63

Thus, the converter is tested under open-loop mode and the output obtained is depicted in figure 3.

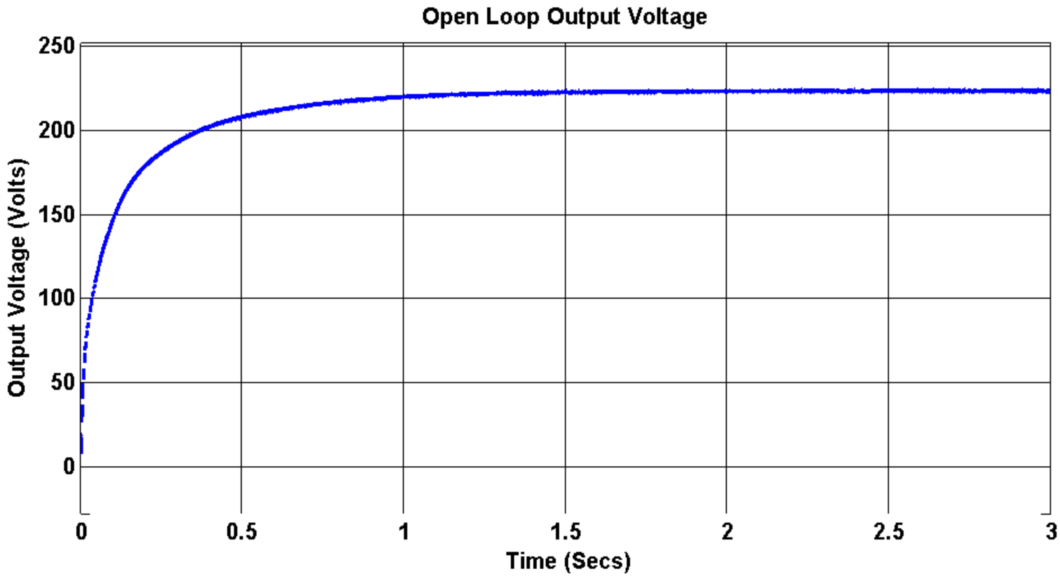

Figure 3. Output voltage of the converter under open-loop control

The suggested converter's efficiency is roughly 90.95 percent at 63 percent duty cycle, 16 kHz switching frequency, 100 W, 18V input, and 220 V output.

As a result, figure 4 depicts an examination of the proposed converter in closed-loop mode.

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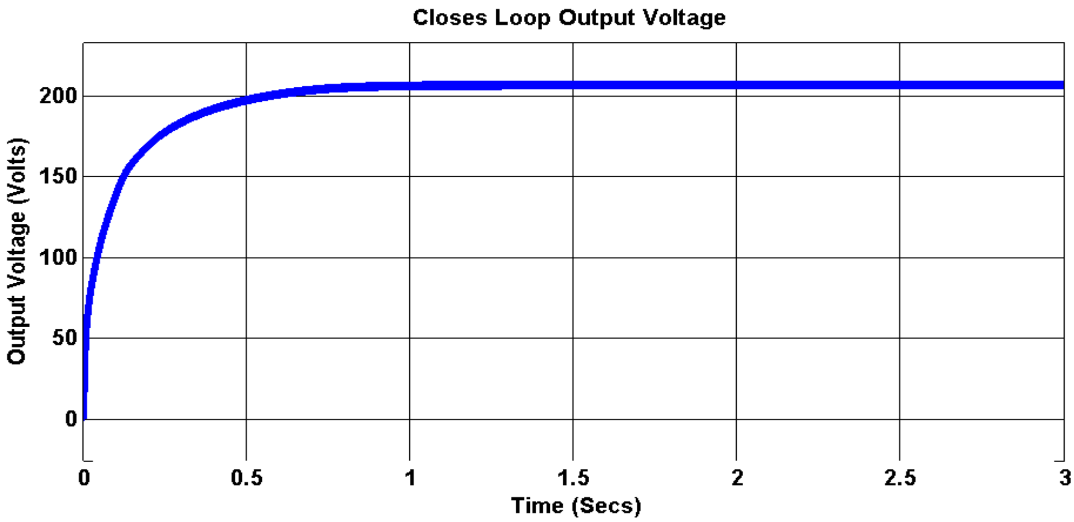

Figure 4. Output Voltage of Proposed converter with PID controller

When compared to open-loop control, there is less fluctuation in the output, as seen in the diagram above. The results show that the PID controlleris more efficient than a traditional controller.

As a result of both the open-loop and closed loop analyses, the suggested converter is found to have a larger voltage gain in both modes of analysis.

The efficiency of the proposed converter is 90.95 percent at 63 percent duty cycle, 16 kHz switching frequency, 100 W, 18V input, and 214 V output.

V.CONCLUSION

In this paper, a DC-DC converter with a high gain is modelled and developed. This suggested converter combines the functions of a flyback converter and a boost converter. In the secondary of the flyback topology, it has an SC network. The gain of the converter will be doubled with this SC network. As a result, the voltage gain of the coupled inductor with the SC network used in this converter is around 12 at a duty cycle of 0.63. Because a single switch is used in this topology and the ZVS condition is achieved, the switching loss is much lower than in other boost converters. The voltage stress on the switch is also lower, resulting in lower conduction loss. As a result, for this converter, a low rating device can be used, increasing the converter's efficiency. As a result, both simulation and experimental findings are used to evaluate the performance of the formed converter.As a result, controllers are used to improve the converter's dynamic behaviour. The PID controller is used in this study to improve the proposed system's dynamic behaviour. It is clear from the simulation testing results that the proposed converter has greater efficiency.

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