Design of High Step-up DC/DC Converter and Switched-Capacitor techniques for Renewable Energy Applications

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***Abstract*:** This paper proposes a design of high step-up DC/DC converter is presented for Renewable Energy Applications. The suggested structure consists of a coupled inductor and two voltage multiplier cells in order to obtain high step-up voltage gain. In addition, two capacitors are charged during the switch-off period using the energy stored in the coupled inductor which increases the voltage transfer gain. The energy stored in the leakage inductance is recycled with the use of a passive clamp circuit. The voltage stress on the main power switch is also reduced in the proposed topology. Therefore, a main power switch with low resistance R_{DS} can be used to reduce the conduction losses. The operation principle and the steady-state analyses are discussed thoroughly. To verify the performance of the presented converter, laboratory prototype circuit is implemented. The results validate the theoretical analyses and the practicability of the presented high step-up converter. These converters boost the low input voltages (24-40 V) to a high voltage level(300-400 V).The simulation will be carried in MATLAB/SIMULINK and results will be presented to validate the claim.

Keywords **- DC/DC Converter, Coupled Inductor, Passive Clamp Circuit, Steady-State Analyses Renewable Energy.**

I.INTRODUCTION

In new technical era, the demands for fossil fuels are reduced, when non conventional sources of energy are used because of energy storage and environmental desecration. The non conventional energy sources such as solar energy, wind energy, hydropower etc generates low output voltage. Therefore, the high step up boost converters are widely used in where the generation of output voltage is less. Also using for these reason, the environmental problems are reduces and problem such as low conversion efficiency, reverse recovery and electromagnetic interference problems to benefit from spotless or neat sources of energy such as solar and wind. In general, a conventional boost converter is used to provide a high step up voltage gain with a large duty ratio. Some transformer-based converters like forward, push-pull or fly back converters can achieve high step-up voltage gain by adjusting the turn ratio of the transformer. However, the leakage inductor of the transformer will cause serious problems such as voltage spike on the main switch and high power dissipation. In order to improve the conversion efficiency and obtain high step-up voltage gain, many converter structures have been presented. Switched capacitor and voltage lift techniques have been used widely to achieve high step-up voltage gain. However, in these structures, high charging currents will flow through the main switch and increase the conduction losses. Modifying a boost–flyback converter is one of the simple approaches to achieving high step-up gain; this gain is realized through a coupled inductor. The leakage energy is recovered to the output terminal. An interleaved boost converter with a voltage-lift capacitor is highly similar to the conventional interleaved type.

Due to impaction of the losses of the diodes and power switches, the conversion efficiency and step up voltage gain are limited. So, the high step up converters are suitable solutions for the above mentioned problems. These converters boost the low input voltage to a high input level. Some conduction losses are caused by resistances of semiconductor components and coupled inductors. Thus, all the components in the proposed converter are not assumed to be ideal, except for all the capacitors.

II.THEORETICAL FRAMEWORK

The characteristics of leakage inductors are neglected because of energy reclaim to use. The equivalent circuit, which includes the conduction losses of coupled inductors and semiconductor components, The main highlights of high step up converters are their large conversion ratio, high efficiency and small size. Generally, the high step up converter is used for these applications which required is used for these applications which requires to have high voltage gain and high efficiency. To achieve high step-up voltage gain, many converters have been proposed. The means on the literature can be discussed in two sections: capacitor means and magnetic means. Capacitor means include cascade technique, switched-capacitor technique and voltage-lift technique. Two cascade boost converter can achieve high step-up voltage gain but it has energy-two-processing structure. Thus, the efficiency is low and needs two switches. The voltage-lift technique and switched-capacitor can achieve high step-up voltage gain. However, the main switch suffers high transient current, the conduction loss is increased. Magnetic means include coupled-inductor-technique.The switched coupled-inductor technique is proposed. The converters can achieve high step-up voltage gain by adjusting the turns ratio of coupled inductor. Although the leakage energy can send to the output directly, the voltage stress of switch is equal to output voltage. It is difficult to chose low *R*ds(on) switch. Thus, the converter is proposed. The third winding is added and the voltage stress of main switch is reduced. Low *R*ds(on) switch can be chose to reduce conduction loss. The switched coupled- inductor technique is a very good method to achieve high step-up voltage gain. This technique can apply in many converters and achieve a good performance.

