Abstract: Z-Source Inverter (ZSI) is a new topology in power converter especially in DC-AC converter at a very interesting power level. For an instance, it only uses a single-stage power converter with the ability of buck-boost characteristic operations. This work introduces a combination of a solar system with dynamic voltage restorer based Z-source inverter for reducing the voltage swell and harmonics under sudden addition of a balanced three-phase nonlinear load. This article also focuses on perturb and observe (P&O) algorithm for automatically find the PV systems operating voltage that produces a maximum power output. The proposed dynamic voltage restorer fed Z-source inverter is designed and modeled by using MATLAB/SIMULINK. The got outcomes are contrasted with classical dynamic voltage restorer fed voltage and current source inverters.

Keywords: Dynamic Voltage Restorer; Perturb & Observe; Maximum Power Point Tracking

1. Introduction

Currently, voltage waveform namely swells and sags are the most problems in the electric power system and quality problems [1, 2]. Enhance the performance of the power system adding some controllable custom power devices like dynamic voltage restorer fed voltage source, current source and Z-Source inverters [3-5]. The disadvantages of a classical dynamic voltage restorer fed voltage and current source converters are explained in [6-8]. ZSI can be used to buck or to have boost operation at the inverter AC output voltage. Because of the nearness of this one of a kind character, it licenses inverters to be operated in the shoot-through mode [9]. Not at all like conventional inverters such as voltage and a current source, a short-circuit mode is not ruinous and truly
has been used in Z-source inverter [5]. Solar energy is one of the most reliable energy sources for renewable energy power generation [10]. It changes the energy from sunlight and converts it using power converters process in order to deliver the generated power to an existing electrical network. The conventional PV power converters circuit requires two-stage converters; first, it step-up the solar voltage and then change direct current input back into alternator current before it can be fed to the existing electrical grid [11, 12]. But Z-source inverter uses a single-stage power converter with the ability of buck-boost characteristic [13]. Since ZSI is considered as a new type of inverter, a lot of researches in this area have increased. However, all of these techniques could not work if the perturb and observe algorithm is not been modified to get more voltage and current from the solar system and also to maintain the voltage at the DC-link of the inverter input [14-16]. This work introduces a combination of a solar system with dynamic voltage restorer fed ZSI for the ameliorating the distorted voltage and current waveforms under switching a three-phase balanced nonlinear load. In this article, the MPPT method such as P&O is utilized to acquire the optimum power from the solar system. The proposed dynamic voltage restorer fed Z-source inverter is validated in MATLAB/SIMULINK software and got outcomes are contrasted with classical dynamic voltage restorer fed voltage and current source inverters.

2. Dynamic Voltage Restorer fed Z-Source Inverter

Figure 1 shows the proposed Dynamic Voltage Restorer fed Z-Source inverter. The proposed system consists of three-phase Z-source inverter, interfacing inductance ($L_f$), unit vector control technique, DC source and solar photovoltaic system. The solar system is used to give DC supply to the DVR based Z-source inverter. The DVR fed Z-source converts this DC supply to AC and ameliorate the voltage related issues namely voltage swells/sags in a distribution system under sudden switching a balanced three-phase nonlinear load.

3. Working Principle of ZSI [6, 8]

The working principle of ZSI can be explained in three different states such as active state, zero state and shoot-through state as highlighted in figure 2(a-c). The detailed explanation of various working states of ZSI is given in [6-8]. The active state is additionally known as non-shoot-through state as depicted in figure 2(c). In shoot-through state, ZSI is working in one of the forty-one distinctive modes as shown in figures 2(b) and 3 and IGBT switches are short-circuited.

