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Research Paper

Performance Analysis of various dc-link Converters for Photovoltaic based Ac Drives

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Abstract

This paper proposes a Performance analysis of DC to DC converters connected to the induction motor drive. The circuit analysis and operating principle of the proposed M-ZS Converter is presented and also characteristics of the different DC-DC are projected. A keen comparison is done between the proposed Modified Z-Source Converter with Boost Converter and Z-Source Converter and MPPT behavior of three converters at different irradiance level and different loading conditions are analyzed. By with the help of MATLAB Simulink, the simulation results are evaluated and presented.

Keywords: *Boost converter, Modified Z-source converter, MPPT, PV panel, Z-source converter.*

1. Introduction

As the energy demand is continuously increasing it is necessary to meet the power demand, the efforts are being made to new energy resources. The most promising reliable energy resource is solar energy [1]. The main advantage of the solar is eco-friendly energy, it does not harm to environment. The output of the solar panels is a low voltage, to reach the demand the output voltage of PV panel is to step-up. So, a DC-DC is to be required. In this paper we made a keen compression between proposed DC-DC converter and convectional DC-DC converters [2] connected to a load as induction drive through the inverter. The mostly commonly known converter is boost converter which is used to boost up the output dc voltage with simple ON and OFF of the switch; the boost converter has some limitations and drawbacks. Low output voltage and high switching stress, that all are overcome by ZSC. It is a distinctive two-port impedance network it combine power source to the converter main circuit, it has buck-boost conversion ability. It cannot be observed in conventional converters. Compared with boost converter the ZSC has high output voltage gain, but even though it has some drawbacks that all overcome Modified ZSC which is proposed in this paper. Modified Z-Source Converter is implemented from convectional ZSC Modified ZSC is a one-port network. The Modified Z-Source Converter has low capacitor and switching voltage stress and having high loading capacity. The above all are not observed in traditional ZSC and Boost converter.

2. Various Dc-Dc Converters

In general, the output of PV panel is low voltage, to boost the output voltage, a DC-DC converter is required, there are several types of DC-DC converters [2] are there, some of them are given below.

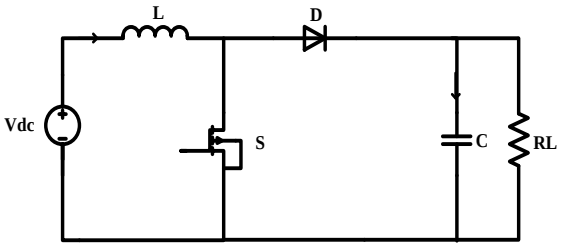


Fig. 1: Boost Converter

The figure 1 represents the Step-up DC-DC Converter, which is named as Boost Converter [2]. The basic function of the converter is to boost the input dc voltage. This converter operation is classified in to two modes.

[Mode 1] In mode1 switch S is turn closed for a time period t_1, the i_L current raises linearly and in the inductor L, energy will be stored.

[Mode 2] Here switch S will be kept open for a time period t_2, the stored energy in inductor L is transferred to load through diode D and the i_L current will be linearly decreases and then the average output voltage of the Boost converter is $v_0 = \frac{v_{dc}}{1-d}$ by increasing the duty (d) the output voltage will vary. The range of duty ratio of the converter lies between 0.5 to 1.

Figure 2 shows the Z-Source converter [3] [4] which is abbreviated as impedance-source converter and its control method is implemented for ac to ac, dc to ac, ac to dc, and dc to dc conversion of power. This impedance source has buck-boost ability and it is a unique impedance source network to link the converter main circuit to the power source. That cannot be observed in convectional converters. The ZSC is a two-port network consists of capacitors C_1, C_2 and split-inductor L_1, L_2 are connected in X-Shape to provide an impedance source coupling converter to the dc source.

