Two Level Voltage Gain Enhancement with Inductor Coupled KY Converter

[1]Anisha Anna Abraham, [2]Vijayasree G.

[1]Research Scholar, [2]Assistant Professor
Government Engineering College Idukki

***Abstract*— Conventional energy sources are on the verge of extinction due to rapid industrialization and population growth. Renewable energy sources have emerged as suitable alternatives for both advanced and developing nations. These kinds of green power facilities include solar cells, fuel cells, etc. In many applications, high voltage conversion converters play an important role in boosting the low output voltages of green power facilities to the high voltages, which the loads need. In this project, a novel voltage-boosting converter is presented, which combines one charge pump and one coupled inductor with the turns ratio. The corresponding voltage gain is greater than that of the existing step-up converter combining KY and buck-boost converters. It possesses a continuous conduction mode through- out its operation which is also a stable one as compared to other existing topologies. Presence of an output inductor and a stable CCM make output current non-pulsating. This further reduces the current ripples in output and thereby reducing the stress over output filter. Mutually independent control variable are used for voltage conversion.**

***Keywords*— Coupled inductor; KY converter; Charge pump;**

I. INTRODUCTION

In the past century, global surface temperatures have increased at a rate near 6°C/century because the global warming is taking place due to effluent gas emissions and increases in Carbon Monoxide. Problems with energy supplies and use are related not only to global warming but also to such environmental concerns as air pollution, acid precipitation, ozone depletion, forest destruction, and radioactive substance emissions. To prevent these effects, some potential solutions have evolved including energy conservation through improved energy efficiency, a reduction in fossil fuel use and an increase in environmental friendly energy supplies. In order to protect the natural environment on the earth, the development of clean energy without pollution has the major representative role in the last decade. By dealing with the issue of global warming, clean energies, such as fuel cell (FC), photovoltaic, and wind energy, etc., have been rapidly promoted. With the development in power electronics technologies the renewable energy sources utilization become an increasing trend for electrical energy. The massy usage of fossil fuels, such as oil, coal and gas results in serious greenhouse effect and environmental pollution, which have a great influence in the world. Meanwhile, there is a big contradiction between the fossil fuel supply and the global energy demand. Energy shortage and environmental pollution have been the major obstacles for human being development. How to find renewable energy sources is becoming urgent. Fuel cells and photovoltaic (PVs) have been gaining a lot of interest as leading renewable energy technologies .The merits of solar these systems are cleanness, long life, relative lack of noise or movement, as well as their ease of installation and integration when compared to others.

Briefly speaking, the output voltages of most distributed energy resources such as fuel cells and photovoltaic (PV) are usually relatively low, requiring a high step up converter for practical applications. In many applications, high-voltage conversion converters play an important role in boosting the low output voltages of green power facilities to the high voltages, which the loads need. Considering the traditional boost converter and buck-boost converter we can see that their voltage gains are not high enough. Up to now, many kinds of voltage-boosting techniques have been presented. Among these KY converter is the most acceptable one. KY converter is a DC to DC voltage boosting up converter [1]. It is invented by the Mr. K. I Hwu and Y. T Yau. Hence, it is called as KY converter. It is a boost converter. The voltage conversion ratio of basic KY converter is higher than that of that of traditional boost converter and buck-boost converter. The main characteristic of KY converter is fast load transient responses as its behavior is similar to that of the buck converter with synchronous rectification (SR) [2]. It always operate in the continuous conduction mode (CCM), so it possess non pulsating output current, thereby not only decreasing the current stress on the output capacitor but also reducing the output voltage ripple [3]. However, the KY converter has the voltage conversion ratio limited up to one plus D, where D is the duty cycle created from the control effort of the controller.

