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# SVPWM MODEL BASED Z-SOURCE INVERTER OPERATED IN DUAL MODE

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***ABSTRACT***

***In recent developments the power electronics, power systems and drives shows an essential part in almost all renewable energy power systems. The technical challenges of feasible renewable energy power generation are improving reliability, reducing the overall cost and increasing the efficiency of power electronics and drives components required for implementation. In the anticipated work the block diagram of the system, modes of operation and simulation model has been conferred thoroughly. The MATLAB simulation has been studied in two modes i.e. grid-connected and islanded mode. The MATLAB based simulation outcome of the proposed model verifies that the proposed methodology has a lower input current aggregate harmonic distortion, a higher input power factor, and a higher effectiveness in contrast with a traditional inverter. The simulation results demonstrate that the utilization of the safe commutation system is a significant enhancement, as it makes it conceivable to stay away from voltage spikes on the switches.***

## 1. INTRODUCTION

The power electronics literature focuses the level and characteristics of the source voltage have been changed using different converter topologies. Each converter topology has its own restrictions regarding different aspects like number of components used, stress on semiconductor switches and converter efficiency [1]. Some of these converters have found places in industry for a variety of applications. Today, efficient power conversion is more important than before because of the alternative energy sources like fuel cells, solar energy, wind energy and ocean wave energy that require proper power conditioning to adapt to different loads. Also hybrid vehicles are very promising new applications of power converters. Moreover, the area of electrical drives is still demanding for new topologies in order to find more efficient and cheaper ways of converting the form of energy from electrical to mechanical or vice versa. Since clean, reliable and high quality energy is one of the main concerns in today's world, power electronics will definitely play an important role in filling this gap.

The inverters classify as Voltage Source Inverter (VSI) and Current Source Inverter (CSI). In the voltage source; inverter has a stiff DC voltage source in the terminals. Similarly, the current source inverter has a stiff DC source and the stiff current source; current output waves will not affect the load. The load, which requires the constant or adjustable voltage, fed with the inverters. So the inverter output voltage controls for the fulfill requirement of AC loads.

## 2. LITERATURE REVIEW

The power electronics literature focuses the level and characteristics of the source voltage have been changed using different converter topologies. Each converter topology has its own restrictions regarding different aspects like number of components used, stress on semiconductor switches and converter efficiency [2]. Some of these converters have found places in industry for a variety of applications. Today, efficient power conversion is more important than before because of the alternative energy sources like fuel cells, solar energy, wind energy and ocean wave energy that require proper power conditioning to adapt to different loads. Also hybrid vehicles are very promising new applications of power converters. Moreover, the area of electrical drives is still demanding for new topologies in order to find more efficient and cheaper ways of converting the form of energy from electrical to mechanical or vice versa. Since clean, reliable and high quality energy is one of the main concerns in today's world, power electronics will definitely play an important role in filling this gap. **Meysam et al [3]** finds that normally, the number of power semiconductor devices connected in series in H-bridge is proportional to the number of level. The minimal device requires expensive LC output filter in order to limit the motor winding insulation stress. **Y. Yang, et. al., [4]** this study explores the integration issues of next-generation high-penetration photovoltaic (PV) systems, besides, this power control strategy can be implemented in commercial PV inverters as a standardized function, and also the operation modes can be achieved online in predesigned PV inverters. Case studies have verified the effectiveness and flexibilities of the proposal to realize the advanced features. **S. Sajadian et. al., [5]** presents a model predictive control (MPC) of dual-mode z-source inverters with capability to operate in islanded and grid-connected mode. The transition from islanded to grid-connected mode and vice versa can cause significant deviation in voltage and current due to mismatch in phase, frequency, and amplitude of grid voltage and load voltage. Direct decoupled active and reactive power control in grid-connected mode enables the proposed power electronics interface to behave as a power conditioning unit for ancillary services such as reactive power compensation. The proposed controller features simplicity, seamless transition between modes of operations, fast dynamic response, and small tracking error in steady state condition of controller objectives. The operation of the proposed system is verified experimentally. **J. M. Bloemink et. al., [6]** an approach for the control of a voltage-sourced converter-interfaced distributed energy resource micro-grid environment with multiple energy sources is analyzed and experimentally validated. The control approach is designed to operate in grid-connected and islanded modes of operation, as well as provide a smooth transition between the two modes. Additional features including islanding detection with positive feedback and dynamic overcurrent limiting are also evaluated. Validation is achieved through the results obtained from a scaled down prototype system with further results from the time-domain simulation of a medium-voltage micro-grid.