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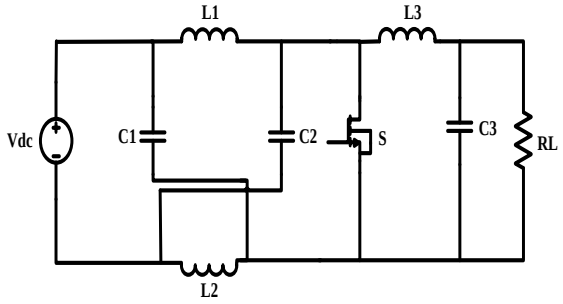


Fig. 2: Z-Source Converter

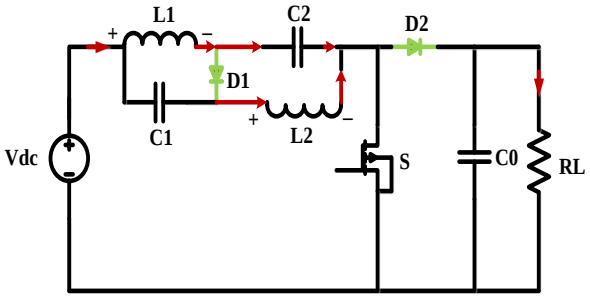


Fig. 3: Modified Z-Source Converter

Figure 3 shows the proposed converter named as Modified Z-Source Converter [5]. The proposed converter is implemented from the basic ZSC. In this paper proposed converter is compared with the traditional ZSC and Boost converter. The traditional ZSC and Boost converter has some limitations, that all are overcome by the Modified ZSC. The Modified ZSC is a one-port impedance network [8][9][10], is consists of an input voltage source V_{dc} with series combination of diode D with the X-shape Z-source network.

3. Operating modes of the proposed Z-source converter

The figure 3 represents the proposed DC-DC Z-Source converter [5] with an input voltage source as V_{dc}, aone-port impedance source, switch S and diode D_1 and D_2,C_0 as output filter capacitor andR_L as load resistor. The impedance network is entailed with two equal inductors and two equal capacitors (L_1, L_2 and C_1,C_2) and a diodeD_1. The source voltageV_{dc} is connected to the one-port impedance network. Before going to the circuit analysis some assumptions are made.

- The functioning of the converter is continuous conduction mode (CCM).
- All components to be ideal.
- The switching control strategy is SPWM technique.

The switching period and duty ratio of the switch is denoted by $\mathbf{T_s}$ and d. Based upon ON and OFF states of the switch 'S' and diodes $\mathbf{D_1}$,$\mathbf{D_2}$. The mode of operation of Modified-ZSC is classified into three modes with in a switching period $\mathbf{T_s}$. Here the $\mathbf{V_0}$ is an output voltage and$\mathbf{V_S}$ is drain to source voltage of switch S, where the input current is $\mathbf{i_i}$ and $\mathbf{i_{d1}}$,$\mathbf{i_{d2}}$are currents of diodes $\mathbf{D_1}$ and $\mathbf{D_2}$ correspondingly. Due to symmetry of one-port impedance network ($\mathbf{C_1}$=$\mathbf{C_2}$, $\mathbf{L_1}$=$\mathbf{L_2}$) therefore following equations are.

$$i_{l1} = i_{l2} = i_L \quad (1)$$

$$i_{c1} = i_{c2} = i_c \quad (2)$$

$$v_{l1} = v_{l2} = v_L \quad (3)$$

$$v_{c1} = v_{c2} = v_C \quad (4)$$

Where V_L and V_c are voltages of the inductor and capacitor, I_L and I_c arecurrent of the inductor and capacitor of the Modified-ZSC.