III.LITERATURE SURVEY

[1] Kuo-Ching Tseng, Chi-Chih Huang, and Wei-Yuan Shih, "A High Step-Up Converter With a Voltage Multiplier Module for a Photovoltaic System," ***IEEE Trans. on Power Electron., vol. 28, pp. 3047-3057 no. 6, June 2013.***

A novel high step-up converter is proposed for a front end photovoltaic system. Through a voltage multiplier module, an asymmetrical interleaved high step-up converter obtains high step up gain without operating at an extreme duty ratio. The voltage multiplier module is composed of a conventional boost converter and coupled inductors. An extra conventional boost converter is integrated into the first phase to achieve a considerably higher voltage conversion ratio. The two-phase configuration not only reduces the current stress through each power switch, but also constrains the input current ripple, which decreases the conduction losses of metal–oxide– semiconductor field-effect transistors (MOSFETs). In addition, the proposed converter functions as an active clamp circuit, which alleviates large voltage spikes across the power switches. Thus, the low-voltage-rated MOSFETs can be adopted for reductions of conduction losses and cost. Efficiency improves because the energy stored in leakage inductances is recycled to the output terminal. Finally, the prototype circuit with a 40-V input voltage, 380-V output, and 1000- W output power is operated to verify its performance. The highest efficiency is 96.8%.

[2] Oded Abutbul, Amir Gherlitz, Yefim Berkovich, and Adrian Ioinovici, "Step- Up Switching-Mode Converter With High Voltage Gain Using a Switched-Capacitor Circuit," ***IEEE Trans. on circuit and system, vol. 50, pp. 1098-1102, no. 8, Aug.2003.***

A new circuit is proposed for a steep step-up of the line voltage. It integrates a switched-capacitor (SC) circuit within a boost converter. An SC circuit can achieve any voltage ratio, allowing for a boost of the input voltage to high values. It is unregulated to allow for a very high efficiency. The boost stage has a regulation purpose. It can operate at a relatively low duty cycle, thus avoiding diode-reverse recovery problems. The new circuit is not a cascade interconnection of the two power stages. Their operation is integrated. The simplicity and robustness of the solution, the possibility of getting higher voltage ratios than cascading boost converters, without using transformers with all their problems, and the good overall efficiency are the benefits of the proposed converter. Their operation is integrated. The simplicity and robustness of the solution, the possibility of getting higher voltage ratios than cascading boost converters, without using transformers with all their problems, and the good overall efficiency are the benefits of the proposed converter.

IV.SYSTEM OPERATION

1. DC / DC Operation

A DC power supply is used in most of the appliances where a constant voltage is required. DC stands for Direct Current, in which the current flow is unidirectional. The process of DC conversion can be don be DC Converters. The charge carriers in DC supply travel in a single direction. Solar cells, batteries and thermocouples are the sources of DC supply. A DC voltage can produce a certain amount of constant electricity, which becomes weak when it travels further longer.

2. Switch Capacitor DC/ DC Operation

A Switch Capacitor DC-DC converters use only capacitors as charge-transfer devices. The inductor-less power transfer provides multiple advantages over inductor-based switching regulators including fast transient response and reduced system size. Capacitors have better energy density and simpler, more cost-effective integration on-die in CMOS processes without additional fabrication steps. These advantages make SC DC-DC converters an attractive for applications where low cost and smaller devices are the norm. Their operation is integrated. The simplicity and robustness of the solution, the possibility of getting higher voltage ratios than cascading boost converters, without using transformers with all their problems, and the good overall efficiency are the benefits of the proposed converter.