Let us consider impedance network elements have similar value ($L_1=L_2=L$ and $C_1=C_2=C$) respectively. Therefore, the Z-network inductor and capacitor voltage can be obtained by using equation (1) [6, 8]
\[ v_{l1} = v_{l2} = v_{l} \]
\[ v_{c1} = v_{c2} = v_{c} \]  

(1)

Where \( v_{c} \) is the capacitor voltage and \( v_{l} \) is the inductor voltage of the ZSI. In ST state \( t_{0} \) is considered as time period and relation between \( v_{c} \) and \( v_{l} \) are obtained by using equation (2) [6, 8].

\[ \begin{align*}
\frac{v_{l}}{v_{c}} &= 1 \\
\frac{v_{dio}}{v_{c}} &= 2 \\
v_{in} &= 0 \text{ (ST state)}
\end{align*} \]

(2)

Where \( v_{in} \) and \( v_{dio} \) are the dc-link input voltage of the inverter and diode voltage. In active as well as zero state relation between \( v_{c} \) and \( v_{l} \) are obtained by using equation (3) and \( t_{1} \) is considered as the time interval.

\[ \begin{align*}
\frac{v_{l}}{v_{c}} &\neq 1 \\
\frac{v_{dio}}{v_{c}} &= v_{pv} = v_{l} + v_{c} \\
v_{l} &= v_{pv} - v_{c} = v_{c} - v_{in} \\
v_{in} &= v_{c} - v_{l} = 2v_{c} - v_{pv}
\end{align*} \]

(3)

Where \( v_{pv} \) is output voltage of PV system. The mean voltage of the Z-network inductor \( (v_{l,mean}) \) at a time period \( t \) is expressed in equation (4)[6, 8].

\[ v_{l,mean} = v_{c} * t_{0} + \left( v_{pv} - v_{c} \right) * t_{1} = 0 \]

(4)

\[ v_{c} = v_{pv} \left( \frac{t_{1}}{t_{1} - t_{0}} \right) \]

The mean input dc-link of the inverter is obtained by using equation (5)(\( v_{in} \))

\[ v_{in} = t_{0} * 0 + t_{1} \left( 2v_{c} - v_{pv} \right) \text{ using equation (4)} \]

\[ v_{in} = \left( \frac{t_{1}}{t_{1} - t_{0}} \right) v_{pv} = v_{c} \]

(5)
The input dc-link voltage of the inverter in active and zero states are expressed by using equation (6)

\[ \hat{v}_{in} = (v_c - v_t) = v_c - (v_{pv} - v_c) \]

\[ \hat{v}_{in} = (2v_c - v_{pv}) \]  

(6)

Comparing equation (4) and equation (6), gives equation (7)

\[ \hat{v}_{in} = \left( \frac{t}{t_1 - t_0} \right) v_{pv} \]

\[ \hat{v}_{in} = b v_{pv} \]  

(7)

Where ‘b’ denotes the boost factor and is also obtained by using equation (8)

\[ b = \left( \frac{t}{t_1 - t_0} \right) = \frac{1}{1 - \left( \frac{t_0}{t} \right)} \geq 1, \ t = t_0 + t_1 \]  

(8)

The converter output voltage can be calculated using equation (9) [6, 8]

\[ \hat{v}_{ac} = \frac{m \hat{v}_{in}}{2} = \left( \frac{mb v_{pv}}{2} \right) \]  

(9)

where m is the modulation index whose value should be less than equal to one. The Z-network capacitor voltage can be obtained by using equations (10) and (11) [6, 8] From equation (4) we have

\[ v_c = \left( \frac{t_1}{t_1 - t_0} \right) v_{pv} \]

\[ v_c = \left( \frac{t_1}{t} \right) \left( \frac{t}{t_1 - t_0} \right) v_{pv} \]  

\[ v_c = \left( 1 - \left( \frac{t_0}{t} \right) \right) \left( 1 - \left( \frac{2t_0}{t} \right) \right) v_{pv} \]  

(10)
\[ v_c = \frac{b+1}{2b} * b * v_p v = \left( \frac{b+1}{2} \right)v_p v \] 

(11)

4. Impedance Source Inverter Design

4.1 Z-Network Inductor Design

In active and zero modes a mean current which is passing through the inductor reduces as expressed in equation (12) [6, 8]

\[ i_{l,\text{mean}} = \frac{p_{\text{in}}}{v_p v} \] 

(12)

For the design of ZSI parameters such as inductor and capacitor, the 30% current ripples are taken.

The maximum current flowing through the inductor [6, 8]

\[ i_{l,\text{max}} = i_{l,\text{mean}} + 30\% \text{ of } i_{l,\text{mean}} \]

The minimum current flowing through the inductor [6, 8]

\[ i_{l,\text{min}} = i_{l,\text{mean}} - 30\% \text{ of } i_{l,\text{mean}} \]

In ST state, \( v_I = v_C = v \)

\[ v_I = v_C = v = \left( \frac{b+1}{2} \right)v_p v \], put the value of \( v \) from equation (11).

