Performance Analysis of ZETA Converter and Multi String Multi Level Inverter for Ac Module Application

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Abstract- *Renewable energy resources (RES) are being increasingly connected in distribution systems utilizing power electronic converters. The renewable energy sources such as PV modules, fuel cells or energy storage devices such as super capacitors or batteries deliver output voltage at the range of around 15 to 40 V DC. A boost converter is used to clamp the voltage stresses of all the switches in the interleaved converters, caused by the leakage inductances present in the practical coupled inductors, to a low voltage level. This project proposes a converter that employs a floating active switch to isolate energy from the PV panel when the ac module is OFF; this particular design protects installers and users from electrical hazards. The proposed concept employs a Zeta converter and a multi string multi level inverter (MSMLI). The leakage-inductor energy is efficiently recycled to the load. These features improve the energy-conversion efficiency.*

Keywords- DC, MSMLI, PV, RES

I. INTRODUCTION

In recent years, there has been an upsurge of interest in solar photovoltaic (PV) energy systems in both industry and academia. In typical PV power generation systems, several photovoltaic panels are connected in series and parallel to form an array and feed energy to a single centralized inverter or to a few parallel 'string' inverters. An alternative approach is to use an AC module, which is a combination of one PV panel and one power conditioning unit, to feed power directly into the grid.

The advantages of an AC module based system over systems based on centralized inverter or parallel string inverters are as follows:

1) The maximum power point (MPP) of each panel can be tracked individually, thereby increasing the utilization of the whole PV system;
2) Detrimental effects due to shading and module mismatches are not present.
3) Potential arcing problems due to DC system wiring are fully avoided.
4) The "plug and play" property allows easy system expansion through simple paralleling of additional AC modules.

However, an AC module based system has a few problems also, including potential reduction in system efficiency and possible cost increase in the overall system cost due to the use of several low power inverters. Greater maintenance may also be required, though overall reliability may actually improve due to the use of several parallel inverters. Among the variety of circuits and control methods that have been developed for the AC module application, the fly back DCM (discontinuous conduction mode) inverter is one of the favored topologies because of its simplicity and potential low cost. The component count is low and the inverter requires only a simple control scheme.

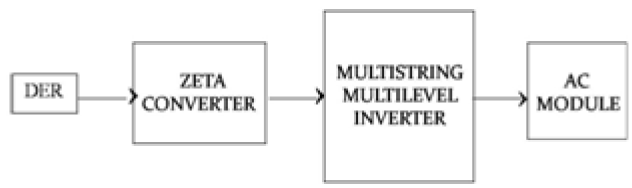


Figure1. Block diagram of proposed concept

In the above figure DER means distributed energy resource. The Distributed Energy Resources are electric generation units typically in the range of 3KW to 50MW.various types of DER Technologies are Photovoltaic systems, Wind systems, Fuel cells, Micro turbines. The typical Zeta converter provides either a step-up or a step-down function to the output, in a manner similar to that of the buck-boost or SEPIC converter topologies. The conventional Zeta converter is configured of two inductors, a series capacitor and a diode. Previous research work developed diverse Zeta converter applications, as follows. A coupled inductor can be employed to reduce power supply dimensions. Some Zeta and fly-back combination converters extend the output range by using this coupled-inductor technique. Employing soft-switching technique, zero-voltage switching and zero-current switching, on the Zeta converter; changing the input inductor of the ZETA converter to a coupled inductor obtains a higher step-up conversion ratio. Many re-search works on high step-up converter topology have included analyses of the switched-inductor and switched-capacitor types, transformer less switched-capacitor type, the boost type integrated with the coupled inductor.

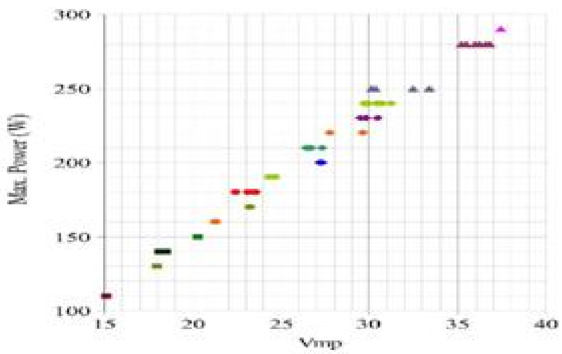


Figure2. MPP voltage ($_{mp}$) distribution with various power capacities of PV panel.

