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Space Vector and Sinusoidal Pulse Width Modulation of Quasi Z-Source Inverter for Photovoltaic System

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ABSTRACT

This paper compares the execution of Sinusoidal Pulse width Modulation (SPWM) and Space Vector Pulse Width Modulation (SVM) methods for a Quasi Z-source inverter (QZSI) is an another topology got from the standard Z-source inverter (ZSI). The QZSI gets each one of the upsides of the ZSI, which can comprehend buck/boost, inversion and power forming in a singular stage with upgraded trustworthiness. In like manner, the proposed QZSI has the novel purposes of enthusiasm of lower part evaluations and unfaltering dc current from the source. The QZSI highlights a broad assortment of voltage expansion which is reasonable for applications in photovoltaic (PV), as a result of the way that the PV cells yield contrasts comprehensively with temperature and daylight based enlightenment. The working qualities of the proposed course of action is analyzed in inconspicuous component and appeared differently in relation to that of the SPWM and SVM. Speculative examination of voltage help and direction methods for the QZSI in PV is explored in this paper. Amusement of the circuit setup for the previously stated equalization procedures have been taken a gander at in MATLAB/Simulation. Besides, the THD examination of both SPVM and SVM is compared.

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1. INTRODUCTION

Renewable energy is generally defined as energy that is collected from resources which are naturally replenished on a human timescale, such as sunlight, wind, rain, tides, waves, and geothermal heat.The Photovoltaic (PV) power generation structure is occupying an important role in the advancement of distributed electric power systems and Micro grids. Also fuel cell system can always produce electric power regardless of climate conditions as long as hydrogen and oxygen are supplied. A fuel cell is an electrochemical device, which converts chemical energy directly to electric energy. The power converter converts a low voltage DC from the fuel cell to high voltage DC or AC. Fuel cell is a DC power source of safe, clean and efficient electric power generation. In [1] presented a model of the utilization of photovoltaic vitality as a distinct option for create power has gets to be noteworthy in the late years exam. In [2], [3] presented a PV inverter is generally used to change over the photovoltaic vitality into usable electrical vitality and reliability. Inverter assumes a critical part in everyday life. There is an extensive interest for power which expands the requirement for inverter discussed in [4]. At first, there are two sorts of inverters-current source inverter (CSI) and voltage source inverter (VSI). In this current inverter the voltage increase is less and more segments are required for boosting of less voltage. This can be overcome by utilizing semi z-source inverter. Both voltage and current can be made stable utilizing semi Z-source inverter which is discussed in [5]. This proposed Quasi Z-source inverter comprises additionally boosting of voltage and high effectiveness.

The proposed framework includes the single stage change system. Both boosting up of voltage and transformation of dc happens in a solitary stage discussed in [6], [7].

2. QUASI Z –SOURCE INVERTER

The Quasi Z-Source inverter is a singular stage power inverter got from the Z source inverter topology, using an impedance framework. In [8] discussed the impedance framework couples the source and the inverter to perform voltage backing and inversion in single stage. The inverter draws a steady current from the PV display and is prepared for dealing with a wide information voltage range examined in [9]. It moreover incorporates bring down part assessments, diminishing changing swells to the PV sheets, cause less EMI issues and decreased source stress appeared differently in relation to the ZSI talked about in [10], [11]. The Figure 1 demonstrates the fundamental topology of QZSI comprises of a split-inductor L1 and L2 and electrolytic capacitors C1 and C2 associated is utilized to give an impedance source. The inductance L1 and L2 can be given through a split inductor or two separate inductors.

To explain the operating principle of the quasi Z-source inverter in the equivalent circuit model of the quasi Z-source inverter is shown in Figure 2. It operates in two modes, they are:

1. Shoot through mode
2. Non-Shoot through mode

In Non-Shoot through mode it acts as a traditional Voltage Source Inverter (VSI). Shoot through mode plays an important role. In shoot through mode, two MOSFET switches are turned on in the same leg.

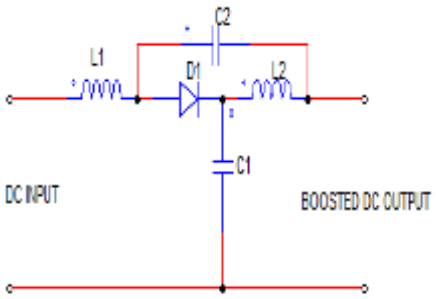

Figure 1. Quasi Z –Source Inverter

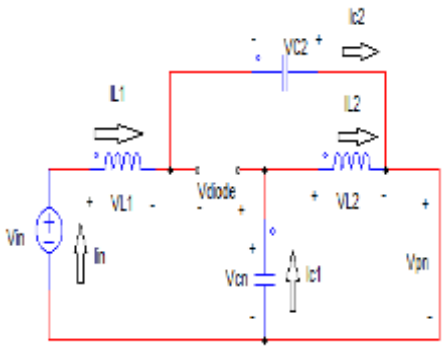

Figure 2. Shoot through Equivalent Circuit

2.1. Mode I

In the shoot through mode, switches of the same stage in the inverter scaffold are exchanged on at the same time for a brief span. The source however does not get short circuited when endeavored to do as such due to the nearness LC system, while boosting the yield voltage. The DC join voltage amid the shoot through states, is helped by a support variable, whose quality relies on upon the shoot through obligation proportion for a given balance record. Accepting that amid one exchanging cycle, T, the interim of the shoot