Using equation (13) find the value of inductor

\[ L = \left( \frac{v * t_0}{\Delta i} \right) \] 

(13)

where, \( \Delta i = \left( i_{l,\text{max}} - i_{l,\text{min}} \right) \)

4.2 Z-Source Capacitor Design

The capacitor value obtained using equation (14) [6, 8]
\[ C = \left( \frac{i_{l,\text{avg}} - i^*_0}{\Delta v_C} \right) \] \quad (14)

\[ \Delta v_C = v \times 3\% \]

In a ST state the value of inductor and capacitor can be calculated by using equation (11) and equation (14) [6, 8].

\[ L = \left( \frac{v^* t_0}{\Delta i} \right) = \left( \frac{167.75 \times 9.83}{2.57} \right) = 0.6 \text{ mH} \]

\[ C = \left( \frac{i_{l, \text{mean}} - i^*_0}{\Delta v_C} \right) = \left( \frac{4.28 \times 9.83}{844.20} \right) = 0.05 \mu f \]

4.3 Voltage Gain

The voltage gain can be expressed in equation (15) [8]

\[ G = m \times b = \left( \frac{m}{\sqrt{5m - 1}} \right) \]

\[ G = \left[ \frac{1}{2} \times \frac{D(1 - D)}{2D - D(1 - D) - 1} \right] \]

4.4 Switching losses [8]

The switching loss of each IGBT during active and ST states \( P_{S - \text{nst}} \) and \( P_{S - \text{st}} \) are calculated using equations (16) and (17).

\[ P_{S - \text{nst}} = \frac{1}{2 \pi T_{SW}} \left( E_{SW - \text{ons}} + E_{SW - \text{offs}} \right) \times \left( \frac{\pi}{6} \right) \]

\[ P_{S - \text{st}} = \frac{1}{2 T_{SW}} \left( E_{SW - \text{ons}} + E_{SW - \text{offs}} \right) \]
\( E_{SW-onn} \) and \( E_{SW-off} \) are the switch ON and switch off energy loss of the IGBT at peak current respectively.

Also \( E_{SW-ons} \) and \( E_{SW-offs} \) are the switch ON and switch OFF energy losses corresponding to the mean turn on current of the shoot-through states, which is \( \frac{2}{3} I_L \).

4.5. Voltage stress across the devices [8]

According to Equation (7), the voltage stress, \( S_S \), can be expressed in equation (18)

\[
S_S = v_{in} = bv_{pv}
\] (18)

5. Modulation algorithm with timing diagram of the ZSI

Figure 3 outlines the structure of the eighty-three IGBT switching modes of a proposed ZSI, which includes forty active modes, two zero modes, and forty-one ST modes. In active and zero modes, two IGBT switches of one or two or three or five or six are the complement to each other like commonly used traditional inverters as well as proposed ZSI. But forty-one ST modes one (E1 to E6) or two (E7 to E21) or three (E22 to E31) or four (E32 to E37) or five (E38 to E40) or six legs (E41) are short-circuited is special to the ZSI. The switching states of a DVR fed ZSI are shown in Table 1.

6. UVT Control Technique [17]

In UVT technique first measures three-phase supply voltages and multiplied by \( g = \frac{I}{V_{mag}} \) as shown in figure 4.

Where \( V_{mag} \) is the input voltage obtained by using equation (19) [17].

\[
V_{mag} = \sqrt{\left(\frac{2}{3}\right)\left(V_{Sa}^2 + V_{Sb}^2 + V_{Sc}^2\right)}
\] (19)

The got voltage signals are given as an input to a phase-locked loop (PLL). After getting input signals PLL used to create a unit vectors \( U_a, U_b, U_c \) is calculated by equation (20) [17].

\[
\begin{align*}
U_a &= \sin(\theta) \\
U_b &= \sin(\theta - 120) \\
U_c &= \sin(\theta + 120)
\end{align*}
\] (20)
The yield \( U_a, U_b, U_c \) from equation (20) is then multiplied with required load voltage \( V_{rl} \) and produces \( V_{La}^*, V_{Lb}^*, V_{Lc}^* \) is obtained in equation (21) [17].