## Z-SOURCE INVERTER

A new type of converter in power conversion, Z-source converter (ZSC) was introduced in 2002, which has unique features that can overcome the limitations of VSI and CSI [2]. This chapter3 introduces Z-Source Inverter or impedance source (or impedance-fed) power converter and its control method for implementing DC-to-AC, AC-to-DC, AC-to-AC, and DC-to-DC power conversion. The AC voltage from the Z-source inverter (ZSI) can be controlled, theoretically to any value between zero and infinity. To differentiate it from any conventional VSI and CSI, the power circuit was named as Z-source converter. Figure 1 shows the general configuration of a Z-source converter.

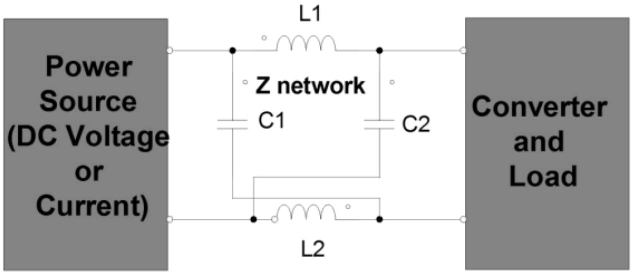


**Figure 1:** The general configuration of a Z-source converter

Figure 2 shows a simplified equivalent circuit for voltage source based ZSC. In the simplified circuit, the VSI inverter bridge is viewed as an equivalent current source or drain in parallel with an active switch S2.

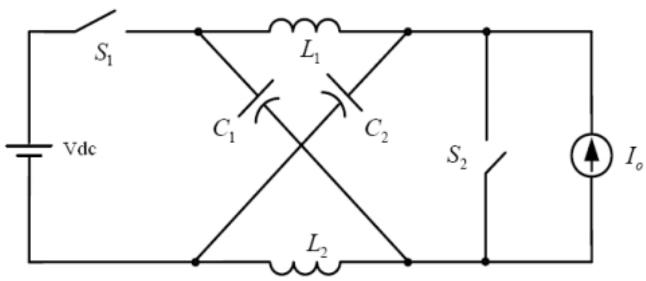


**Figure 2:** Equivalent circuit of voltage source based Z-Source Converter

Unlike a conventional VSI, the shoot-through state is not harmful and actually has been utilized in ZSI. The analysis in [7] shows how the shoot-through state over the non-shoot-through state controls the buck-boost factor of the system.

It is important to note that the process of energy transfer between DC and AC overlaps the process of energy transfer from DC source to the Z-network. The overlap process seems very demanding on Switch "$S_1$". Therefore, for both motoring and generating operation, $S_1$ is subject to substantial current stresses. In particular, for a high starting current application, the total current will impose a tremendous stress on $S_1$ (the starting current plus the current needed to store energy in the Z network).

The ripple current through C is higher than that through the dc bus capacitor used in a conventional VSI. In terms of voltage, the boosted dc voltage is the voltage across the capacitor in ZSI. Additionally, for starting and generating operation, S1 need to handle bi-directional current and, thus, a diode with an antiparallel transistor should be used. The selection of inductors and capacitors for Z network is also of great importance. Firstly the reactive components selection should be guaranteed that no resonance would occur. In addition, the inductance and capacitance should be large enough to make the inductor current and capacitor voltage ripple as small as possible. With the shoot-through states evenly distributed among the Pulse Width Modulation (PWM) cycles, the equivalent switching frequency seen by the Z-network will be several times of that used in VSI part, implying that minimization of reactive components is possible [8].

## SPACE VECTOR MODULATION

Space Vector PWM (SVPWM) generates the suitable gate pulse for each PWM cycle [9]. The switching states depend on the number of levels. The SVPWM has unique calculations of switching time for each of these states. This technique can be easily improved to higher level and works with topologies of MLI. The three vectors which form one triangle to provide duty cycle time for each will give the desired voltage vector (Vref). The SVPWM that uses a vector as a reference is the main difference from other PWM techniques. Figure 3 shows the space vector diagram of a nine level inverter.