through state is T0; the interim of non-shoot-through states is T1; consequently one has T=T0 +T1 and the shoot-through obligation proportion, D=T0/T1.

2.2. Mode II

In the non shoot through mode, the switching pattern for the QZSI is similar to that of VSI. The inverter bridge, viewed from the DC side is equivalent to a current source the available at the DC link voltage input to the inverter, which makes the QZSI behave similar to a VSI.
Assume that,

$$T_Z=T_a + T_b \text{ (Switching period)} \quad (1)$$

T_a-Total duration of shoot through zero vectors.
T_b-Total duration of non-shoot through switching vectors.
V_{in} is the output voltage of fuel cell

Under steady state condition, the average voltage of inductor under one switching frequency is zero. In the non-shoot through mode, the switching pattern for the QZSI is similar to that of a VSI. The inverter bridge, viewed from the DC side is equivalent to a current source, the input dc voltage is available as DC link voltage input to the inverter shown in Figure 3, which makes the QZSI behave similar to a VSI.

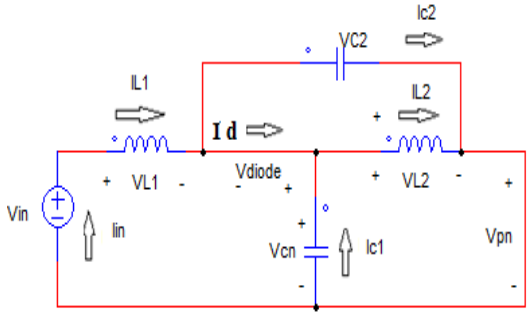

Figure 3. Non-Shoot through Equivalent Circuit

Thus QZSI acquires all the upsides of the ZSI. It can buck or support a voltage with a given help variable. It can deal with a shoot through state and in this way it is more solid than the customary VSI. It is pointless to include a dead band into control plans, which decreases the yield bending. Moreover, there are some one of a kind benefits of the QZSI when contrasted with the ZSI.

3. SINUSOIDAL PULSE WIDTH MODULATION

Sinusoidal pulse width modulation is a system for controlling a voltage as a piece of inverters. In this arrangement, the switches in the two legs of the full-associate inverter are not traded in the meantime, as in the bi-polar arrangement. The QZSI layout has six component vectors when the DC voltage is awed over the heap and two zero vectors when the heap terminals are shorted through either lower or upper three switches talked about in [12]. These aggregate eight exchanging states and their blends have been made different PWM control organizes. Sinusoidal PWM is the most for the most part utilized PWM approach as a part of the VSI. Then again, QZSI has extra zero vectors or shoot through exchanging communicates that are unimaginable in standard VSI. For a yield voltage be gotten, a shoot through state ought to dependably be trailed by component state. Three phase inverter must be controlled so that at no time both the switches in the same leg are turned on or else the DC supply would be shorted. This crucial might be met by the complimentary operations of the switches inside a leg. In this unipolar arrangement the legs An and B of the full-interface inverter are controlled freely by differentiating transporter triangular wave vcar and control sinusoidal sign vc and -vc independently. This SPWM is generally used as a piece of cutting edge applications. The amount of heartbeats per half-cycle depends on the extent of the repeat of conveyor sign (fc) to the adjusting sinusoidal sign. The repeat of control sign or the adjusting signal sets the inverter yield repeat (fo) and the top enormity of control sign controls the direction list mother which hence controls the

rms yield voltage. The locale of each pulse relates around to the reach under the sine wave between the abutting midpoints of off periods on the gating signals.