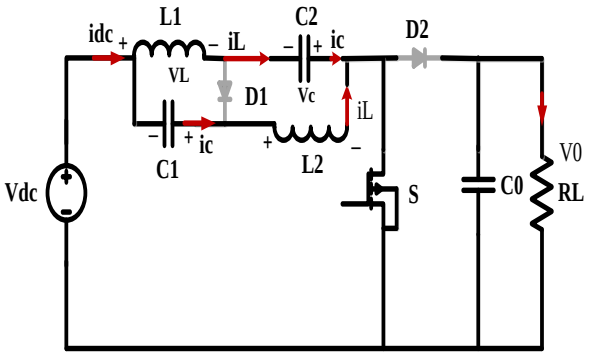


Fig. 4: Mode 1

In Mode 1, the switch S will be turned ON, and the diodes D1, D2 are reverse biased are shown in Fig. 4. where the capacitor C1&C2, inductor L1&L2 are charged by the source voltage (V_{dc}) and resistive load R_L fed the capacitor C_0.Thus the inductor current $i_L$is linearly increases and reaches the extreme level until the switch is tuned OFF .The waveform of this mode are shown in interval [t_0,t_1] in Fig. 7 and the duration time is dT_s.

$$i_L = -i_c \quad (5)$$

$$i_i = 2i_L \quad (6)$$

$$v_L = v_i + v_c \quad (7)$$

$$v_s = v_i + 2\, v_c \quad (8)$$

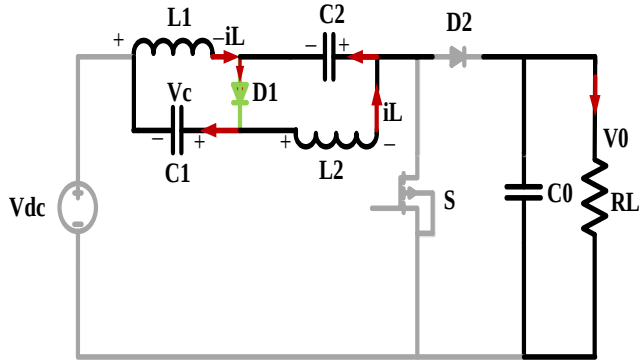


Fig. 5: Mode 2

The figure 5 shows the Mode 2 operation the switch S in OFF state and diode D_1 is forward biased. Then the current equations are.

$$i_L = -i_c \quad (9)$$

$$i_{D1} = 2i_L \quad (10)$$

$$i_{D1} = 2i_L \quad (11)$$

$$v_s = v_i + 2\, v_c \quad (12)$$

The inductors L_1,L_2 are charge the capacitors C_1,C_2 correspondingly. Then inductor current i_L is linearly decreases. From interval [t_1,t_2] the equivalent waveform of this mode is shown in figure 7. The one-port impedance network is inaccessible from input source as well as with the load resistor once the voltage V_s rises to be more than V_0 ,then the diode D_2 will be conduct and mode 2 will be terminated.

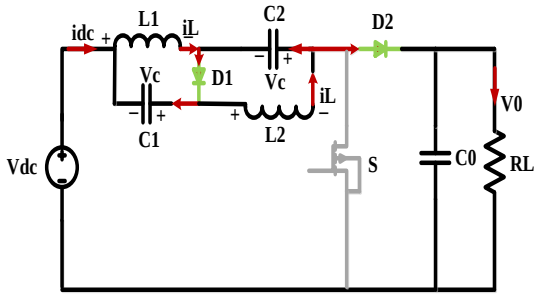


Fig. 6: Mode 3

From figure 6 the switch S is even in OFF mode, but the diodes D_1,D_2 are ON and the formed equations are.

$$i_i = i_L - i_c \tag{13}$$

$$i_{D1} = 2i_L - i_i \tag{14}$$

The voltage across the switch is,

$$v_s = v_i + 2\,v_c \tag{15}$$

The inductors (L_1,L_2) of the one-port Z-Source network charge the capacitors (C_1,C_2) and to fed the output capacitor C_0 and resistive load R_L by the input voltage V_{dc}. But inductor current $I_L$still reduces linearly. Finally mode 3 will be terminated, when the switch is ON over the following switching time period. From interval [t2, t3] the equivalent waveform of this mode is in figure 7. Thus, the period of mode 2 and 3 is (1-d)T_s.