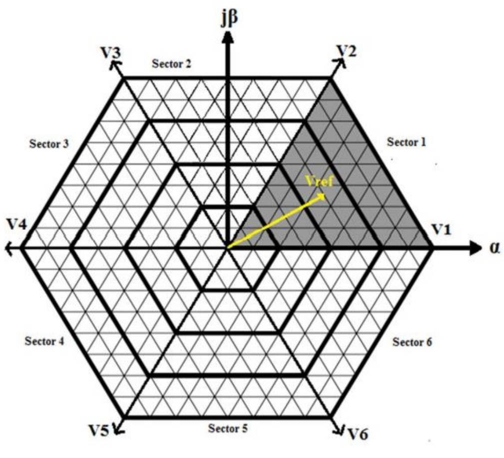


**Figure 3:** Space Vector diagram

- **REFERENCE VECTOR**

The reference vector which is represented in a αβ-plane is a two dimensional plane transformed from a three dimensional plane which has the vectors of the three phase. Figure 4 shows reference vector in the two and three dimensional plane. The switches being ON or OFF are determined by the location of the reference vector on this αβ -plane.

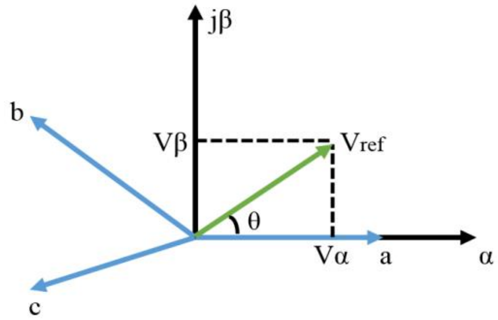


**Figure 4:** Reference vector in the two and three dimensional plane

In three phase system, phase voltage is the space vectors which are transformed into the stationary reference plane αβ according to the transformation relationship.

$$\begin{pmatrix} V_\alpha \\ V_\beta \end{pmatrix} = \frac{2}{3}\begin{pmatrix} 1 & -1/2 & -1/2 \\ 0 & \sqrt{3}/2 & -\sqrt{3}/2 \end{pmatrix}\begin{pmatrix} V_a \\ V_b \\ V_c \end{pmatrix}$$

…..3.1

After the transformation, all space vectors are the stationary vectors in a complex plane as shown in Figure 5 the magnitude of active vectors is 0.666 of direct axis voltage (Vd).

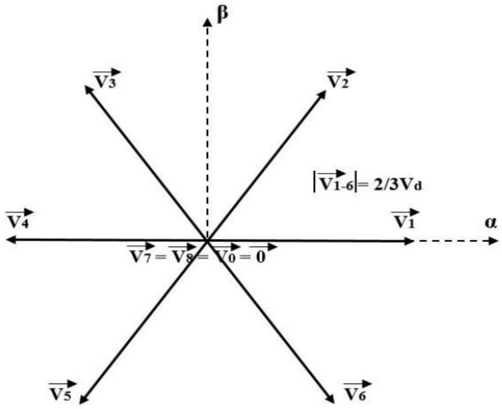


**Figure 5:** Space vectors in complex plane

  

There are eight possible switching states, of which two of them are zero switching states while V7 and V8 are passive or usually called zero vectors and are placed in the axis origin and six of the space vectors V1 and V6 are active vectors. Any other space vector can be created using these eight space vectors. The SVM technique is used to make a reference vector by modulating the switching time of space vectors in each of the six sectors [10]. The space voltage vector is produced by two active vectors and zero vectors at each sector. Active vectors (T1 to T6) is calculated by angle created by the reference vector by modulating the switching time and subsequent active vector and zero vector (T0) at each sector is calculated.

Mathematically, this can be given by the formula:

$$V^* = \frac{V_1T_1+V_2T_2+V_3T_3}{T_S}$$

…..3.2

The V* in Figure 6 can be constructed by the three closest vectors i.e. two active and one passive using geometry summation.

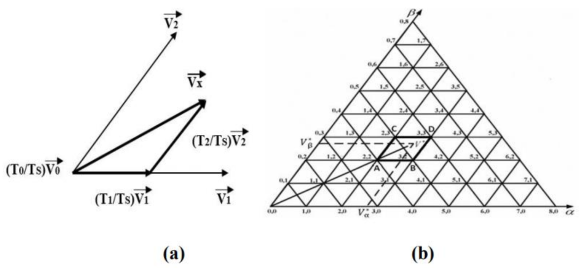

**Figure 6:** (a) Composition of any space vector (b) Space vectors in the 60o coordinate system (sector I)

When the reference vector lies on ¨BCD, the dwell time is calculated as follows

$$V^*\epsilon\Delta BCD \rightarrow \begin{cases} T_B = (V_{A\beta} + 1 - V_\beta^*)T_S \\ T_C = (V_{A\alpha} + 1 - V_\alpha^*)T_S \\ T_D = T_S - T_B - T_C \end{cases}$$