Fig. 2 shows that the maximum power point (MPP) voltage range is from 15 V to 40 V with various power capacities of about 100 W to 300 W for a single commercial PV panel.

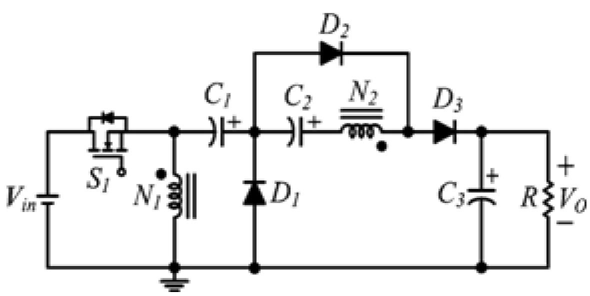


Figure3.Circuit configuration of zeta converter

Some converters successfully combine both boost and fly-back converters into one and other converter combinations have been developed to carry out high step-up voltage gain by using the coupled-inductor technique. However, the efficiency and voltage gain of the dc-dc boost converter are restrained by either the parasitic effect of power switches or the reverse-recovery issue of diodes. In addition, the equivalent series resistance (ESR) of the capacitor and the parasitic resistances of the inductor also affect overall efficiency. In regard to increasing voltage gain, this attribute is constricted by the voltage stress on the active switch; however, if the leakage-inductor energy of the coupled inductor can be recycled, then the voltage stress on the active switch is reduced, meaning the coupled-inductor and the voltage-multiplier or voltage-lift techniques are able to accomplish the goal of achieving higher voltage gain.

The proposed converter is shown in Fig. 3; its basic con-figuration came from a Zeta converter, but the input inductor has been replaced by a coupled inductor. Employing the turn's ratio of the coupled inductor increases the voltage gain and the secondary winding of the coupled inductor series with a switched capacitor for further increasing the voltage. The coupled-inductor Zeta converter is configured from a coupled inductor T_1 with the floating active switch S_1. The primary winding N_1 of a coupled inductor T_1 is similar to the input inductor of the conventional boost converter, except that capacitor C_1 and diode D_1 are recycling leakage-inductor energy from N_1. The secondary winding N_2 is connected with another pair of capacitors C_2 and with diode D_2, all three of which are in series with N_1. The rectifier diode D_3 connects to its output capacitor C_3 and load R. The features of the proposed converter are: 1) the leakage-inductor energy of the coupled inductor can be recycled, increasing the efficiency; and the voltage spike on the active switch has been restrained; 2) the voltage-conversion ratio is efficiently increased by the switched-capacitor and coupled-capacitor techniques; and 3) the floating active switch isolates the PV panel's energy during non-operating conditions, thus preventing any potential electric hazard to humans or facilities.

II. OPERATING PRINCIPLES OF THE ZETA CONVERTER

The operating principles for continuous-conduction mode (CCM) are now presented in detail. Fig. 4 shows the typical waveform of several major components during one switching period. The five operating modes are described as follows.

