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High Step up Dc-Dc Converter For Distributed Power Generation

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ABSTRACT: This paper presents, a high voltage gain DC-DC converter for distributed generation (DG) systems with MPPT controller. A high step-up ratio and clamp- mode converter are proposed to achieve high voltage gain and high efficiency. This can be obtained by using two capacitors and one coupled inductor. During the switch-off period, the capacitors are charged in parallel and during the switch-on period they are discharged in series by the energy stored in the coupled inductor. A passive clamp circuit is used to recycle the leakage inductor energy of the coupled inductor, thus voltage stress on the main switch is reduced. The control method for the circuit is implemented using a MPPT controller which tracks the maximum power of the sources. The converter is suitable for high power applications because of the reduced conduction loss and low input current ripple. The operating principle and MATLAB simulations are discussed in detail.

I. INTRODUCTION

The distributed generation (DG) systems based on the renewable energy sources have rapidly developed in recent years.It is a technique that employs small-scale technologies like photovoltaic (PV) cells, fuel cells and wind power to produce electricity close to the end users of power. Compared to traditional power generators, distributed generators can provide lower-cost electricity, higher power reliability and security with fewer environmental consequences. But these are low voltage sources, thus high step-up dc-dc converters with good efficiency are necessary for connecting these for high voltage applications. To step from low voltage to high voltage, high step-up dc-dc converters are usually used as the front-end converters which are required to have a large conversion ratio, high efficiency and small volume.

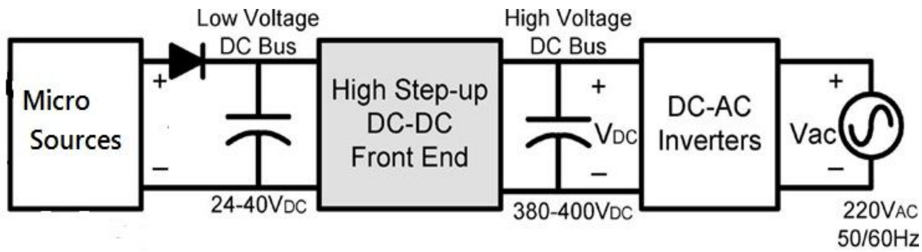

Figure 1 Power Generation Systems

Theoretically the conventional boost converter can provide a high step-up voltage gain with a duty cycle greater than 0.9. But in practice, it cannot achieve a high voltage gain with parasitic parameter limitations. Many step-up converters have been proposed to improve the conversion efficiency. The switched capacitor technique can provide a high step-up voltage gain, but the conduction loss and voltage stress on the switch is more. The coupled inductor technique can be used to obtain a high step-up gain, but the conversion efficiency is limited by the leakage inductor

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II.MAXIMUM POWER POINT TRACKING

Maximum Power Point Tracking is a technique that grid connected inverters, solar battery chargers and similar devices used to get maximum possible power from one or more photovoltaic devices. The purpose of the MPPT systems is to sample the output of the cells and apply the proper load to obtain maximum power for any given environmental conditions.

MPPT ALGORITHM

MPPT algorithms are necessary in PV applications because the MPP of a solar panel varies with the irradiation and temperature, so the use of MPPT algorithms is required in order to obtain the maximum power from a solar array. Over the past decades many methods to find the MPP have been developed and published. These techniques differ in many aspects such as required sensors, complexity, cost, range of effectiveness, convergence speed, correct tracking when irradiation and/or temperature change, hardware needed for the implementation.

Different MPPT techniques

1) Perturb and Observe (hill climbing method)
2) Incremental Conductance method (INC)
3) Fractional short circuit current
4) Fractional open circuit voltage
5) Neural networks
6) Fuzzy logic

Nevertheless, the Perturb and Observe (P&O) and Incremental Conductance (INC) techniques are widely used, especially for low cost implementation. The MPPT algorithm used is Incremental Conductance method (INC).