……3.3

Assuming that $V^*$ and θ of the reference vector as shown in Fig.3.12.b whose values are 4.5 and $22^o$ , the dwell time is computed as

a) $V_\alpha^* = 2.76$, and $V_\beta^* = 2.70$

b) $V_{A\alpha}$ = int(2.76) = 2, $V_{A\beta}$ = int(2.70) = 2

c) $V^*$ is in ΔBCD since $(V_\alpha^* + V_\beta^*) < (V_{A\alpha} + V_{A\beta} + 1)$

d) $T_B = (2 + 1 - 2.70)T_S = 0.30T_S$, and

$T_C = (2+1-2.76)T_S=0.24T_S$

$T_D = (1-T_B-T_C)T_S=0.46T_S$

In MLI, a space voltage vector could be represented by more than one switching state which produces an output voltage with the same magnitude and phase angle. With the increase in the voltage levels, there exists more redundant switching state. It is desirable to find a general expression to describe the relationship between space vectors and their corresponding switching states for any cascaded H-bridge multilevel inverter. After the dwell time calculation for the active and zero vectors, a proper switching pattern should be chosen to obtain the gating pulses for all switches to achieve the desired phase voltages.

The anticipated technique reduces the computational complexity of the conventional SVPWM strategies due to the large number of space vectors and redundant switching states. This is achieved with a fast location of reference vector, a generalized dwell-time equation irrespective of the number of levels, and with the optimum determination and selection of switching states the voltage harmonic distortion is also minimized considerably.

Vector $V_1$ is selected for the time $T_1$, vector $V_2$ is selected for the time $T_2$, zero vector $V_0$ is selected for the time $T_0$ and $T_s$ is the switching time of the PWM control which is the total time spent at each vector. The switching time has to be fulfill the condition $T_S=T_1+T_2+T_0$. SVM is based on vector selection in the q-d stationary reference frame. The transitions between particular triangles have no unified rules and the control becomes complicated. To avoid the above drawback, the given steps are to be followed to obtain the switching sequence:

a) SVM method is to identify the three nearest vectors.
b) Determine the dwell time i.e., the amount of time that is spent at each vector.
c) Find the relationship between space vectors and their corresponding switching states.
d) The final step in the SVM method is to determine a switching sequence for the voltage vectors by switching state selection rule method.

The process is repeated alternatively when the reference vector moves along for the other triangles, identifying the three nearest vectors, calculating the switching times, and scheduling the switching sequence.

## SYSTEMS MODEL

Basically, Traditional Inverters( VSI's and CSI's) are used for intrefaces between local loads and microgrids. However impedance-source converter is developed for the same pupose and which undermine the limitations of VSI's and CSI's. These new coverter are widely used in the power

  

industry. These new converters has sevral applications over various advantages. The z-source inverters can step up/down the voltage easily and freely. Figure 8 illustrated a harvesting system built using Z-Source Inverter(ZSI).
This work focuses on reliable and efficient control strategies for a dual mode operation.

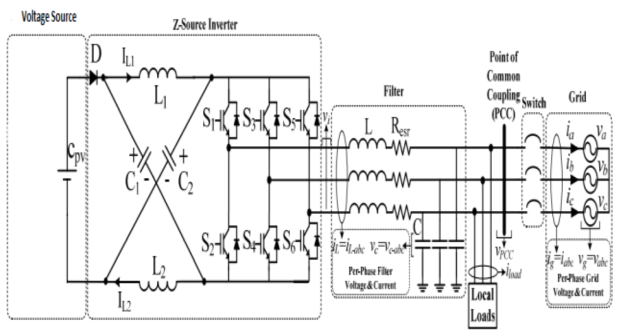


**Figure 8:** System model for SVPWM based Z – Source Inverter

## MODES OF OPERATION

The systems operations are divided into two mode: study state mode and transition mode. The study state has two mode grid connected and Island mode. The transition mode are transition from grid-connected mode to island mode and vice versa. The four modes of operation of the system is illustrated in figure 4. 2 in which state diagram is illustrated. A power factor correction method is used in grid connected mode using decoupled active and reactive power. In islanded mode the load voltage (required) is being regulated the controller. The voltage and current of the impedance network will be adjusted using ZSI gain for both the steady state. A grid-synchronization and phase adjustment algorithm is used to move from grid connected mode to islanded mode and vice – versa.