In this paper, a novel voltage-boosting converter is presented, which combines one charge pump and one coupled inductor. The corresponding voltage gain is greater than that of the existing KY converter. It possesses a continuous conduction mode throughout its operation which is also a stable one. Presence of an output inductor and a stable CCM make output current non pulsating. This further reduces the current ripples in output and thereby reducing the stress over output filter. Mutually independent control variables, turns ratio of coupled inductor and duty cycle of switch, are used for voltage conversion. Moreover variation of Turns Ratio is independent of circuit design and will be constant during the operation. It can be decided in accordance with the demand of application. Hence through an online tap changer and a selection switch variation of turns ratio can be achieved, in order to fulfill the second level of voltage enhancement. By this multiple voltages can be generated at same output terminal.

II. PROPOSED CIRCUIT TOPOLGY

Proposed topology consist of complimentary switch pair S1 & S2. Since they are complimentary to each other both will not be switched on and switched off simultaneously. So that switching signals to S1 can be fed to S2 after complimenting. Two MOSFET switches are used in the topology. Coupled inductor with turns ratio provide a second level of voltage enhancement. Along with that it provides isolation between input and output side. So that components at input side will not experience the high voltage at output. The dot conversion of coupled inductor will decide the polarity of secondary winding voltage. Charge pumping capacitor C1 pumps the charge from low voltage input side to output side. General inductor coupled based converter topology exhibit a high amount of pulsation at input current. To reduce this ripple an input filter is essential. And this Charge Pumping Capacitor also fulfills the needed filtering purpose. Charge Transferring Capacitor C2 transfer the energy from input side to outside. Filter inductor Lo serve the purpose of conditioning the output current waveform. Pulsations in the output current are reduced by providing adequate energy demand of the load when needed. Output capacitor Co provides voltage regulation across the load.

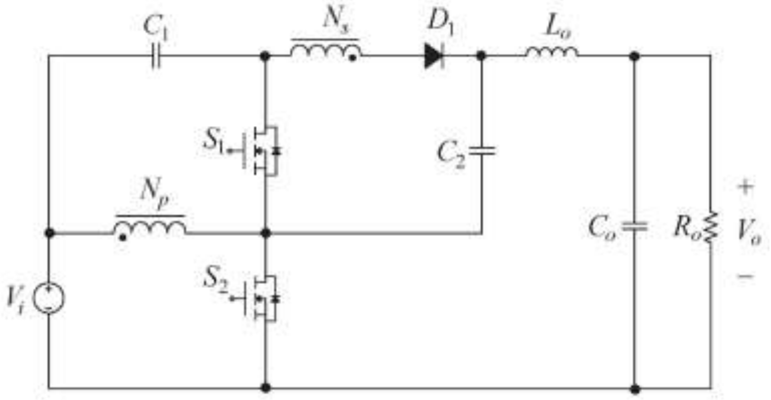

Fig. 1: Circuit Diagram of Proposed Topology

A. *Modes of Operation*

For the convenience to understand and evaluate the mode of operation coupled inductor is modeled as an ideal transformer except that one magnetizing inductor Lm is connected in parallel with the primary winding

Modes of operation are generally divided into two with respect to the switching of two switches. As both of them serve as a complimentary switch pair, they won't be turned on or turned off simultaneously. Both these mode can be further subdivided based on the current flow path.

Mode 1: Switch S2 ON and Switch S1 OFF

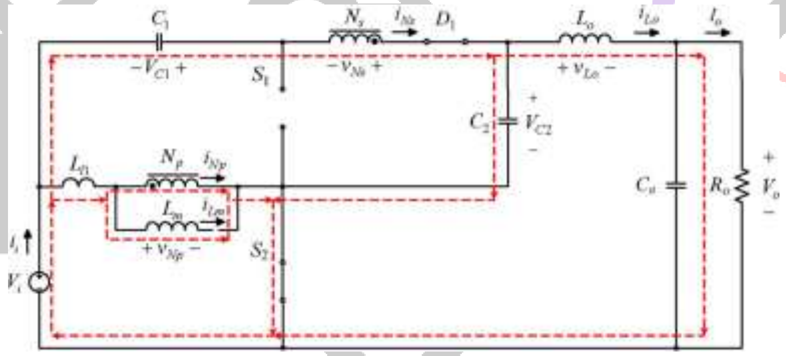

Fig. 2 . Power flow in mode 1

1) Energisation of Magnetizing Inductance Lm

As switch S2 is turned on magnetizing inductance get connected in parallel with supply. Feeding from supply magnetizing inductance Lm get energized. Voltage across coupled inductor Np is vNp = Vi and its polarity is given in fig.2.