\[
\begin{bmatrix}
V_{La}^* \\
V_{Lb}^* \\
V_{Lc}^*
\end{bmatrix} = \begin{bmatrix}
U_a \\
U_b \\
U_c
\end{bmatrix}
\]

(21)

The three-phase supply voltages are compared with obtained \( V_{La}^*, V_{Lb}^*, V_{Lc}^* \) and generate reference compensator voltage \( V_{Cabc}^* \). The PWM generator generates switching pulses after comparing the reference compensator voltages and compensator voltages.

7. **Perturb and Observe (P&O) Algorithm [18-20]**

The P&O technique is commonly embraced for hunting down the MPPT in light of fact that it is straightforward and requires just estimation of the voltage \( v_{pv} \) and current \( i_{pv} \) of the PV system [21]. P&O works by perturbing (increasing or decreasing) the measured photovoltaic voltage \( v_{pv} \) and comparing the instantaneous power previously, then after the perturbation [18-21]. The perturb and observe algorithm is depicted in figure 5.

8. **Results and Discussion**

The proposed dynamic voltage restorer based Z-source inverter system in figure 1 is modulated using MATLAB/SIMULINK under sudden switching a balanced three-phase nonlinear load. Figure 6(a-c) shows the different characteristics of the solar cell under different irradiations of the sun. As the irradiation increases the open circuit voltage as well as the short circuit current also increases as shown in figure 6a and b. Consequently, perturb and observe algorithm is used to get the most extreme power from the solar cell as highlighted in figure 7. The simulation specifications utilized in the simulation are shown in Table 2.

8.1 **Swell Alleviation by Dynamic Voltage Restorer fed Voltage Source Inverter**

A 31% three-phase balanced voltage swell (VS) happens at the supply side because of sudden switching a nonlinear load as shown in figures 8a and b. At the period t= 0.05 second to 0.15 second a voltage source inverter based DVR is connected to a distribution system and inject a compensated voltage to compensate three-phase balanced voltage swell as shown in figure 8c. Figure 8d highlights the sinusoidal load voltage after
minimizing the voltage swell effect. Figure 8e outlines the nature of the capacitor voltage of the dynamic voltage restorer based voltage source inverter.

8.2 Swell Alleviation by Dynamic Voltage Restorer fed Current Source Inverter

Figures 9a and b show the voltage swell of magnitude 31% under sudden switching a three-phase balanced nonlinear load. Which begins at t= 0.05 second and terminates at t= 0.15 seconds. Figure 9c depicts the ability of dynamic voltage restorer fed current source inverter to ameliorate three-phase balanced voltage swell by injecting compensating voltage. Figure 9d highlights the sinusoidal load voltage after minimizing the voltage swell effect. The behavior of inductor current of a dynamic voltage restorer fed current source inverter during voltage swell event exposed in Figure 9e.

8.3 Swell Alleviation by Dynamic Voltage Restorer fed Z-Source Inverter

Figures 10a and b shows the voltage swell of magnitude 31% under sudden switching a three-phase balanced nonlinear load in a distribution network. Which begins at t= 50 milliseconds and terminates at t= 150 milliseconds. Figure 10c depicts the ability of dynamic voltage restorer fed Z-source inverter to alleviate voltage swell by injecting compensating voltage. Figure 10d highlights the sinusoidal load voltage after minimizing the voltage swell effect. Figure 10(e-f) outlines the nature of capacitor voltage and inductor current of a proposed dynamic voltage restorer based Z-source inverter.

9. Comparison of Dynamic Voltage Restorer fed Voltage, Current and Z-Source Inverters

Figure 11 outlines the comparison of compensated voltages of a classically used dynamic voltage restorer fed voltage, current and proposed Z-source inverters. Without association of dynamic voltage restorer fed voltage, current and proposed Z-source inverters a voltage swell of magnitude 31% (98 V) at t=0.5 s for a duration of 0.35 s is noted. Therefore, dynamic voltage restorer fed inverters are associated with the system and generate voltages of 132 V, 66.65 V, and 95 V respectively. The proposed dynamic voltage restorer fed Z-source inverter demonstrates the better execution than dynamic voltage restorer fed voltage and current source inverters as highlighted in figure 11.