- **GRID-CONNECTED AND ISLANDED MODE**

In the grid-connected mode the controller for ZSI behaves like a current regulator and will inject the power to the grid. The controller's aim in this mode is decoupled active and reactive power control of elements of impedance network. The system anticipated can operate by adjusting power factor enabled by using decoupled power control. This can be set zero for unity, negative for leading and positive for the lagging power factor.

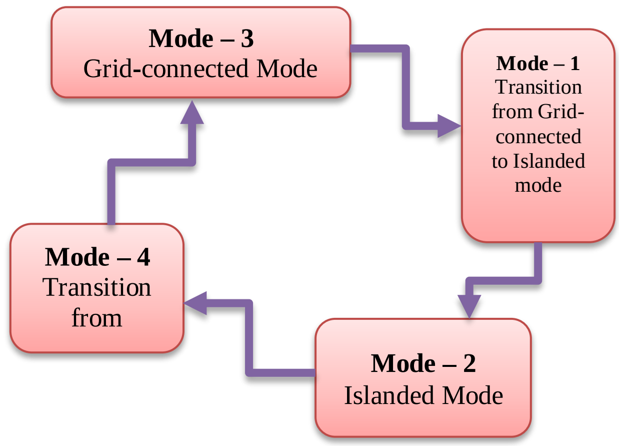


**Figure 9:** Modes of operation

- **TRANSITION MODES**

During the transition modes the grid synchronization and phase adjustment will be happened to ensure transition. The inputs for the grid synchronization are peak grid voltage ($V_g$) and α component of the grid voltage ($V_{g-\alpha}$). The grid synchronization starts by determining the estimated grid voltage phase $\phi_g$. Due to symmetric characteristics of the sinusoidal component of waveform, the phase angle $\phi_g$ can correspondence to two different magnitude over single cycle, so it is required to determine actual phase angle. The zonal detection approach can be used for detecting actual phase angle correspond to voltage. A LUT (Look up Table) with saved values of a sine function will be used four deferent zones are identified over the cycle in order to get the appropriate point in the LUT with the right phase angle information of the grid voltage.
Grid synchronization is required for transition modes. In transition from islanded to grid-connected mode, a phase adjustment will be required after grid voltage is triggered. The phase adjustment algorithms evaluates the phase angle difference between the local load and the grid, if their difference is negligible (smaller than predefined ε), then the phase angle information. If the phase difference is bigger than ε, then a unit increment and decrement in the frequency

  

approach is done to adjust the phase difference for transition from islanded to grid-connected mode.

## RESULTS

In this chapter, the Z-source inverter using SVPWM techniques has been conceded and the results on load currents, load voltage and harmonics spectra have been discussed in both the mode. Main requirements and parameters of simulation circuit are as follows as shown in table1

**Table 1 Simulation Parameters**

| **S. No.** | **Name of Parameter** | **Value** |
|---|---|---|
| 1 | Capacitor C1 | 1000µF |
| 2 | Capacitor C2 | 1000µF |
| 3 | Inductor L1 | 0.7mH |
| 4 | Inductor L2 | 0.7mH |

To verify the theoretical analysis and confirm the proposed technique of Z-source inverter, simulation and experiments have been conducted with the configuration discussed. The parameters for both simulation and experiments are given. Simulations have been performed to prove the capabilities of proposed SVPWM model predictive control of dual-mode operations Z-Source multi inverter islanded and grid-connected algorithms and comparison of them for previous work table 1 shows the parameters and comparative analysis of work done over previous work. The whole SVPWM control system has main subsystems as:

1. Three-phase sinusoidal signal generator,
2. Reference angle sector,
3. Duration time calculation block,
4. Space Vector Modulation signal generator.

The SVPWM control system model is used to generate the SVPWM control signal for inverter and verify the output results are shown. SVPWM control method is be used in the Z-source network inverter the system parameters are listed in Table 1.

The transitions from grid-connected mode stator current and source voltage are firstly examined and shown in Fig. 10. Waveforms for this transition are shown in the MATLAB scope screen shots in Fig.