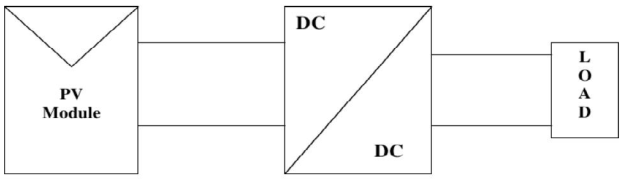

Figure 2 Power conditioning of PV Module

INCREMENTAL CONDUCTANCE

The theory of the incremental conductance method is to determine the variation direction of the terminal voltage for PV modules by measuring and comparing the incremental conductance and instantaneous conductance of PV modules. If the value of incremental conductance is equal to that of instantaneous conductance, it represents that the maximum power point is found. Incremental conductance method uses voltage and current sensors to sense the output voltage and current of the PV array.

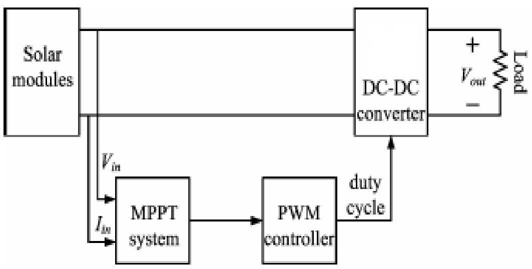

Figure 3 Incremental conductance MPPT

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III. PROPOSED SYSTEM

The proposed converter combines the switched capacitor and coupled inductor techniques. The switching circuit is formed by using two capacitors and two diodes are connected to the secondary side of the coupled inductor to achieve a high voltage gain. Since the voltage across the capacitors can be adjusted by the turns ratio, a high step-up gain can be achieved. The capacitors are charged in parallel and discharged in series by the coupled inductor. A passive clamp circuit is used to clamp the voltage level on the switch

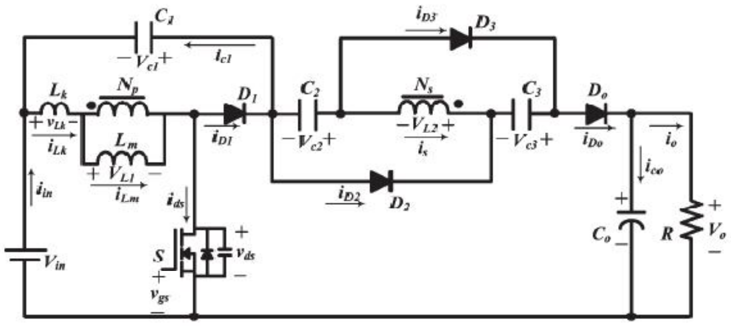

Figure 4 DC-DC converter

Figure 4 shows the circuit topology of the proposed converter, which is composed of dc input voltage V_{in}, main switch S, coupled inductors N_p and N_s, one clamp diode D_1, clamp capacitor C_1, two capacitors C_2 and C_3, two diodes D_2 and D_3, output diode D_o, and output capacitor C_o. The equivalent circuit model of the coupled inductor includes magnetizing inductor Lm, leakage inductor 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 stress on the switch is reduced significantly. Thus, low conducting resistance $R_{DS(ON)}$ of the switch can be used. The proposed converter combines the concept of switched-capacitor and coupled-inductor techniques. Based on the concept, the proposed converter puts capacitors C_2 and C_3 on the secondary side of the coupled inductor. The capacitors C_2 and C_3 are charged in parallel and are discharged in series by the secondary side of the coupled inductor when the switch is turned off and turned on respectively. Because the voltage across the capacitors can be adjusted by the turn ratio, the high step-up gain can be achieved significantly. Also, the voltage stress of the switch can be reduced. The parallel-charged current is not inrush. Thus, the proposed converter has low conduction loss. Moreover, the secondary-side leakage inductor of the coupled inductor can alleviate the reverse-recovery problem of diodes, and the loss can be reduced. In addition, the proposed converter achieves a high step-up gain without an additional winding stage of the coupled inductor. The coil is less than that of other coupled inductor converters.