V.IMPLEMENTATION OF PROPOSED CONVERTER

1. POWER SWITCH(MOSFET)

Features of power switch MOSFET is Dynamic dv/dt Rating, Repetitive Avalanche Rated, Isolated Central Mounting Hole, Fast Switching, Ease of Paralleling**.**

Simple Drive Requirements V_{DSS} = 200, V_{ID} (cont) = 46 A, R_{DS}(on) = 55 mΩ

2. FAST DIODE U1560

Features of Fast Diode UI560 is Low forward voltage drop ,High current capability Case, Low reverse leakage current, Latest P/G technology with super fast recovery time, High surge current capability, High efficiency, Low power loss, High switching speed .

3. COUPLED INDUCTOR

A coupled inductor is actually a pair of inductors. A normal inductor is coupled only to itself -that is, it has one input and one output. From power distribution across large distances to radio transmissions, coupled inductors are used extensively in electrical applications. Their properties allow for increasing or decreasing voltage and current, transferring impedance through a circuit, and they can isolate two circuits from each other electrically. There are a wide variety of applications which exploit properties of transformers, such as tesla coils, impedance matching in audio frequency applications.There are two inductors are used in this project that is L_k and L_m.

4. CAPACITORS

There are four capacitors are used in this paper. That is C_1=47 µF, C_2=47 µF, C_3=100 µF, C_4=220 µF

A capacitor is a passive two-terminal electrical component that stores potential energy in an electric field. The effect of a capacitor is known as capacitance. While some capacitance exists between any two electrical conductors in proximity in a circuit, a capacitor is a component designed to add capacitance to a circuit. The capacitor was originally known as a condenser.

The physical form and construction of practical capacitors vary widely and many capacitor types are in common use. Most capacitors contain at least two electrical conductors often in the form of metallic plates or surfaces separated by a dielectric medium. A conductor may be a foil, thin film, sintered bead of metal, or an electrolyte. The non conducting dielectric acts to increase the capacitor's charge capacity. Materials commonly used as dielectrics include glass, ceramic, plastic film, paper, mica, and oxide layers.

5. **INPUT- OUTPUT DC VOLTAGE**

Input DC voltage = 40volts Output DC voltage = 400voltsThe input offset voltage is a parameter defining the differential DC voltage required between the inputs of an amplifier, especially an operational amplifier (op- amp), to make the output zero (for voltage amplifiers, 0 volts with respect to ground or between differential outputs, depending on the output type). A voltage divider is a simple circuit which turns a large voltage into a smaller one. Using just two series resistors and an input voltage, we can create an output voltage that is a fraction of the input. Voltage dividers are one of the most fundamental circuits in electronics

6. **SWITCHING FREQUENCY**

The rate at which the DC voltage is switched on and off during the pulse width modulation process in a switching power supply. The switching frequency in an inverter or converter is the rate at which the switching device is turned on and off. Typical frequencies range from a few KHz to a few megahertz.In electronics, switching frequency refers to the rate at which an electronics witch performs its function. Switching frequency is an important design and operating parameter in systems such as: The Class-D amplifier, an audio power amplifier with a switched-mode output.

A DC/DC converter is class of power supply that converts a source of direct current (DC) from one voltage level to another. There are two types of DC/DC converters: linear and switched. A linear DC/DC converter uses a resistive voltage drop to create and regulate a given output voltage, a switched- mode DC/DC converts by storing the input energy periodically and then releasing that energy to the output at a different voltage. The storage can be in either a magnetic field component like an inductor or a transformer, or in an electric field component such as a capacitor. Transformer-based converters provide isolation between the input and the output.

VI. DIFFERENT TYPES OF CONVERTER

1. BUCK CONVERTER

The buck converter is a type of DC-DC converter that produces an output voltage that is less than its input. A buck converter (step-down converter) is a DC-to-DC power converter which steps down voltage (while stepping up current) from its input (supply) to its output (load). It is a class of switched-mode power supply (SMPS) typically containing at least two semiconductors and at least one energy storage element, a capacitor, inductor, or the two in combination. To reduce voltage ripple, filters made of capacitors are normally added to such a converter's output (load-side filter) and input (supply-side filter). A Buck converter steps down a DC voltage from the input to the output. The circuit operation depends on the conduction state of the MOSFET:

On-state: The current through the inductor increases and the diode blocks.