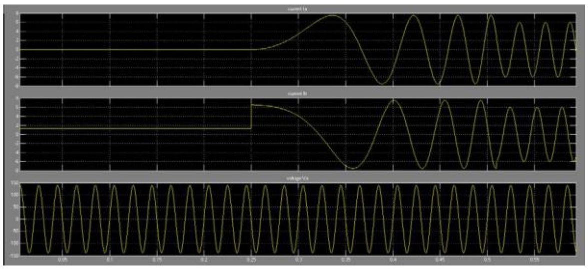

**Figure 10:** Stator Current and Source Voltage in Grid Connected Mode.

Grid connected mode PCC and source voltages scope waveform screen is shown in Fig. 11 the execution of the proposed controller is assessed by investigating critical legitimacy criteria: consistent progress between grid-associated mode and islanded mode, consistent change between grid-associated mode with mode PCC and source voltages is appeared in figure. Fast dynamic response of active and reactive power due to change in level or change in reactive power required by the grid at PCC.

Scope waveform of PCC and Source Voltages in Islanded Mode is shown in Fig. 12. A grid is framed by adjusted energy generators associated with a point of common coupling (PCC) that feeds nearby loads and can work alone or associated with the mains. Islanding is where the DG stays working in the distribution system with the utility disconnected

.

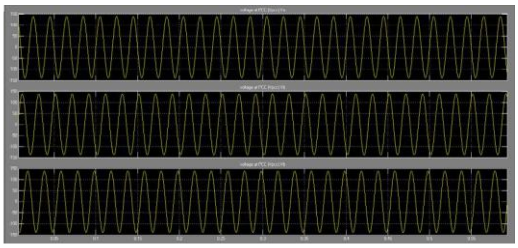

**Figure: 11** PCC and Source Voltages in Grid Connected Mode

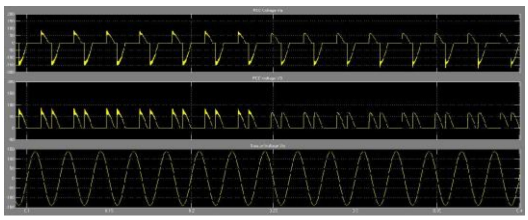

**Figure: 12** PCC and Source Voltages in Islanded Mode.

  

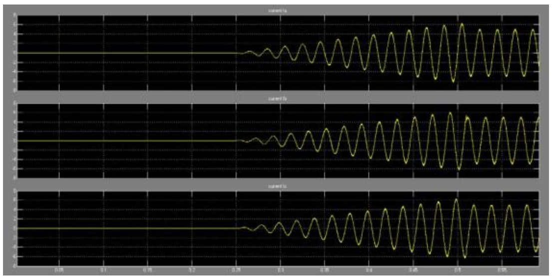

**Figure: 13** Grid Input Currents in Grid Mode.

Grid Input Currents scope waveform screen in grid mode is shown in Fig. 13 three individual waveforms represents three phases of input currents.

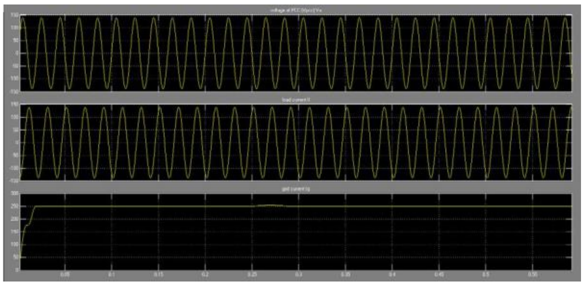

**Figure 14** Source Voltage, Source Current and Grid DC Voltage in Grid Mode.

A source voltage, source current and grid DC voltage in grid mode scope waveform has shown in Fig. 14. In order to demonstrate the flexibility and reliability of the proposed controller the local loads in islanded mode are assumed to operate. These case studies demonstrate the capability of the proposed system to seamlessly transfer to islanded mode while the local load frequency is different than the grid frequency.