IV .OPERATING PRINCIPLE

The main operating principle is that, when the switch is turned on, the coupled-inductor-induced voltage on the secondary side and magnetic inductor L_m is charged by V_{in}. The induced voltage makes V_{in}, V_{C1}, V_{C2}, and V_{C3} release energy to the output in series. When the switch is turned off, the energy of magnetic inductor L_m is released via the secondary side of the coupled inductor to charge capacitors C_2 and C_3 in parallel. The converter operating in continuous conduction mode (CCM) is discussed below. In CCM operation, there are five operating modes in one switching period. The operating modes are described as follows.

Mode I :

During this mode, S is turned on. Diodes D_1 and D_o are turned off, and D_2 and D_3 are turned on. The current-flow path is shown .The voltage equation on the leakage and magnetic inductors of the coupled inductor on the primary side is expressed as $V_{in} = V_{Lk} + V_{Lm}$. The leakage inductor L_k starts to charge by V_{in}. Due to the leakage inductor $L_{k,}$ the

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secondary-side current i_s of the coupled inductor is decreased linearly. Output capacitor *Co* provides its energy to load *R*. When current i_{D2} becomes zero, this operating mode ends.

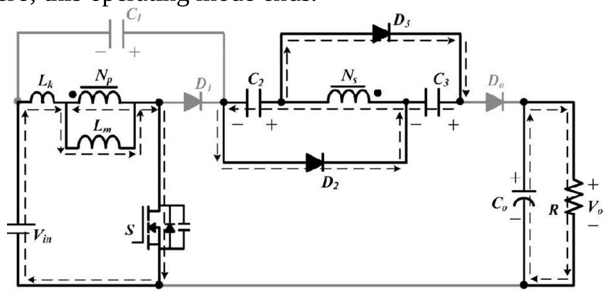

Figure 5 Mode I

Mode II :

During this time interval, *S* remains turned on. Diodes D_1, D_2, and D_3 are turned off, and D_o is turned on. The current-flow path is shown. Magnetizing inductor L_m stores energy generated by dc source V_{in}. Some of the energy of dc-source V_{in} transfers to the secondary side via the coupled inductor. Thus, the induced voltage V_{L2} on the secondary side of the coupled inductor makes V_{in}, V_{C1}, V_{C2}, and V_{C3}, which are connected in series, discharge to high-voltage output capacitor C_o and load *R*. This operating mode ends when switch *S* is turned off .

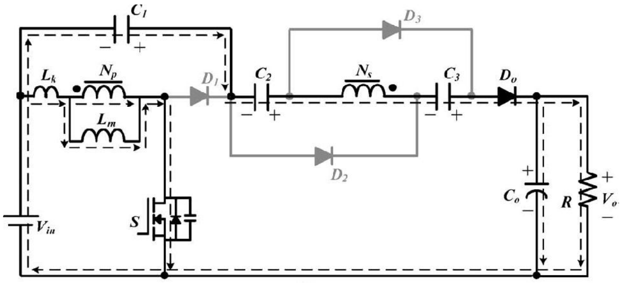

Figure 6 Mode II

Mode III

During this time interval, *S* is turned off. Diodes D_1, D_2, and D_3 are turned off, and D_o is turned on. The current-flow path is shown. The energies of leakage inductor L_k and magnetizing inductor *Lm* charge the parasitic capacitor C_{ds} of main switch *S*. Output capacitor *Co* provides its energy to load *R*. When the capacitor voltage V_{C1} is equal to V_{in} + V_{ds} diode D_1 conducts, and this operating mode ends.