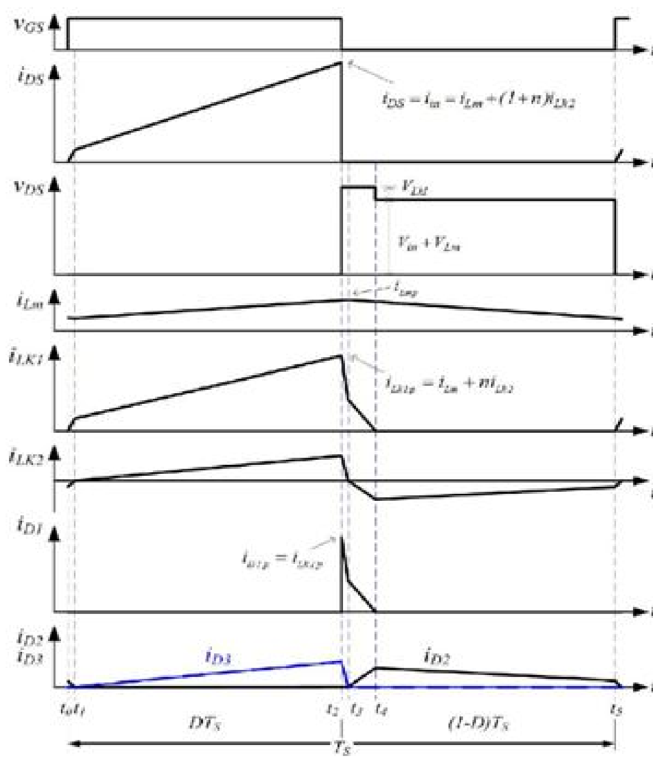


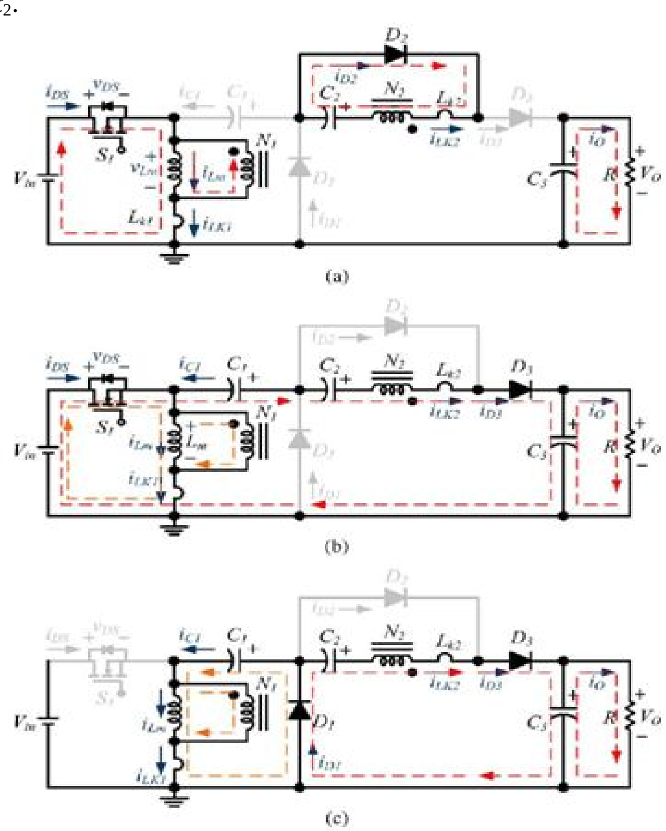
Figure 4. Typical waveforms of the zeta converter at CCM operation

The coupled inductor T_1 includes a magnetizing inductor Lm, primary and secondary leakage inductors L_{k1} and

L_{k2}, and an ideal transformer primary winding N_1 and secondary winding N_2.

Mode I [t_0, t_1]*:* In this transition interval, the secondary leakage inductor L_{k2} is continuously releasing its energy to capacitor C_2. The current flow path is shown in Fig. 5(a); as shown, switch S_1 and diodes D_2 are conducting. The current i_{Lm} is descending because source voltage V_{in} is applied on magnetizing inductor L_m. and primary leakage inductor L_{k1}; meanwhile, L_m is also releasing its energy to the secondary winding, as well as charging capacitor C_2 along with the decrease in energy, the charging current i_{D2} and i_{C2} are also decreasing. The secondary leakage inductor current i_{Lk2} is declining according to i_{Lm}/n. Once the increasing i_{Lk1} equals the decreasing i_{Lm} at t=t_1, this mode ends.

Mode II [t_1, t_2]*:* During this interval, source energy V_{in} is series connected with C_1, C_2, secondary winding N_2, and L_{k2} to charge output capacitor C_3 and load *R*; meanwhile, magnetizing inductor L_m is also receiving energy from V_{in}. The current flow path is shown in Fig. 5(b); as illustrated, switch S_1 remains on, and only diode D_3 is conducting. The i_{Lm}, i_{Lk1}, and i_{D3} are increasing because the V_{in} is crossing L_{k1}, L_m and primary winding N_1; L_m and L_{k1} are storing energy from V_{in}; meanwhile, V_{in} is also in series with N_2 of coupled inductor T_1, and capacitors C_1 and C_2 are discharging their energy to capacitor C_3 and load *R*, which leads to increases in i_{Lm}, i_{Lk1}, i_{DS}, and i_{D3}. This mode ends when switch S_1 is turned off at $t = t_2$.