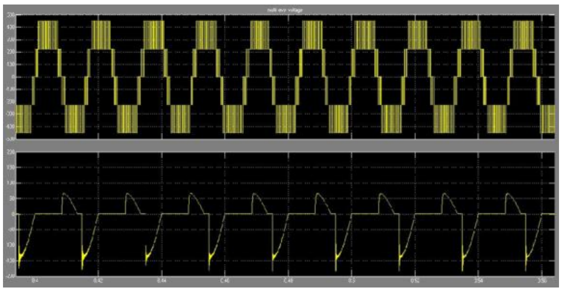

**Figure: 15** Multi-Level Voltage and Stator Current in Islanded Mode.

The generator generates output pulses Fig. 5.8 shows multi-level voltage and stator current in grid connected mode. those pulses generated are to drive the devices in to ON for a multilevel level inverter of the proposed topology a multi-level voltage and stator current in islanded mode is shown in Fig. 15

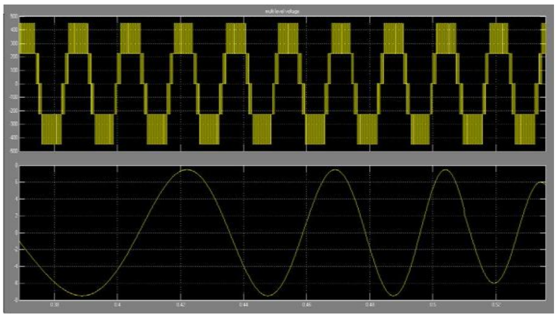

**Figure: 16** Multi-Level Voltage and Stator Current in Grid Connected Mode.

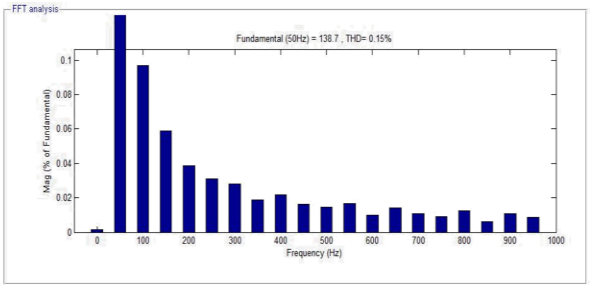


**Figure 17:** Total Harmonic Distortions in the systems

Fig.16 the output currents are controlled independently by the proposed controller and the circulating current flows through the inverter. Although there is a three-phase, inverter can supply the loads with low (0.15%) of total harmonic distortion (THD), as shown in Fig. 17.

The comparative analysis of harmonic performance of proposed work with existing work is shown in Table 2. Where THD of proposed work has been compared with existing work significant improvement in THD are visible.

## REFRENCES

[1] B. K. Bose, "Modern Power Electronics and AC Drives". Upper Saddle River, NJ: Prentice-Hall PTR, 2002.

[2] Muhammad H. Rashid, "Power Electronics Handbook", by Academic Press 2001.

[3] Meysam Saeedian, Jafar Adabi & Seyyed Mehdi Hosseini 2017, 'Cascaded Multilevel Inverter based on Symmetric–Asymmetric DC Sources with reduced number of components', IET Power

  

Electronics, vol.10, no 12, pp. 1468 – 1478.

[4] Y. Yang, F. Blaabjerg, H. Wang and M. G. Simões, "Power control flexibilities for grid-connected multi-functional photovoltaic inverters," in IET Renewable Power Generation, vol. 10, no. 4, pp. 504-513, 4 2016.

[5] S. Sajadian and R. Ahmadi, "Model predictive control of dual-mode operations Z-source inverter: Islanded and grid-connected," 2017 IEEE Energy Conversion Congress and Exposition (ECCE), Cincinnati, OH, 2017, pp. 4971-4977.

[6] J. M. Bloemink and M. R. Iravani, "Control of a Multiple Source Microgrid With Built-in Islanding Detection and Current Limiting," in IEEE Transactions on Power Delivery, vol. 27, no. 4, pp. 2122-2132, Oct. 2012.

[7] Fang Zheng Peng, Miaosen Shen, Alan Joseph, L. M. Tolbert, D. J. Adams, “Maximum Constant Boost Control of the Z- Source Inverter”, In proc. IEEE IAS’04, 2004.

[8] Fang Zheng Peng; Miaosen Shen; Zhaoming Qian, “Maximum Boost Control of the Z-source Inverter”, IEEE transactions on Power Electronics, Vol.20, No 4. July 2005.

[9] Fang Zheng Peng and Y. Huang, “Z-Source Inverter for Power Conditioning and Utility Interface of Renewable Energy Sources”, IEEE explorer 2008.

[10] Babak Nia Roodsari & Edwin P Nowicki 2013, ‘Fast space vector modulation algorithm for multilevel inverters and its extension for operation of the cascaded H-bridge inverter with non-constant DC sources’, IET Power Electronics, vol. 6, no.7, pp.1288 - 1298.

  