“ANALYSIS OF CONVERTER BASED COUPLED –INDUCTOR WITH SWITCH CAPACITOR”

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Abstract

In recent converter technology, same of energy loss in inductor used in that converter. So, Efficiency of converter is reduced because of this loss energy. This loss is minimizing by using coupled inductor with switch capacitor. The recommended structure consist voltage multiplier circuits with coupled inductor to get maximum voltage gain. Two capacitors are charged amid the turn off period utilizing stored energy of coupled inductor windings which helps to increase the voltage conversion efficiency. The leakage inductive current is recycled through the clamp circuit because of that the voltage stress on switch is reduced and durability of converter will increase as well as efficiency. In this paper, Converter in view of Coupled inductor and Switch Capacitor is analyzed by using MATLAB SIMULINK and hardware implementation.

Key Words : Coupled-inductor, voltage multiplier cells, clamp circuit, dc/dc converter.

1. Introduction

The lack of ordinary petroleum products and the natural issues has been requiring the hunt and use of sustainable power sources. Among them, photovoltaic cells, energy units, wind power, et cetera have pulled in much consideration in late year. In the private PV framework, the low yield voltage (commonly lower than 50V) of PV boards should be first supported to a high-voltage level (300V~400V for the full-connect inverter). Correspondingly, Fuel cell includes low voltage and high present. What's more, cause the electrochemical response, energy unit stack with high yield voltage is both troublesome and costly to produce. Therefore, high-advance up converters are regularly required to support the low-level voltage for 380~400V network associated systems. Take the TEG for instance. TEG can be connected to little frameworks, for example, implantable medicinal sensors, to give support free task to years. For the little frameworks, the TEG yield voltage is generally a few 100 millivolts because of low temperature distinction [1]. These events additionally require high advance up converters. The most generally investigated gathering of high-advance up converters is those in due to the coupled inductor. Coupling or tapping the inductor speaks to a basic, viable and promising -contrasting option to accomplish wide voltage change proportions. For high-advance up applications, the inductors of ordinary Boost, Zeta, Cuk or Sepic converters can be coupled to expand the voltage transformation proportion [2]. Among them, the coupled-inductor help converter and its inferred topologies have gotten extraordinary considerations.

Ordinary lift converters can accomplish high voltage up with a to a great degree high duty ratio [3]. Be that as it may, the execution of the system will be weakened with a high obligation cycle because of a few issues, for example, low change proficiency, turn around -re recuperation and electromagnetic impedance issues [4]. Some transformer-based converters like forward, push-pull or flyback converters can accomplish high up voltage pick up by altering the turn proportion of the transformer. In any case, the leakage inductor of the transformer will cause difficult issues, for example, voltage spike on the primary switch and high power scattering [5]. Switched capacitor and voltage lift methods have been used generally to accomplish high advance voltage pick up. Nonetheless, in propose structures, high charging streams will move through the fundamental switch and increment the conduction misfortunes. Coupled-inductor based converters can likewise accomplish high up voltage by altering the turn proportions [6], [7]. In any case, the vitality put away in the leakage inductor causes a voltage spike on the fundamental switch and break down the transformation efficiency. Some high advance up converters with two switch and single-switch are presented in the current distributed literary works. In any case, the change proportion isn't sufficiently extensive.

This paper presents structure having two Voltage multiplier circuits as well as coupled inductor, both of this component use for getting high step up voltage gain. Moreover, a capacitor is charged amid the turn off period utilizing the vitality put away in the coupled inductor which builds the voltage exchange pick up. The energy store in leakage inductor is reused with the utilization of an inactive clamp circuit. The voltage on the fundamental power switch is likewise diminished in the proposed topology.
2. System Description of Proposed Converter

The circuit of converter is shown in figure 1, the converter circuit consist DC voltage input (Vin), MOSFET as switch, coupled inductor as well as four capacitors and diodes. Diode D1 and capacitor C1 works as clamp circuit. Diode D2 and capacitor C2 works as voltage multiplier circuit. Coupled inductor having turns ratio (Np/Ns), Lm and Lk are magnetizing inductance and leakage inductance respectively.