Tables 3-4 highlights the capability of voltage, current and proposed dynamic voltage restorer z-source inverter for the elimination of a current and voltage harmonics.
The total harmonic distortion (THD) of the supply current without dynamic voltage restorer fed voltage, current, and Z-source inverters connected to the system is observed as 7.97% but when dynamic voltage restorer fed voltage, current and proposed Z-source inverters are connected to the system, the THDi noted as 0.65%, 0.75% and 0.6% as shown in Table 3. Therefore, 93.72% decrease in THDi has been accomplished utilizing proposed dynamic voltage restorer fed Z-source inverter compared with 91.8% and 90.58% decrease in THDi of a voltage and current source inverter fed DVRs.

In Table 4, load voltage THDv is noted as 18.62% when dynamic voltage restorer fed voltage, current, and proposed Z-source inverters are not associated with the system. But when dynamic voltage restorer fed voltage, current and proposed Z-source inverters are associated with the system, the THDv noted as 3.5%, 2.48% and 1.8% as shown in Table 4. Therefore, 90.33% decrease in THDv has been accomplished utilizing proposed dynamic voltage restorer fed Z-source inverter compared with 81.2% and 86.68% decrease in THDv of a voltage and current source inverter fed DVRs.

10. Conclusion

This work introduces a combination of a solar system with dynamic voltage restorer based Z-source inverter for ameliorating the voltage swell and harmonics under sudden addition of a balanced three-phase nonlinear load. Results show, at the swell condition, dynamic voltage restorer based Z-source inverter has the ability to ameliorate the distortions in voltage by injecting the correct amount of compensation voltage compared to classical dynamic voltage restorer fed voltage and current source inverters. The results also show the ability of dynamic voltage restorer fed Z-source inverter for the elimination of a current and voltage harmonics during switching a three-phase balanced nonlinear load compared to classical dynamic voltage restorer fed voltage and current source inverters. This article also focuses on perturb and observe (P&O) algorithm for automatically find the PV systems operating voltage that produces a maximum power output.

References


**Figure 1:** Combination of a Dynamic Voltage Restorer fed Z-Source Inverters

**Figure 2** ZSI (a) Configuration (b) Shoot-Through State and (c) Active and Zero State

**Figure 3** Modulation of the ZSI

**Figure 4** Schematic diagram of a Control Algorithm

**Figure 5** Perturb and Observe Algorithm

**Figure 6** Characteristics of Solar Photovoltaic under various Irradiations (a) V-I characteristics (b) P-I characteristics and (c) P-V characteristics

**Figure 7** Perturb & Observe (P&O) Algorithm

**Figure 8** PV-VSI-DVR at 31% Swell (a) $V_S$ (b) RMS $V_S$ (c) $V_{Inj}$ (d) $V_{Load}$ and (e) $V_{dc}$

**Figure 9** PV-CSI-DVR at 31% Swell (a) $V_S$ (b) $V_S$ (c) $V_{Inj}$ (d) $V_{Load}$ and (e) $I_{dc}$

**Figure 10** Proposed PV- ZSI-DVR at 31% Swell (a) $V_S$ (b) RMS $V_S$ (c) $V_{Inj}$ (d) $V_{Load}$ (e) $V_{dc}$ and (f) $I_{dc}$

**Figure 11** Compensation Voltages

**Table 1** Switching States of proposed DVR fed ZSI

(!SWY is the complement of SWY, where Y=1, 3, 5, 7, 9 OR 11)

**Table 2**: DVR fed ZSI Specifications

**Table 3**: Comparison of supply current THDi

**Table 4**: Comparison of load voltage THDv
Figure 1: Combination of a Dynamic Voltage Restorer fed Z-Source Inverters

Figure 2 ZSI (a) Configuration (b) Shoot-Through State and (c) Active and Zero State
CONVENTIONAL PWM CONVERTERS