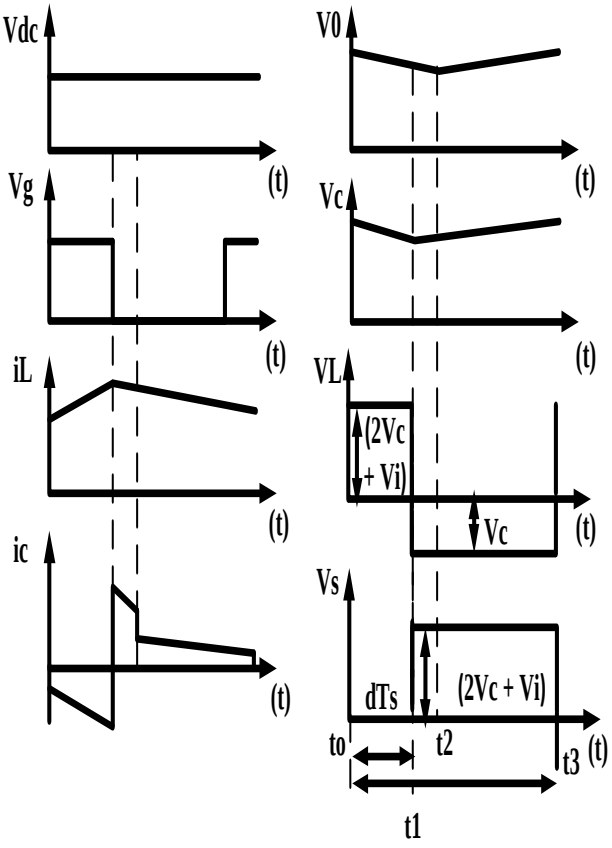


Fig. 7: Waveforms of M-ZSC

4. Voltage Association

Due to high switching frequency and huge capacitance of the impedance source network, therefore voltage of the capacitor is to be assumed constant [5]. Based upon operating principle of the M-ZSC, the voltage V_L equals to V_i+V_c during the ON period of switch S and it will be equals to –V_c during OFF period of switch S. The Volt-Sec balance principle is applying for the inductor. Then the equation is

$$(v_i+v_c)dT_s + (-v_c)\,(1\text{-}d)T_s = 0 \tag{16}$$

Therefore,

$$v_c = v_i \frac{d}{1-2d} \tag{17}$$

Replacing eq 15 in the 13, then the voltage gain is G

$$G = \frac{v_0}{v_i} = \frac{d}{1-2d} \tag{18}$$

The converter output voltage is

$$v_0 = \frac{d}{1-2d} v_i \tag{19}$$

From the above equations we observed that maximum duty range‘d’ between 0 to 0.5.

Table 1: Voltage compression between Boost, ZSC and MZSC

Voltage	Boost converter	ZSC	M-ZSC
v_0	$\frac{v_i}{1-D}$	$v_i \frac{1-d}{1-2d}$	$v_i \frac{1}{1-2d}$
v_c	$v_0 = \frac{v_i}{1-D}$	$v_i \frac{1-d}{1-2d} = v_0$	$v_i \frac{d}{1-2d} = dv_0$
v_s	$v_0 = \frac{v_i}{1-D}$	$v_i \frac{1}{1-2d} = v_0 \frac{1}{1-d}$	$v_i \frac{1}{1-2d} = v_0$