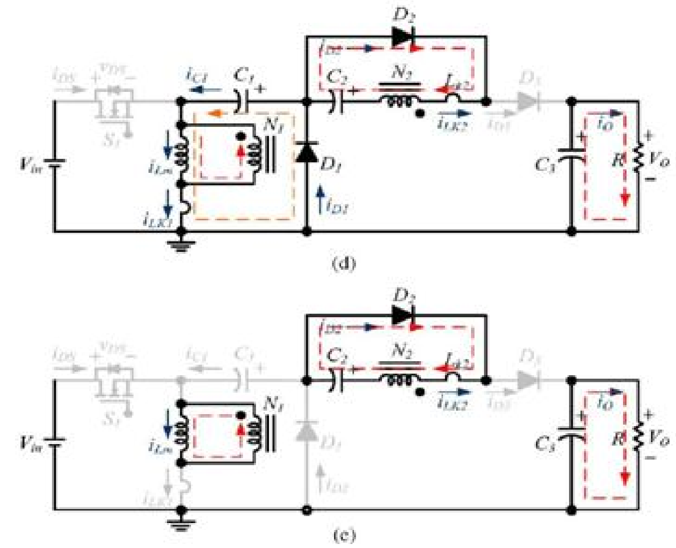


Figure 5. Current flow path in five operating modes during one switching period in CCM operation. (a) Mode I. (b) Mode II. (c) Mode III. (d) Mode IV. (e) Mode V.

Mode III [t_2, t_3]: During this transition interval, secondary leakage inductor L_{k2} keeps charging C_3 when switch S_1 is off. The current flow path is shown in Fig. 5(c), and only diodes D_1 and D_3 are conducting. The energy stored in leakage inductor L_{k1} flows through diode D_1 to charge capacitor C_1 instantly when S_1 turns off. Meanwhile, the L_{k2} keeps the same current direction as in the prior mode and is in series with C_2 to charge output capacitor C_3 and load R. The voltage across S_1 is the summation of V_{in}, V_{Lm}, and V_{Lk1}. Currents i_{Lk1} and i_{Lk2} are rapidly declining, but i_{Lm} is increasing because L_m is receiving energy from L_{k2}. Once current i_{Lk2} drops to zero, this mode ends at t = t_3.

Mode IV [t_3,t_4]: During this transition interval, the energy stored in magnetizing inductor Lm releases simultaneously to $C_1$and C_2. The current flow path is shown in Fig. 5(d). Only diodes D_1 and D_2 are conducting. Currents i_{Lk1} and i_{D1} are persistently decreased because leakage energy still flows through diode D1 and continues charging capacitorC1.The Lm is delivering its energy through T_1 and D_2 to charge capacitor C_2. The energy stored in capacitors C3is constantly discharged to the load R. The voltage across S1 is the same as previous mode. CurrentsiLk1 and i_{Lm} are decreasing, but i_{D2} is increasing. This mode ends when current i_{Lk1} is zero at t=t_4.

Mode V [t_4,t_5]: During this interval, magnetizing inductor L_m is constantly transferring energy to C2. The current flow path is shown in Fig. 4.8, and only diode D_2 is conducting. The i_{Lm} is decreasing due to the magnetizing inductor energy flowing continuously through the coupled inductor$T_1$to secondary winding N_2 and D_2 to charge capacitorC_2. The energy stored in capacitors$C_3$is constantly discharged to the load R. The voltage acrossS1is the summation of V_{in} and V_{Lm}. This mode ends when switchS1is turned on at the beginning of the next switching period.

III. BASIC FIVE LEVEL MULTI STRING MULTI LEVEL INVERTER (MSMLI)

The basic five level multi string multi level inverter is shown in Fig.6 and corresponding output voltage waveforms are shown in Fig.7. In this approach, all the six switches are operated with a switching frequency of 50 Hz and the input voltage of V_{dc} =100V. The symmetrical multilevel approach of the multi string multilevel inverter is operated with equal voltage values at the input side of the inverter. These symmetrical multilevel inverters are operated with PWM procedure to generate the gating signals.