Off-state: Since the current through the inductor cannot abruptly change the diode must carry the current so it commutates and begins conducting. Energy is transferred from the inductor to the capacitor resulting in a decreasing inductor current. During steady state the circuit is said to operate:

2. BOOST CONVERTER

A boost converter (step-up converter) is a DC-to-DC power converter that steps up voltage (while stepping down current) from its input (supply) to its output (load). It is a class of switched-mode power supply (SMPS) containing at least two semiconductors and at least one energy storage element: a capacitor, inductor, or the two in combination. To reduce voltage ripple, filters made of capacitors are normally added to such as converter's output (load-side filter) and input (supply-side filter).

3. BUCK- BOOST CONVERTER

The buck–boost converter is a type of DC-to-DC converter that has an output voltage magnitude that is either greater than or less than the input voltage magnitude. It is equivalent to a flyback converter using a single inductor instead of a transformer. Two different topologies are called buck–boost converter. Both of them can produce a range of output voltages, ranging from much larger than the input voltage, down to almost zero. The DC input to a boost converter can be from many sources as well as batteries, such as rectified AC from the mains supply, or DC from solar panels, fuel cells, dynamos and DC generators. The boost converter is different to the Buck Converter in that it’s output voltage is equal to, or greater than its input voltage.

VII. PROPOSED METHODOLOGY OF DC/DC CONVERTER

Designing the DC/DC boost converter based on coupled inductor and switched capacitor. Simulation is done in MATLAB software. Completion and study of result.

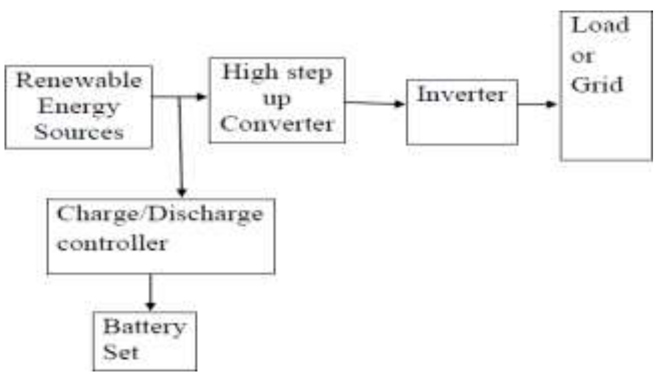

Figure (1):.Block diagram of proposed methodology.

The circuit configuration of the proposed converter is shown in Figure(2). The proposed converter comprises a DC input voltage (V_1), active power switch (S), coupled inductor, four diodes and four capacitors. Capacitor C_1 and diode D_1 are employed as clamp circuit respectively. The capacitor C_3 is employed as the capacitor of the extended voltage multiplier cell. The capacitor

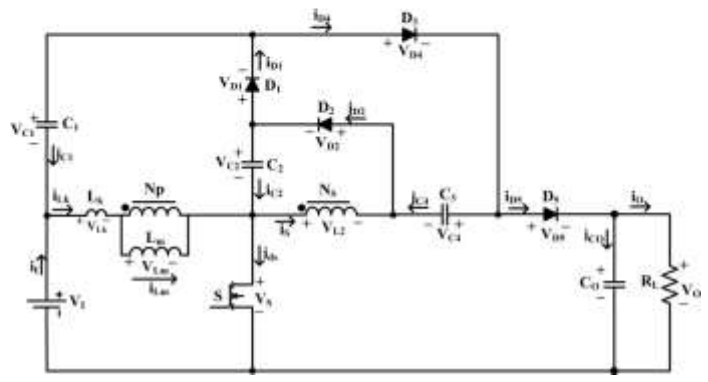

Figure (2):Circuit configuration of the presented high step-up converter

C_2 and diode D_2 are the circuit elements of the voltage multiplier which increase the voltage of clamping capacitor C_1. The coupled inductor is modeled as an ideal transformer with a turn ratio N (NP/NS), a magnetizing inductor Lm and leakage inductor L_k.