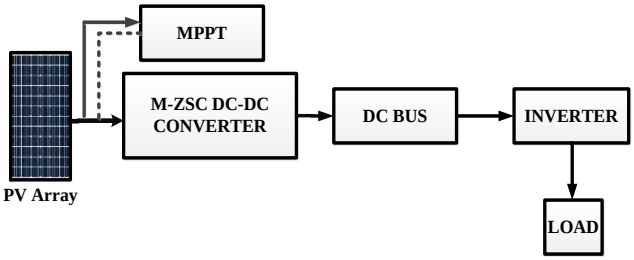


Fig. 8: Proposed Block Diagram

The above figure 8 represents proposed block diagram of the DC-DC Modified-ZSC applied for Photovoltaic Applications. The major drawback of the PV panel is a lower output power, the output voltage of the PV panel is mainly depending upon two constrain one is temperature and another is irradiation. Based upon that two constrains output power will be vary. To defeat this problem, it is necessary to sum an alternative device, that it is an MPPT controller [7] with DC to DC converter. These changes in solar temperature the solar panel is unable to deliver theoretical power unless MPPT is used. There are different types of MPPT techniques, here we applied P&O method for all three converters. In this paper we made a keen compression between proposed M-ZSC and traditional converters like (Boost & ZSC). The performance characteristics of these three converters are analyzed at different irradiance levels with corresponding different loading conditions are simulated. The output characteristic of each converter is tabulated as given in tables.

Table 2: Comparison of three converters at different irradiance without MPPT technique

Types of converters	BC	ZSC	M-ZSC
Irradiance W/m²	Settling time t_s(s)		
1000	0.6	0.6	0.5
900	0.75	0.7	0.65
800	0.8	0.7	0.6
750	0.9	0.8	0.7
700	0.9	0.9	0.8

Table 3: Comparison of three converters at loading condition (without MPPT technique)

Types of converters	BC	ZSC	MZSC	BC	ZSC	MZSC
Irradiance W/m²	Settling time with 20% of load variation, t_s(s)			Settling time with 60% of load variation, t_s (s)		
1000	1.3	1.3	1.2	1.7	1.7	1.6
900	0.18	1.72	1.7	1.7	1.68	1.65
800	1.35	1.25	1.2	1.75	1.7	1.7
750	1.4	1.35	1.3	1.75	1.72	1.7
700	1.35	1.25	1.2	1.8	1.7	1.7

5. MPPT Technique

There are different MPPT techniques are there to obtain more efficiency of PV panel out of the techniques P&O is technique [6] to obtain more efficiency.

Perturb and Observe:

This method is used to operate frequently incrementing or frequently decrementing of PV panel output voltage and measure the power obtained existing phase with the preceding phase. If the voltage varies the power will increase in the control switches the operating point will be in that direction or else will change the operating point in the opposite direction. The given below flow chart describes the algorithm of P&O method [7]. If the instantaneous power P (n) is more than calculated power earlier P (n-1) then direction of perturbation is continued or otherwise it is inverted. When $^{dp}/_{dv} < 0$, the voltage is decreased by D (n) =D (n-1)-ΔV and $^{dp}/_{dv} > 0$, the voltage is increased by D (n) =D (n-1)-ΔV