Fig. 1 : Circuit of the presented converter

Keeping in mind the end goal to streamline the circuit investigation of the converter, a few suspicions are considered as take after:

- All Capacitors are adequately expansive. Accordingly, voltages over all capacitors are thought to be steady amid one exchanging period.
- All segments are perfect however the spillage inductance of the coupled inductor is considered.

3. Switching Modes of Operation of Proposed Converter

The operating Modes are explained as follows.

A. Mode-I: In mode first, MOSFET is ON. Diode D2 & D4 are On as well as D1 & D3 are in off state. Lm is magnetize through MOSFET by DC input(Vin).Current of Lk increased and secondary current decreases linearly. Power required by RL is supplied by Co. This mode will stop when secondary current becomes zero.

B. Mode-II: In Second mode switch and D3 are On and D1,D2 and D4 are off. In this mode Lm is magnetize by DC input. The current of Lk and Lm increased linearly. Secondary side of coupled inductor, clamp circuit and input voltage charge the capacitor C3. The capacitor Co provide energy to RL. This mode will end when switch will OFF.

C. Mode-III: In third mode diode D1,D3 is in on state and switch ,diode D2,D4 are in off state. Magnetizing inductance, leakage inductance and C2 will charged up the capacitor C1.Secondary current is also increased as decreased in leakage current in inductor. The capacitor Co provide required amount of energy to RL,C3 is charged through D3. This mode ends when ilk will equals to ilm.

D. Mode-IV: In fourth mode MOSFET are in off state. Diode D2,D3 are in off state and D1,D4 are in on state. The capacitor C2,Lk & Lm together charged up Clamping Capacitor C1.The current in Lk and Lm decreases linearly as well as some part of energy stored in Lm is transferred to secondary side of coupled inductor .The input voltage,C3 and primary and secondary sides of coupled inductor provide energy to RL and charged up Capacitor Co. This mode ends when D1 get off.
E. Mode-V: In fifth mode switch, diode D1, D3 are in off state and diode D2, D4 are in on state. The current of Lk and Lm decreases linearly. The energy stored in Lm is transferred through D2 to charge the capacitor C2. In this mode the input voltage, capacitor C3 & all sides of coupled inductor will provide energy to RL as well as charge capacitor Co. This mode ends when MOSFET is turned on.

4. Results and Discussion

Keeping in mind the end goal of the given topologies, reenactment investigations of the individual converters are done in MATLAB. A ordinary battery source with low voltage of 40V is utilized in the converter module.

A) Software Analysis of Converter Model

For software analysis of converter model MATLAB software is used. The structure of converter model is constructed on MATLAB. By varying switching frequency numbers of change in output voltage, output power as well as efficiency of converter is noted. Following observation table shows the reading took on MATLAB model of converter.

| Switching Frequency (kHz) | Output Voltage (V) | Output Power (W) | Efficiency (%) |
|---------------------------|--------------------|------------------|----------------|
| 40                        | 377.00             | 267.5            | 97.00          |
| 45                        | 377.00             | 266.8            | 97.10          |
| 50                        | 376.60             | 266.2            | 97.15          |
| 55                        | 376.10             | 265.4            | 97.20          |
| 60                        | 375.75             | 264.9            | 97.25          |
| 65                        | 375.25             | 264.2            | 97.30          |
| 70                        | 374.80             | 263.6            | 97.35          |
| 75                        | 374.25             | 262.8            | 97.44          |

The bar graph of output voltage with respect to switching frequency is shown in figure 7. The bar graph shows that with increase in switching frequency output voltage is decreasing.

The bar graph of output power with respect to switching frequency is shown in figure 8. This bar graph shows that with increase in switching frequency output power is decrease.

Table 1
Component Specification

| Name of Component | Specification |
|-------------------|---------------|
| Input Voltage     | 40 V          |
| C1                | 47µF          |
| C2                | 47µF          |
| C3                | 100µF         |
| C0                | 220µF         |
| Lk                | 1µH           |
| Lm                | 330 µH        |
| Switching Frequency | 65kHz        |
The bar graph of converter efficiency with respect to switching frequency is shown in figure 9. This bar graph shows that the efficiency of converter model is increase with increase in switching frequency.

Now the observation shows that on 65 KHz maximum efficiency can found. Now by changing the duty ratio we took reading. The reading by changing switching frequency are shown as bellow.