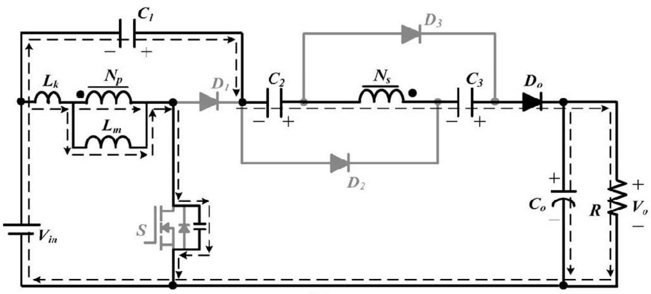

Figure 7 Mode III

Mode IV :

During this time interval, *S* is turned off. Diodes D_1 and D_o are turned on, and D_2 and D_3 are turned off. The current-flow path is shown .The energies of leakage inductor L_k and magnetizing inductor L_m charge clamp capacitor C_1. The energy of leakage inductor L_k is recycled. Current i_{Lk} decreases quickly. Secondary-side voltage V_{L2} of the coupled inductor continues charging high-voltage output capacitor C_o and load *R* in series until the secondary current of the

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coupled inductor i_s is equal to zero. Meanwhile, diodes D_2 and D_3 start to turn on. When i_{Do} is equal to zero this operating mode ends.

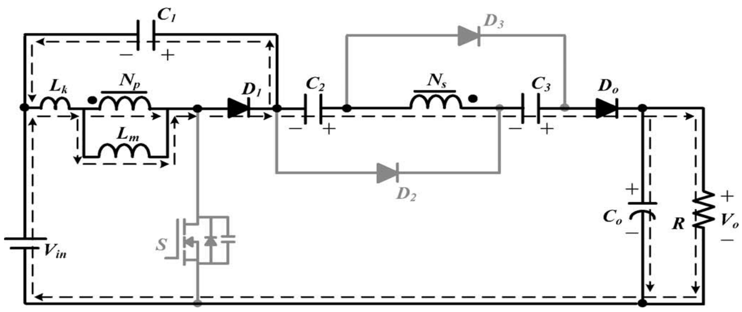

Figure 8 Mode IV

Mode V :

During this time interval, S is turned off. Diodes D_1, D_2 and D_3 are turned on, and D_o is turned off. The current-flow path is shown. Output capacitor C_o is discharged to load R. The energies of leakage inductor L_k and magnetizing inductor L_m charge clamp capacitor C_1. Magnetizing inductor L_m is released via the secondary side of the coupled inductor and charges capacitors C_2 and C_3. Thus, capacitors C_2 and C_3 are charged in parallel.

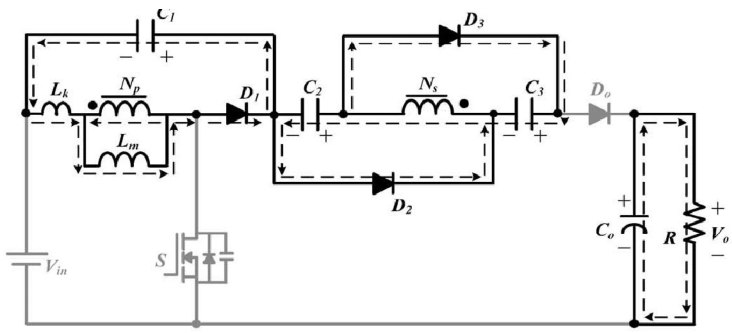

Figure 9 Mode V

V.BASIC SIMULATION

The converter was simulated with MATLAB software.