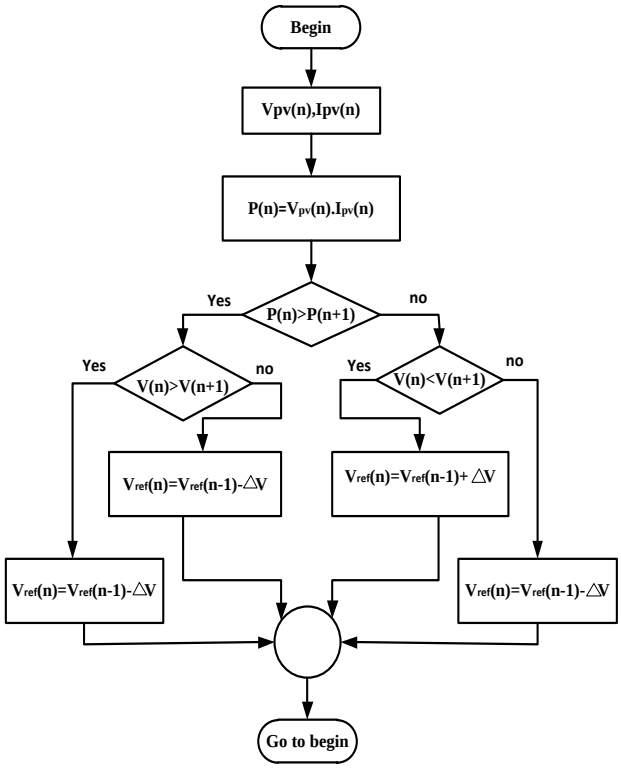


Fig. 9: Perturb and observe method flow chart

Table 4: Performance of M-ZSC at different irradiance with MPPT technique

Types of converters	M-ZSC	M-ZSC	M-ZSC
Irradiance W/m²	Settling time t_s(s)	Settling time with 20% of load variation, t_s(s)	Settling time with 60% of load variation, t_s(s)
1000	0.45	1.1	1.4
900	0.55	1.5	1.55
800	0.5	0.8	1.5

6. Simulation results

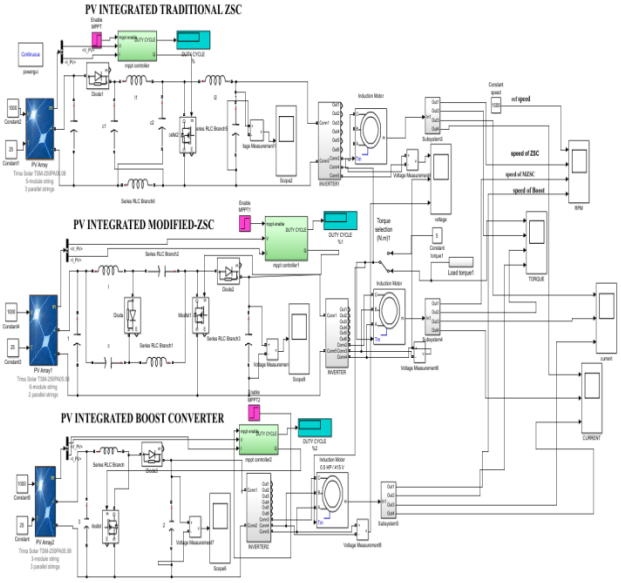


Fig. 10: Modeling diagram

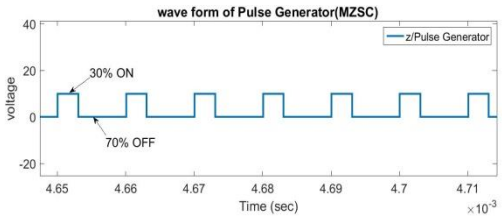


Fig. 11: Waveform of M-ZSC pulse generator with 30% duty

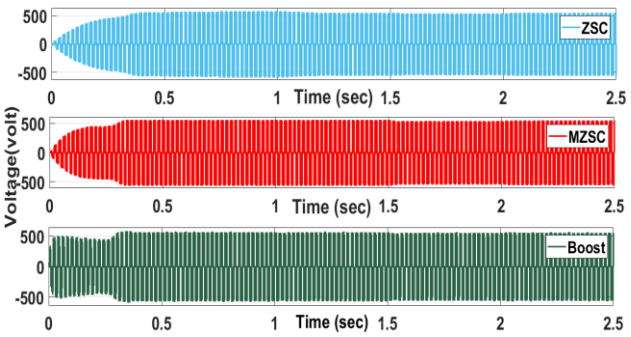


Fig. 12: Inverter Output Voltage Compression of three Converters

The figure 13 shows the speed characteristics of the three converters from here we observe that the MZSC based one has taken less settling time and it is nearer to reference speed. Even the

sudden change in load the modified one has slightly less in speed change.