PROPOSED Z-SOURCE INVERTER

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Figure 9: PV-CSI-DVR at 31% Swell (a) $V_s$ (b) RMS $V_s$ (c) $V_{inj}$ (d) $V_{load}$ and (e) $I_{dc}$
Figure 10 Proposed PV-ZSI-DVR at 31% Swell (a) $V_S$ (b) RMS $V_S$ (c) $V_{Inj}$ (d) $V_{Load}$ (e) $V_{dc}$ and (f) $I_{dc}$

Figure 11 Compensation Voltages
Table 1: Switching States of proposed DVR fed ZSI

(!SWY is the complement of SWY, where Y=1, 3, 5, 7, 9 OR 11)

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<tr>
<td>State<a href="finite">111111</a></td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Null<a href="0V">000000</a></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Null[111111](0V)      | 1   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0    | 0    | 0    |

#Shoot-through E1 (0V) 1 1 1 1 SW3 SW3 SW5 SW5 SW7 SW7 SW9 SW9 SW11 SW11
#Shoot-through E2 (0V) SW1 SW3 SW3 SW5 SW5 SW7 SW7 SW9 SW9 SW11 SW11
#Shoot-through E3 (0V) SW1 SW3 SW5 SW7 SW7 SW9 SW9 SW11 SW11
#Shoot-through E4 (0V) SW1 SW3 SW5 SW7 SW7 SW9 SW9 SW11 SW11
#Shoot-through E5 (0V) SW1 SW3 SW5 SW7 SW7 SW9 SW9 SW11 SW11
#Shoot-through E6 (0V) SW1 SW3 SW5 SW7 SW7 SW9 SW9 SW11 SW11
#Shoot-through E7 (0V) SW1 SW3 SW5 SW7 SW7 SW9 SW9 SW11 SW11
#Shoot-through E8 (0V) SW1 SW3 SW5 SW7 SW7 SW9 SW9 SW11 SW11
#Shoot-through E9 (0V) SW1 SW3 SW5 SW7 SW7 SW9 SW9 SW11 SW11
#Shoot-through E10 (0V) SW1 SW3 SW5 SW7 SW7 SW9 SW9 SW11 SW11
#Shoot-through E11 (0V) SW1 SW3 SW5 SW7 SW7 SW9 SW9 SW11 SW11
#Shoot-through E12 (0V) SW1 SW3 SW5 SW7 SW7 SW9 SW9 SW11 SW11
#Shoot-through E13 (0V) SW1 SW3 SW5 SW7 SW7 SW9 SW9 SW11 SW11
#Shoot-through E14 (0V) SW1 SW3 SW5 SW7 SW7 SW9 SW9 SW11 SW11
#Shoot-through E15 (0V) SW1 SW3 SW5 SW7 SW7 SW9 SW9 SW11 SW11
#Shoot-through E16 (0V) SW1 SW3 SW5 SW7 SW7 SW9 SW9 SW11 SW11
#Shoot-through E17 (0V) SW1 SW3 SW5 SW7 SW7 SW9 SW9 SW11 SW11
Table 2: DVR fed ZSI Specifications

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply Voltage (Vs)</td>
<td>380 V</td>
</tr>
<tr>
<td>Frequency (f)</td>
<td>50 Hz</td>
</tr>
<tr>
<td>Supply Resistance (Rs)</td>
<td>0.05 Ω</td>
</tr>
<tr>
<td>Supply Inductance (Ls)</td>
<td>3.5 µH</td>
</tr>
<tr>
<td>Linear Load</td>
<td></td>
</tr>
<tr>
<td>Active Power (P)</td>
<td>5kW</td>
</tr>
<tr>
<td>Inductive reactive power (QL)</td>
<td>10 kVAR</td>
</tr>
<tr>
<td>Nonlinear Load</td>
<td></td>
</tr>
<tr>
<td>Diode rectifier, Rd= 10 Ω, Ld= 3µH</td>
<td></td>
</tr>
<tr>
<td>Injection Transformer</td>
<td>240/120 V</td>
</tr>
<tr>
<td>DC-bus Voltage (Vdc)</td>
<td>150 V</td>
</tr>
<tr>
<td></td>
<td>VOC = 36.1 V</td>
</tr>
<tr>
<td></td>
<td>Isc = 6 A</td>
</tr>
<tr>
<td></td>
<td>No of solar cells (C) = 36</td>
</tr>
<tr>
<td></td>
<td>Pmax = 151 W</td>
</tr>
<tr>
<td>Solar module</td>
<td></td>
</tr>
<tr>
<td>Vmpp = 29.6 V</td>
<td></td>
</tr>
<tr>
<td>Impp = 5.1 A</td>
<td></td>
</tr>
<tr>
<td>Diode identity factor (n) = 1</td>
<td></td>
</tr>
<tr>
<td>Rs = 0.18 Ω</td>
<td></td>
</tr>
<tr>
<td>Rp = 360.002 Ω</td>
<td></td>
</tr>
</tbody>
</table>
Z-Source Inverter