In order to simplify the circuit analysis of the converter, some assumptions are considered as follow:

- All Capacitors are sufficiently large. Therefore V_{C1}, V_{C2}, V_{C3}, and V_O are considered to be constant during one switching period.
- All components are ideal but the leakage inductance of the coupled inductor is considered.

VIII. RESULT

The performance of the presented converter is assessed using the prototype circuit implemented in the laboratory. The specifications of the implemented circuit are given in Table 1. The results verify the analysis of the steady state operation. The voltage on the switch (V_{ds}) during the turn-off state is clamped to about 80V. Therefore, a low-voltage-rated switch can be used to improve the efficiency of the presented converter. The energy stored in the leakage inductance is recycled to capacitor C1 through diode D1. The current waveforms of the diodes, switches and the coupled inductor (i_{lk}) validate the analysis and the feasibility of the proposed converter. The input current waveform with and without an input filter. The input current ripple is as much as other proposed high step-up converters such as the converters. However, a low pass filter can be used to reduce the input current ripple.

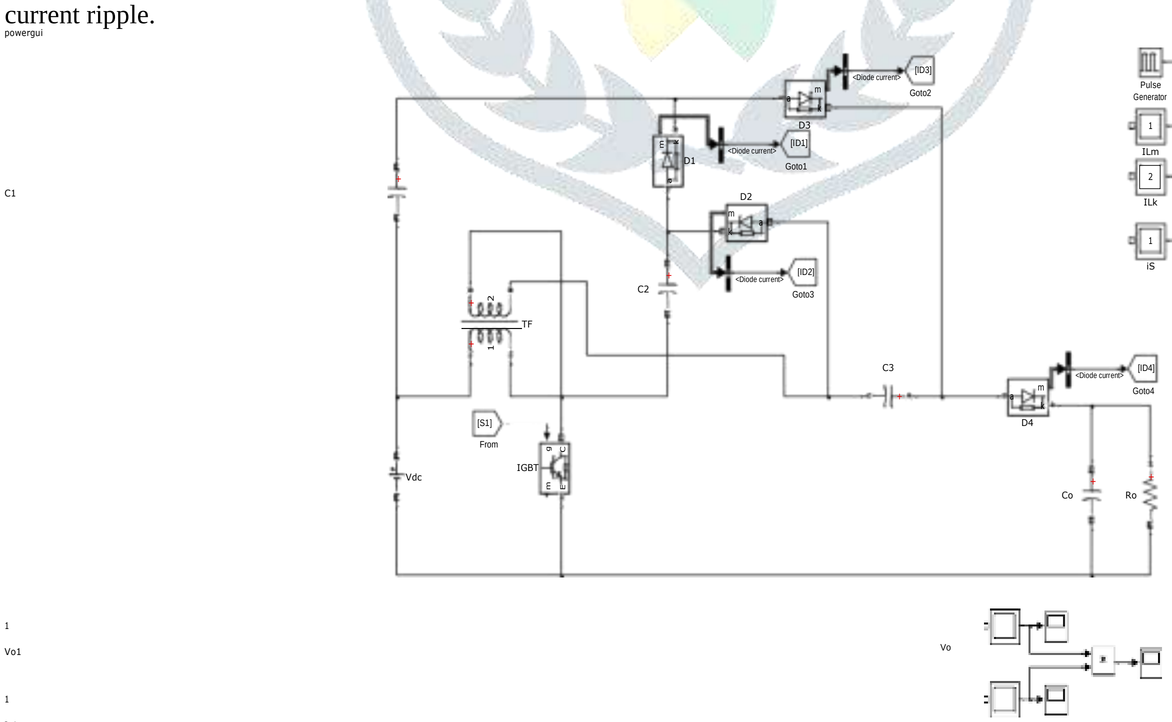

Figure (3): Proposed MATLAB simulation model

Product Po

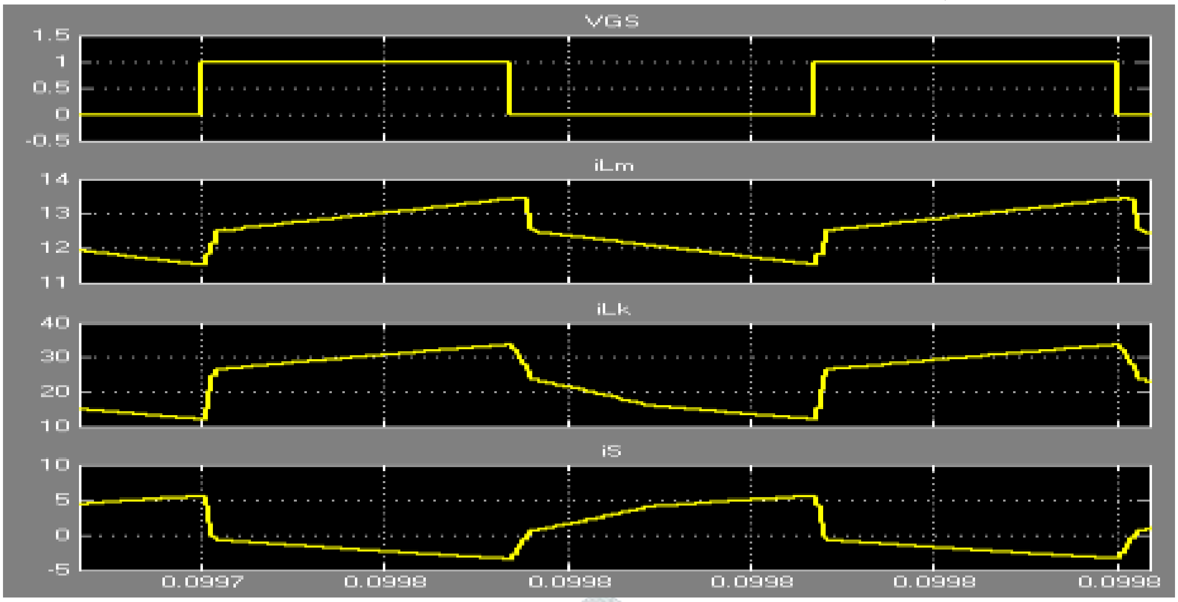

Figure (4): V_{GS} Vs Current Values

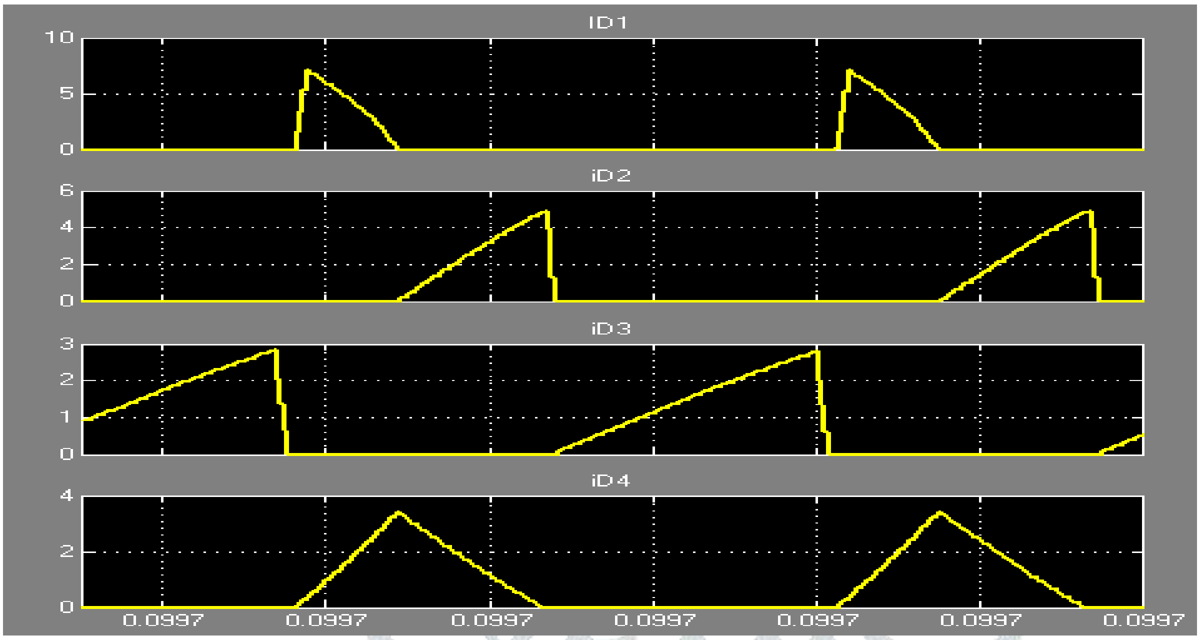

Figure (5): Waveforms of Diode Current

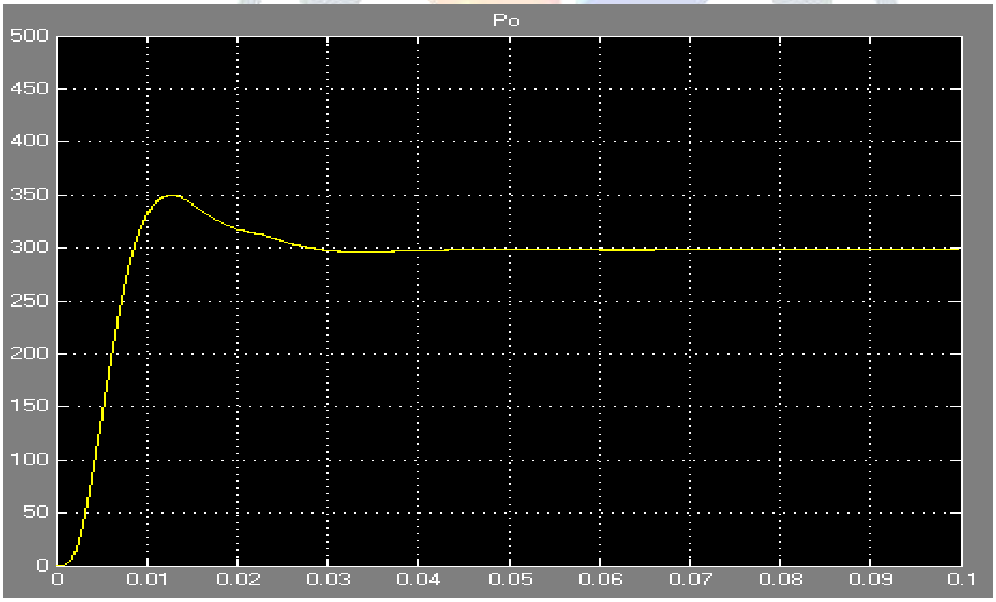

Figure (6): Waveform of output Power

IX. CONCLUSION

This paper presents the modified high step up boost converter for non conventional applications. The introduced converter is successfully implemented in an efficiency high step up conversion without an extreme duty ratio and number of turns ratios. The energy stored in the inductor to reclaim for further use to improve the performance of presented converter. The voltage stress on main power supply is diminished. When comparing the conventional converter and proposed converter then one can seen that the efficiency is improved by using high step up boost converter. Thus the proposed converter is suitable for non conventional energy applications that need high step up high power energy conversion.

A new modular interleaved boost converter by integrating a forward energy- delivering circuit and voltage-doubler is proposed for achieving high step-up and high- efficiency objective. Steady-state analyses are then made to show the merits of the proposed converter topology. For further understanding the dynamic characteristic for the proposed converter module, steady state and small-signal models of this converter are derived using state-space averaging technique. For higher power applications and satisfying the demands of low-voltage and high-current distributed power sources, a two-module parallel high step up converter system is given for demonstration. Analysis and control of the proposed system are also made. Experimental results show that the proposed new high step-up boost converter module can achieve an efficiency of 95.8% approximately.

X. REFERENCES

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