Table 1

Parameters	Ratings
Input voltage	24V
Switching Frequency	50kHz
Coupled Inductor	L_m=48μH,L_k=0.25 μH
Capacitors	C_1=56μF/100V, C_2/C_3 = 22μF/200V, C_0= 180 μF/450V

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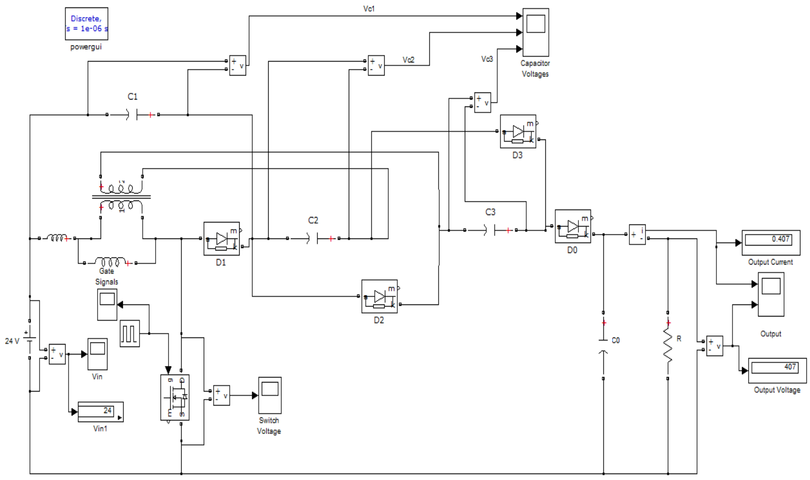

Figure 10 Simulink Model Of converter

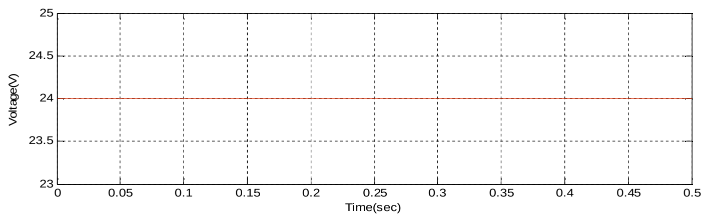

Figure 11 Simulation Result of Input Voltage

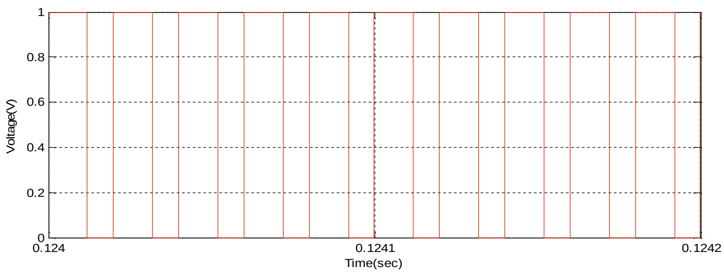

Figure 12 Simulation Result of Switching Signals

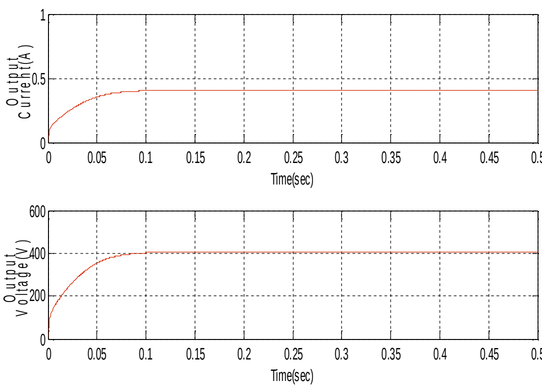

Figure 13 Simulation Result of Output Current & Output Voltage

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The DC-DC converter was simulated for an input of 24V and a load resistance of 1kΩ .The output voltage was obtained as 400V.

PV SIMULATION WITH MPPT CONTROLLER

The converter can be used for distributed generation systems so it is simulated in MATLAB software with a photovoltaic array as input. MPPT controller is used to get the maximum output. The simulink model of the system is shown in figure 14.The output voltage was obtained as 400V.