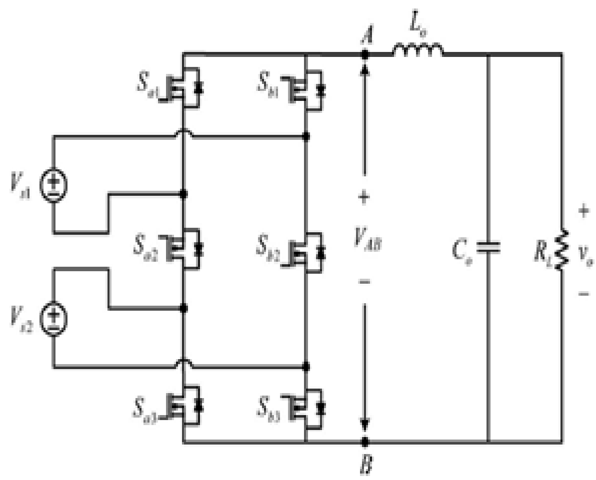


Figure6. Circuit Diagram Basic Five level MSMLI

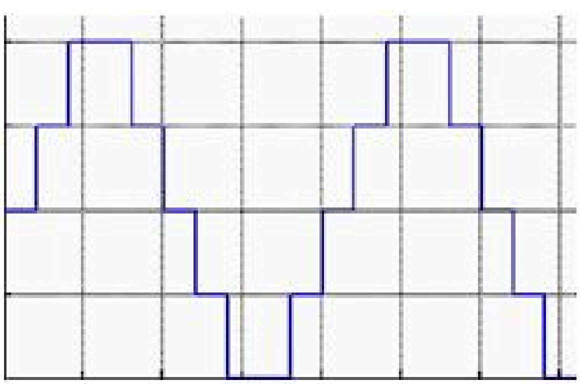


Figure7. Output voltage of Basic Five level MSMLI

The corresponding Switching states of five-level multi string multilevel inverter are shown in Table.1

Output Voltage V_{ac}	Switches in Five level Multi string multi level inverter					
	S1	S2	S3	S4	S5	S6
+2Vs	0	1	0	1	0	1
+Vs	0	1	1	1	0	0
0	1	1	1	0	0	0
-Vs	1	0	0	0	1	1
-2Vs	1	0	1	0	1	0

Table 1 Switching states of Basic Five level MSMLI

IV. MODELLING OF ZETA CONVERTER AND MSMLI

The below figure shows the design of zeta converter using mat-lab or simulink software. A 15V dc supply which is collected from a PV module is given as the input of the zeta converter.

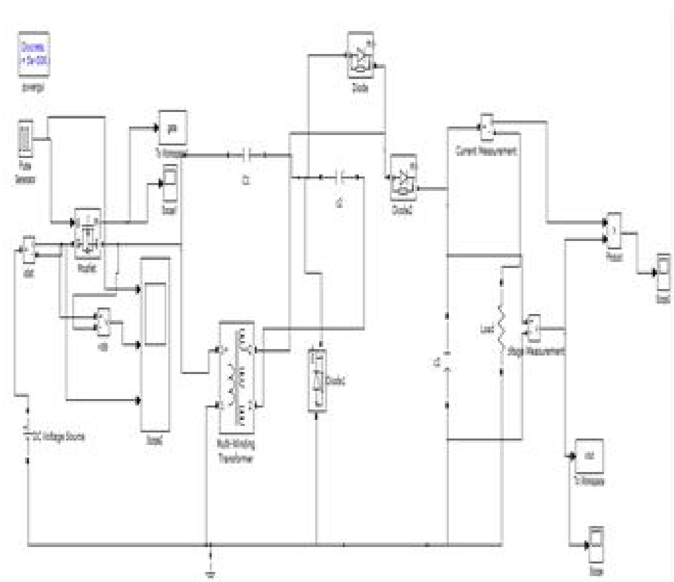


Figure 8. Matlab/ Simulink Model of zeta Converter

The output of zeta converter is given to the basic five level multi string multi level inverter. The design of multi string multi level inverter using matlab is shown in below figure.