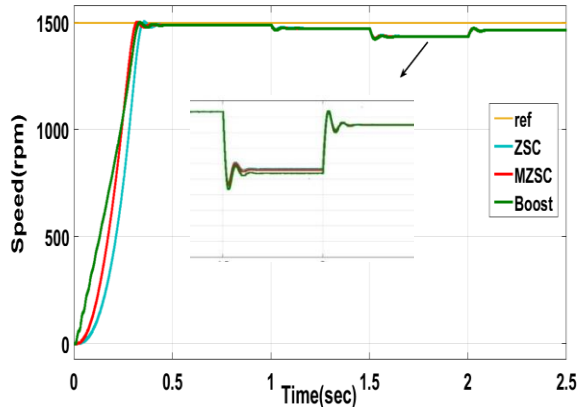


Fig. 13: Speed Characteristics

From figure14 shows the Torque Characteristics of the three converters from here we observe that the MZSC based one has less torque ripple and settling time and it is nearer to reference torque. Even the sudden change in load the torque ripple is not more. Here initially Boost converter has more torque ripple.

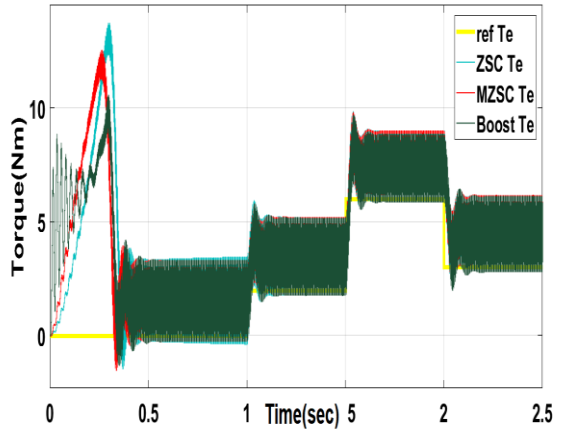


Fig. 14: Torque Characteristics

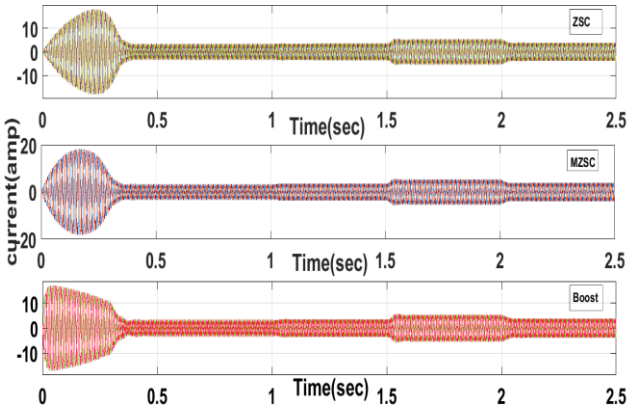


Fig.15: Output currents of three converters

Table 5: Machine parameter

Nominal power(watts)	1800
Stator resistance Rs(ohm)	2.56
Inductance LIs(H)	0.01472
Rotor resistance	1.97
Inductance LIr'(H)	0.01124
Mutual inductance Lm(H)	0.2815
Inertia	0.012024
Friction factor	0.01
Pole pairs	2
Nominal voltage	415V, 3-phase

Table 6: Proposed Converter Parameters

Inductor L1&L2	450µH
Capacitor C1&C2	750µF
MOSFET	-
Diodes	-
PV panel	1.5kw
Switching frequency	100KHz

7. Conclusion

A DC-DC Modified Z-Source converter has projected in this paper. The operating modes of the converter and circuit analysis and is clearly presented, the proposed M-ZSC is compared with traditional converters like (Boost and Z-Source converter), it concluded that the MZSC has lower switching stress with more voltage gain and less capacitor voltage stresses, the output of three converters is connected a 3-phase induction motor as a load through the inverter. As compared with other two converters the Modified ZSC connected induction drive has low torque ripple with the rated speed and it has taken less settling time than others at the different load conditions with corresponding different irradiance levels. So therefore, we concluded that the proposed Modified ZSC is suitable for solar energy system to get high voltage gain and also for wide range of loading capacity.

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