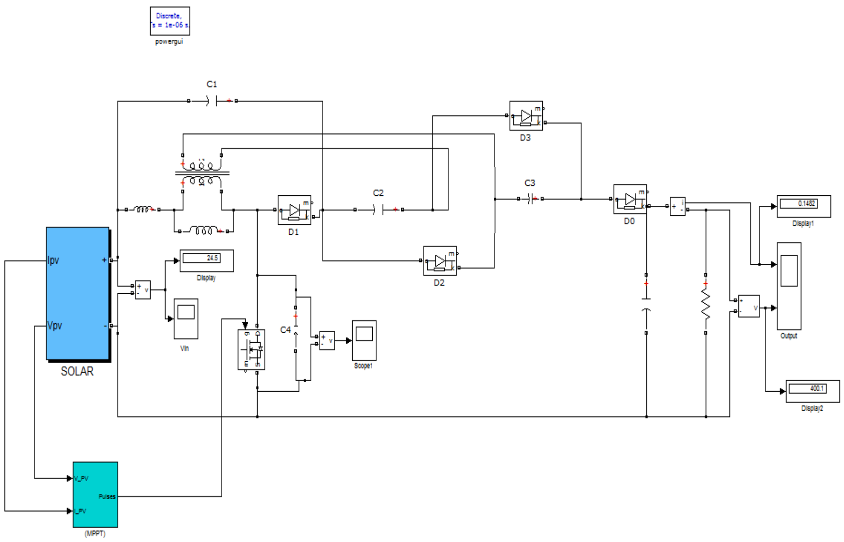

Figure 14 Simulink Model Of converter with PV and MPPT

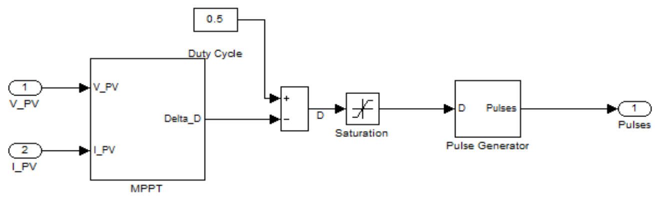

Figure 15 Simulink Model Of MPPT

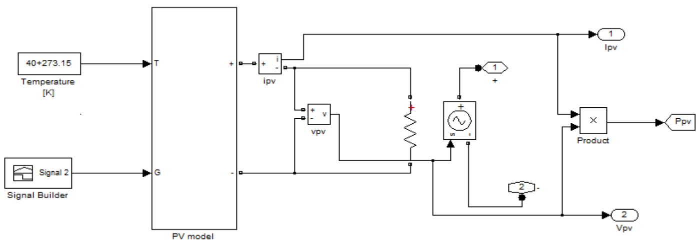

Figure 16 Simulink Model Of PV Cell

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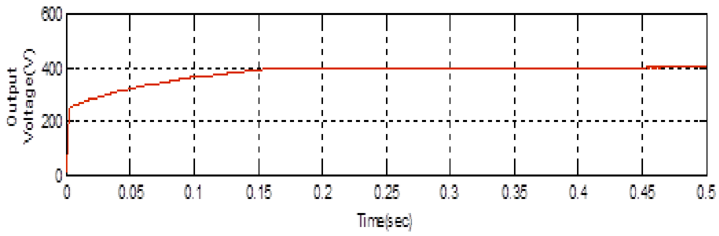

Figure 17 Simulation Result of Output Voltage

VI. EXPERIMENTAL RESULTS

A prototype of the converter with following specifications has been implemented.

Table 2

Parameters	Ratings
Input voltage	12V
Coupled Inductor	ETD 39,N_p:N_s =1:20 ,L_m=3mH
Capacitors	C_1=150µF/450V, C_2 /C_3 = 10µF,C_0= 220 µF/450V
Load Resistance	100kΩ
Microcontroller	PIC18F4550
MOSFET	IRF830
Diode	MUR1520