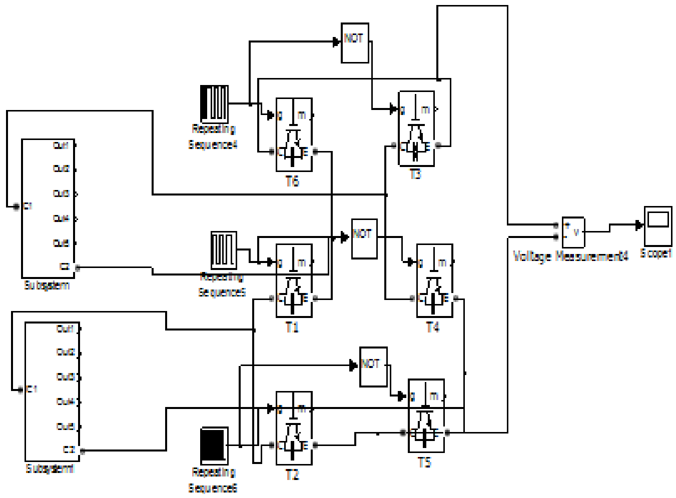


Figure 9. Matlab / Simulink model of MSMLI with zeta converter

V. SIMULATION RESULTS

The below figure shows the input voltage given to the zeta converter.

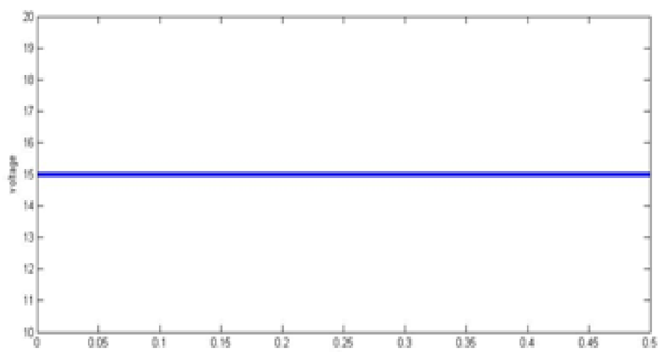


Figure10. Input voltage waveform of zeta converter

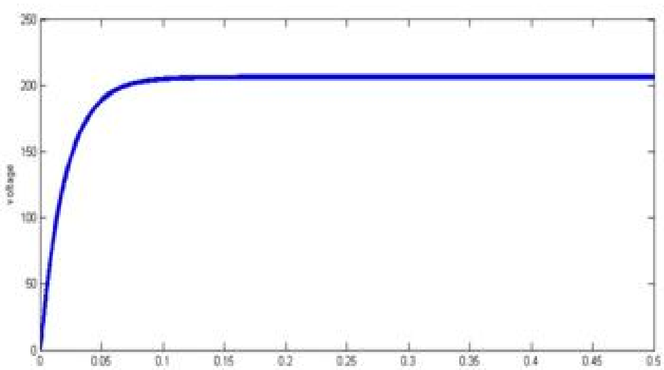


Figure11. Output voltage waveform of zeta converter

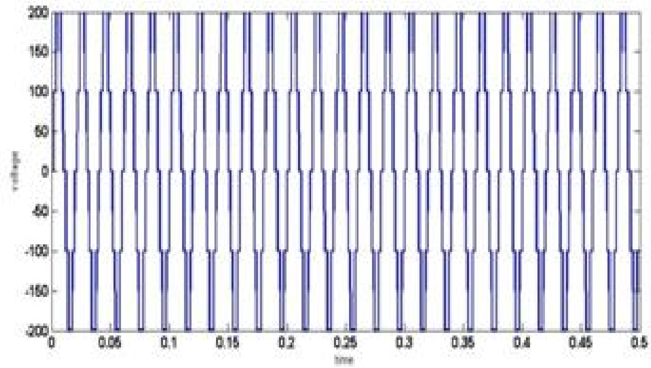


Figure12. Output voltage of the system

Finally a 200V output voltage is obtained by using MSMLI and that is shown in the figure12.

VI. CONCLUSION

This paper presents a zeta converter with multi string multi level inverter for ac module application. The Zeta converter and multi string multi level inverter has been simulated. During the simulation a 15V Dc supply is step up to 200V Dc by means of Zeta converter. This Dc supply is given to five level multi string multi level inverter it converts the Dc supply into 200V AC supply. Here the leakage-inductor energy of the coupled inductor is efficiently recycled to the load. These features improve the energy-conversion efficiency.

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