### Table 3
Observation of System Output

| Duty Cycle(%) | Output Voltage(V) | Output Power(W) | Efficiency(%) |
|---------------|-------------------|----------------|--------------|
| 40            | 302               | 171            | 97.02        |
| 45            | 336               | 212            | 96.95        |
| 50            | 375               | 264            | 97.29        |
| 53            | 400               | 300            | 97.60        |
| 55            | 421               | 334            | 97.90        |
| 60            | 478               | 430            | 98.66        |
| 65            | 548               | 564            | 99.34        |
| 70            | 635               | 757            | 99.75        |

The bar graph of output voltage, output power and efficiency with respect to duty ratio is shown in figure 10, figure 11 and figure 12 respectively.

From all bar graph we can say that output voltage, output power and efficiency of converter are increased with increase in duty ratio.

From above perception and analysis at Switching Frequency 65KHz, output power, output voltage and also proficiency give stable yield response. As per investigation on 65KHz switching frequency the effectiveness is 97.30% which is higher than other kind of coupled-inductor base converters.

### A) Hardware Analysis of Converter Model

For hardware analysis of converter, converter components are used same which are used for software analysis in table-I. Numbers of readings has been taken for hardware analysis of converter model by changing switching frequency, the readings are given in table-IV.

As we know after software analysis, the converter output voltage, output power and efficiency all are changed by changing switching frequency of switch. In order to get high step up voltage gain with maximum efficiency the converters hardware model is tested.
Voltage input (Vi) = 40 V
Input Current (Ii) = 0.685 A
Output Resistance (R_o) = 526 Ω
Input power (P_i) = Vi × Ii
= 40 × 0.685
= 27.4 W

Table 4
Observation of Hardware Output

| Switching Frequency (KHz) | Output Voltage (V_o) | Output Current (I_o) | Output Power (W_o) |
|--------------------------|----------------------|---------------------|-------------------|
| 45                       | 460 V                | 0.874 A             | 402.00 W          |
| 50                       | 450 V                | 0.855 A             | 384.97 W          |
| 55                       | 440 V                | 0.386 A             | 368.06 W          |
| 60                       | 430 V                | 0.817 A             | 351.48 W          |
| 65                       | 374 V                | 0.711 A             | 265.90 W          |
| 70                       | 360 V                | 0.684 A             | 246.38 W          |

The figure 13 and figure 14 shows the bar graph of output voltage and output power with respect to change in switching frequency.

The bar graph show that the output voltage and power both decreases with increase in switching frequency.

From above analysis, the efficiency of converter is found 97.08 % at 226 W power output and output voltage 374 V.

Efficiency of converter = \( \frac{P_o}{P_i} \times 100 \)
\( = \frac{266}{27.4} \times 100 \)
\( = 97.08 \% \)

5. Comparative Analysis of Presented Converter

Here in Table V. and figure 15. the comparison between some same type of converters with Presented converter is given. On basis of Table V. we can say that presented converter is better than other converter. The figure 15. is also show that the presented converter is more efficient other converter.

Table 5
Comparative Analysis of Presented Converter

| Specification                  | Converters [12] | Converters [13] | Converter [11] | Presented converter |
|--------------------------------|-----------------|-----------------|----------------|---------------------|
| Output voltage                 | 380V            | 400V            | 400            | 374V                |
| Rated power                    | 100W            | 300W            | 200W           | 266W                |
| Switching frequency            | 65KHz           | 50KHz           | 50KHz          | 50KHz               |
| MOSFET Switch                  | 2               | 1               | 1              | 1                   |
| No. of Diodes                  | 4               | 5               | 6              | 4                   |
| No. of Capacitor               | 4               | 5               | 6              | 4                   |
| Efficiency                     | 90.95%          | 93%             | 94%            | 97.08%              |

Fig. 13 : Graph of output voltage and switching frequency

Fig. 14 : Graph of output power and switching frequency

6. Conclusion

This paper deals with the high step up DC/DC converter. In this paper analysis of converter model is provided. The software analysis is done on MATLAB model of converter and hardware is also implemented of same. From hardware and software investigation it is clear that converter can provide high voltage gain with high efficiency. The proposed structure is providing 97.08 % efficiency at 266 W output power and 374V output voltage.
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