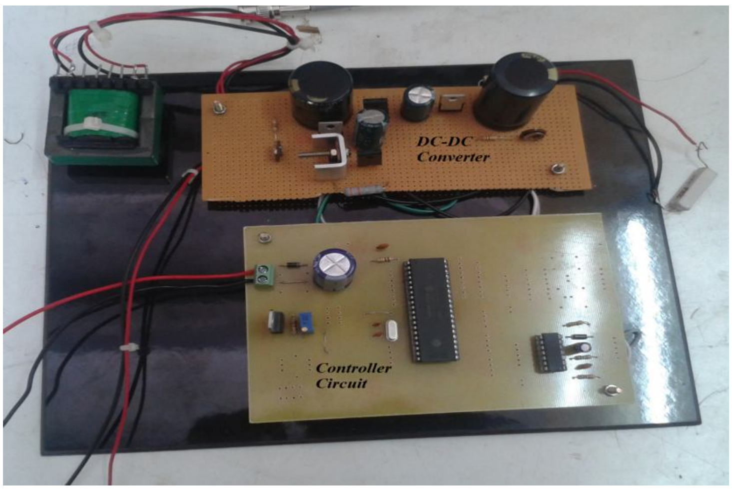

Figure 18 Experimental set up of converter

A 5V power supply is given to the PIC microcontroller for generating the gating signals to the MOSFET. The gating signals are given to the MOSFET through MOSFET driver. An input voltage of 12V was applied to the converter using a battery.The switching signals to the MOSFET are generated at a frequency of 50kHz.An output voltage of 200V was obtained.The converter was also connected to a PV panel and the output voltage was verified. The switching signals are as shown in Figure 19.

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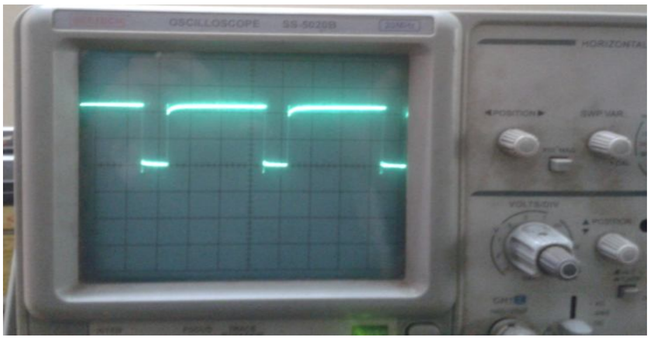

Figure 19 Switching Signals to MOSFET

The output was verified using a CRO. The output waveform is as shown in Figure 20.

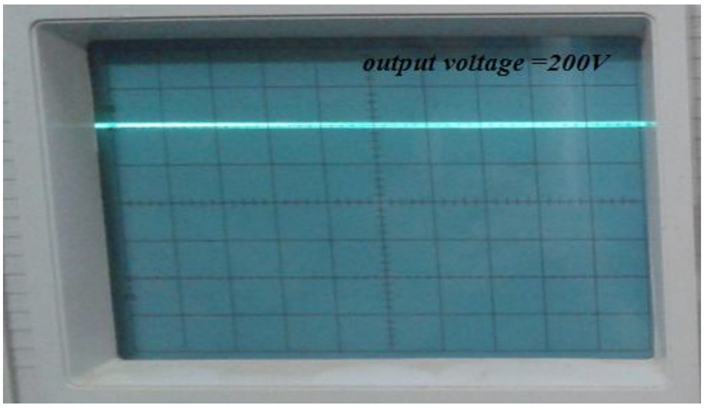

Figure 20 Output Voltage Waveform

VII.CONCLUSION

In this paper a high step-up dc-dc converter for distributed power generation is discussed. By using the capacitor charged in parallel and discharged in series by the coupled inductor this converter provide high step-up voltage gains and high efficiency. It also has low input current ripple and low conduction losses, making it suitable for high power applications. The turn ratio of the coupled inductor is 1:4, but the output voltage of the converter is 16 times greater than the input voltage. The converter transfers the capacitive and inductive energy simultaneously to increase the total power delivery.

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