2) Charging of Charge Pumping Capacitor C2

Voltage induced across coupled inductor Np is transferred to Ns through magnetic induction. As per the dot convention voltage $VNs = VNp \times \frac{Ns}{Np}$ is induced across Ns. This induced voltage make diode D1 forward biased. Capacitor C1 which is under charged state discharge to C2 through D1. Therefore C2 get charged to a voltage $Vc2 = Vi + Vc1 + Vi \times \frac{Ns}{Np}$.

3) Filter Inductor Lo Feeding Energy to Load

Filter inductor serve the purpose of conditioning the output current waveform. Any outbalance in the demand from the load is taken care of filter inductor and reduce the pulsation in output current. Through diode D1 filter inductor feed the load during addition demand situation.

Mode 2: Switch S1 ON and Switch S2 OFF

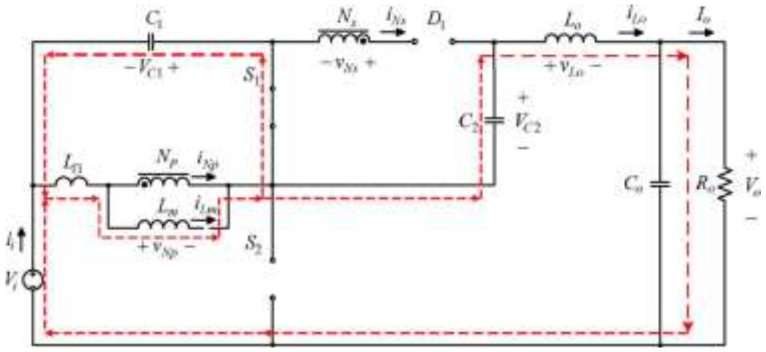

Fig. 3. Power flow in mode 2

1) *Charging of Energy Transferring Capacitor C1*

As switch S1 is turned on energized inductor will get a path to discharge. Capacitor C1 is capable of getting charged beyond supply voltage Vi. And its level of charging depends upon the duty ratio of switch S1. In this mode voltage across the coupled inductor Np is decide by VC1 . So voltage induced across Ns is equal to $VNp = -Vc1 \times \frac{Ns}{Np}$ and this makes the diode D1 reverse biased.

2) *Filter Inductor Lo Energizing From C2*

Initially charged, capacitor C2 along with supply and energized magnetizing inductor will charge the output inductor Lo through load. Mode 2 operations will demagnetize the coupled inductor leaving its chance to get saturated.

Expression for Duty Ratio

By applying the voltage second balance principle to Lm and Lo over one switching period , voltage gain is obtained as

$$\frac{Vo}{Vi} = \frac{2-D}{1-D} + \frac{Ns}{Np} \quad (1)$$

III. SIMULATION RESULT

The simulation result for the proposed step-up dc-dc converter is explained below. The proposed converter is designed for 12V input voltage, 72V output voltage and 60W output power and simulated in MATLAB. The energy transferring capacitor C1 is designed in such a way that the peak-to peak value of capacitor voltage is minimized.
The charge pump capacitor C2 value is obtained in order to minimize the variation in capacitor voltage .
Magnetizing inductor Lm is designed to operate in the positive region.
Assuming duty cycle as 50% and frequency as 100 kHz we get the values of all the components use in the converter.

A. Modeling of Converter with Single Output

Using the designed circuit components, MATLAB-Simulink model of proposed topology is generated. The closed loop model of the proposed topolgy incorporating PI controller is shown below. Output voltage waveform obtained from the converter is also given.