\[ L_1 = L_2 = L = 0.6 \text{ mH} \]
\[ C_1 = C_2 = C = 0.05 \mu \text{F} \]
\[ m = 0.5 \]
\[ t_0 = 9.83 \mu \text{s} \]
\[ I_{i,av} = 4.28 \text{ A} \]
\[ I_{i,max} = 5.56 \text{ A} \]
\[ i_{i,min} = 2.99 \text{ A} \]
\[ \Delta i = 2.57 \text{ A} \]

### Table 3: Comparison of supply current THDi

<table>
<thead>
<tr>
<th>Before Compensation</th>
<th>DVR fed VSI (With DVR fed VSI Enhancement in THDi (%))</th>
<th>DVR fed CSI (With DVR fed CSI Enhancement in THDi (%))</th>
<th>Proposed DVR fed ZSI (Proposed DVR fed ZSI Enhancement in THDi (%))</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>7.97 (0.65)</td>
<td>91.8 (0.75)</td>
<td>90.58 (0.5)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>93.72</td>
</tr>
</tbody>
</table>

### Table 4: Comparison of load voltage THDv

<table>
<thead>
<tr>
<th>Before Compensation</th>
<th>DVR fed VSI (With DVR fed VSI Enhancement in THDv (%))</th>
<th>DVR fed CSI (With DVR fed CSI Enhancement in THDv (%))</th>
<th>Proposed DVR fed ZSI (Proposed DVR fed ZSI Enhancement in THDv (%))</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>18.62 (3.5)</td>
<td>81.2 (2.48)</td>
<td>86.68 (1.8)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>90.33</td>
</tr>
</tbody>
</table>

**Biographies**

**M. Prasad,** born in India, received the B.E in Electrical & Electronics Engineering from GITAM, University, Andhra Pradesh, India, M.Tech in power systems from NIT Jamshedpur, Jharkhand, India, in 2010 and 2013, respectively. Currently, he is pursuing his Ph.D. degree in Electrical Engineering Department, NIT Jamshedpur, India. His main research interests are power quality, custom power devices and power electronics.
Ashok Kumar Akella, born in India, received the B. Sc (Engineering) and M. Tech. (Control System) degree from MIT Muzaffarpur, India in 1987 and 1992, respectively and completed his Ph.D. (Renewable Energy System) from IIT Roorkee, India in the year 2006. He is a life member of ISTE. Since 1996 he has been serving as a faculty in the Department of Electrical Engineering, NIT Jamshedpur, Jharkhand, India. His main research interests are control system, renewable energy system and power quality.

Almoataz Y. Abdelaziz received the B.Sc. and M.Sc. degrees in electrical engineering from Ain Shams University, Cairo, Egypt, in 1985 and 1990, respectively, and the Ph.D. degree in electrical engineering according to the channel system between Ain Shams University, Egypt, and Brunel University, U.K., in 1996. He is currently a Professor of electrical power engineering at Ain Shams University. Dr. Abdelaziz is the chair of IEEE Education Society chapter in Egypt, a senior editor of Ain Shams Engineering Journal, editor of Electric Power Components & Systems Journal, member of editorial board, and a reviewer of technical papers in several international journals and conferences. He is a senior member in IEEE, a member in IET and the Egyptian Sub-Committees of IEC and CIGRE’. He has been awarded many prizes for distinct researches and for international publishing from Ain Shams University, Egypt. He has authored or coauthored more than 300 refereed journal and conference papers in his research areas which include the applications of artificial intelligence, evolutionary and heuristic optimization techniques to power system operation, planning, and control.