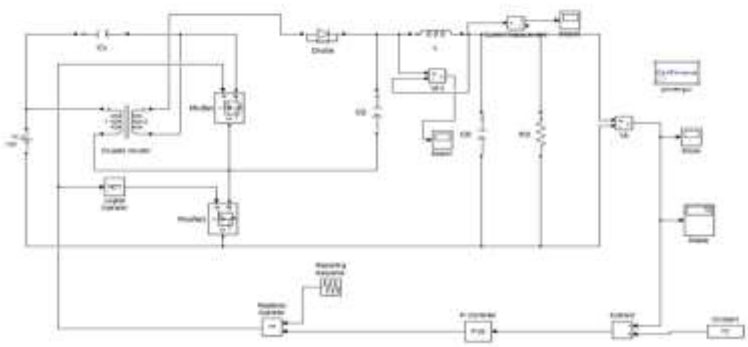

Fig. 4: Simulink Model of Converter with Single Output

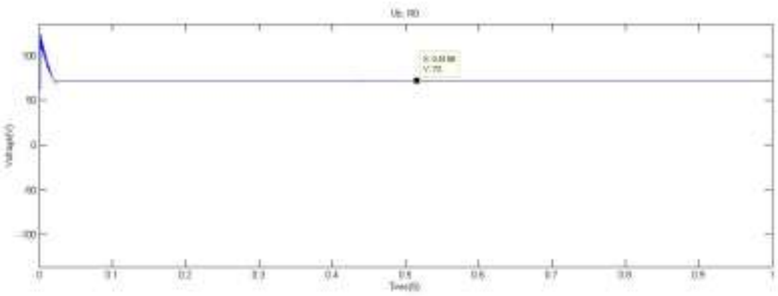

Fig. 5: Output Voltage Waveform

B. Modeling Of Converter With Multiple Output

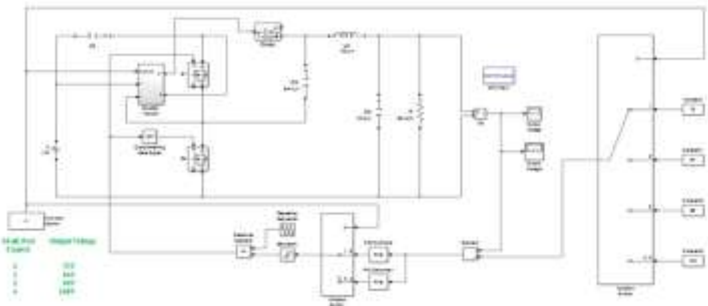

Fig. 6: Simulink Model of Converter with Multiple Output

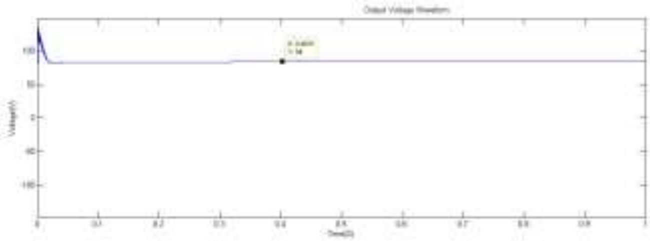

Fig. 7: Output Voltage Waveform for 84 V Arrangement

Using a selective switch the turns ratio of coupled inductor is varied. From this converter any one of the four different output 72V, 84V, 96 and 108V can be obtained at a time. Voltage waveform of closed loop modified topology with Simulink model is given in Fig. 7.

IV. CONCLUSION

A novel high step-up converter has been presented herein. By combining the coupled inductor and the switched capacitor, the corresponding voltage gain is higher than that of the existing converter. Furthermore, the proposed converter has no floating output, and it has one output inductor; hence, the output current is non-pulsating. Moreover, the structure of the proposed converter is quite simple and very suitable for industrial applications.

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