4. SPACE VECTOR MODULATION

Space vector equalization (SVM) was at first made as vector approach to manage pulse with modification for three phase inverter. In [13] presenteda best technique for creating sine wave that gives a higher voltage furthermore minimizes the music. In [14] presented SVM system is a moved figuring heightened PWM methodology and possibly the best methodologies for variable repeat drive. The circuit model of a normal three phase voltage source inverter is showed up in Figure 4. M1 to M6 are the six power switches that shape the yield, which are controlled by the trading variables A^+, A^-, B^+, B^-, C^+ and C^-. The switches must be controlled so that at no time are both switches in the same leg turned on or else the DC supply would be shorted. This key might be met by the fundamental operation of the switches inside a leg. i.e. in the event that A^+ is on then A^- is off and the an alternate way. This prompts eight conceivable exchanging vectors for the inverter, V0 through V7 with six component exchanging vectors and two zero vectors. Note that looking down the fragments for the component exchanging vectors V1-6, the yield voltages shift as a beat sinusoid, with every leg balance by 120 degrees of stage edge.To execute space vector change, a reference signal Vref is tried with a repeat fs (Ts=1/fs). The reference sign may be created from three separate stage references using the αβγ change. The reference vector is then consolidated using a mix of the two connecting dynamic trading vectors and either of the zero vectors. Distinctive procedures of selecting the solicitation of the vectors and which zero vector(s) to use exist. Procedure determination will influence the symphonious substance and the exchanging misfortunes

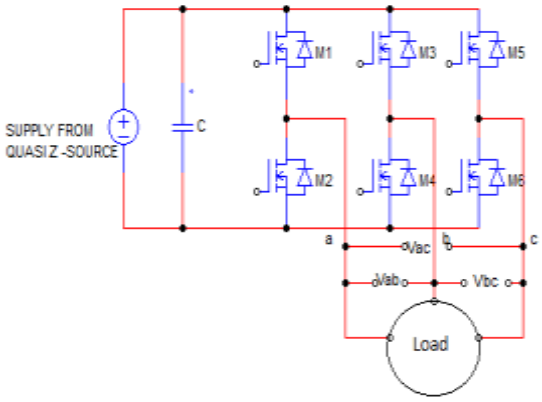

Figure 4. Three Phase Inverter

Space vector PWM strategy is leverage as a result of expanded adaptability in the decision of exchanging vector for both info current and yield voltage control. The eight changing vectors, output line to nuetural voltage and yield line to line voltages as far as DC-linkVdc are given in Table 1.

Table 1. Switching vectors, Phase Voltages and Output Line Voltages

Voltage Vectors	Switching Vectors			Line to neutral voltages			Line to line voltages		
	A	B	C	V_{an}	V_{bn}	V_{cn}	V_{ab}	V_{bc}	V_{ca}
V_0	0	0	0	0	0	0	0	0	0
V_1	1	0	0	2/3	-1/3	-1/3	1	0	-1
V_2	1	1	0	1/3	1/3	-2/3	0	1	-1
V_3	0	1	0	-1/3	2/3	-1/3	-1	1	0
V_4	0	1	1	-2/3	1/3	1/3	-1	0	1
V_5	0	0	1	-1/3	-1/3	2/3	0	-1	1
V_6	1	0	1	1/3	-2/3	1/3	1	-1	0
V_7	1	1	1	0	0	0	0	0	0

In [15] Space Vector PWM implies a novel trading gathering of the three organized inverter's vitality transistors. This methodology has been known not less consonant twisting in the yield voltages and gives more capable usage of the supply voltage in examination with direct sinusoidal alteration technique. Eight trading vectors are obtained with the help of each leg's trading states –Vx(Sa, Sb, Sc). The Figure 5 demonstrates the Vectors V1 to V6 are called dynamic vectors since they make voltages at the VSI's yield. V0 and V7 are unmoving vectors or zero vectors, they don't deliver yield voltages yet they are used as a part of the strategy. Because of these 8 vectors dislodged at 60 degree as appeared in Figure 6.

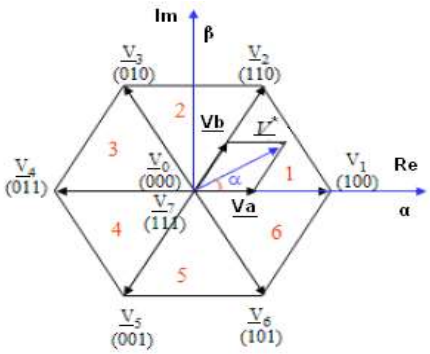

Figure 5. Space Vector Modulation

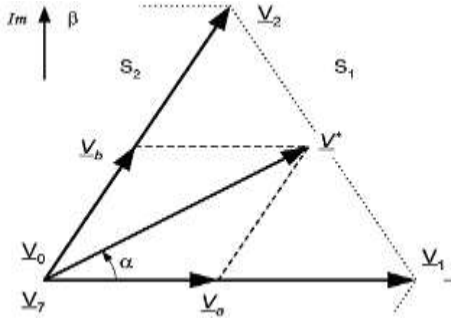

Figure 6. Space Vector Modulation principle

The V* (called the reference vector) vector rotates counter clockwise with the angle α varying between 0 and 360 degrees. At each moment

$$\underline{V}^{*} = V_a + V_b \tag{2}$$

At the point when the motor is begun the size of V* is V start. As the supply voltage is raised, the greatness of the vector will develop in this way portraying a winding. Duty cycles for each sector are discussed in Table 1. The duty cycles for each phase are determines:

$$D_x = \frac{1}{T_s}\int_0^{Ts} S_x dt, \qquad x = a, b, c \tag{3}$$

Ts = the period Sx = switch state of leg x
Duty cycles for each sector are mentioned in Table 2:

Table 2. Duty cycles

Sector S_1	$D_1=\mu_\alpha-\mu_\beta$	$D_2=2\mu_\beta$	$D_0+D_7=1-D_1-D_2$
Sector S2	$D_2=\mu_\alpha+\mu_\beta$	$D_3=\mu_\beta-\mu_\alpha$	$D_0+D_7=1-D_3-D_2$
Sector S3	$D_3=2\mu_\beta$	$D_4=\mu_\alpha-\mu_\beta$	$D_0+D_7=1-D_3-D_4$
Sector S4	$D_4=\mu_\beta-\mu_\alpha$	$D_5=-2\mu_\beta$	$D_0+D_7=1-D_4-D_5$
Sector S5	$D_5=\mu_\alpha-\mu_\beta$	$D_6=\mu_\alpha-\mu_\beta$	$D_0+D_7=1-D_5-D_6$
Sector S6	$D_6=-2\mu_\beta$	$D_1=\mu_\alpha+\mu_\beta$	$D_0+D_7=1-D_1-D_6$

5. RESULTS & DISCUSSION

The examination results for the QZSI yield voltage of SPVM and SVM are appeared in Figure 9 and Figure 13. Yield voltage of PV board is a low voltage DC, which is given to the inverter through a Quasi Z source system. Inverter supports this voltage by shoot-through-mode and believers the DC voltage into AC voltageThis transformation is finished with the assistance of the inverter in view of both SVM and SPWM method. The general scaffold inverter changing over the DC to AC three stage voltage by utilizing both space vector adjustment and sinusoidal heartbeat width balance. This circuit takes the reference voltage from the three stage inverter yield. The Quasi Z-source inductor and capacitors are go about as a channel and they

create thunderous to the switches. Yield voltage got three stage AC which is given to the lattice or to the heap. Acquiring AC contains swells which are sifted by LC channel. The sub arrangement of SVM system is appeared in Figure 12. The Figure 7 and Figure 10 are recreated by utilizing SIMULINK programming. The correlation after effects of FFT examination are appeared in Figure 8 and Figure 11. Finaly, the aggregate consonant mutilation of SPWM and SVM is thought about in Table 3. Finaly, the total harmonic distortion of SPWM and SVM is compared in Table 3.

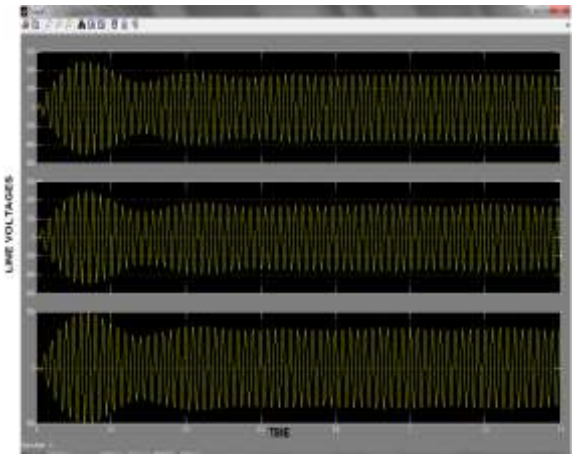

Figure 7. Output waveform of Quasi Z source Inverter for SPWM Technique

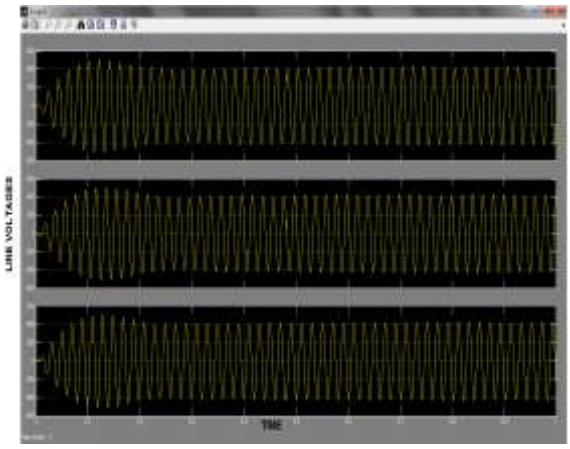

Figure 8. Output waveform of Quasi Z source Inverter for SVM Technique

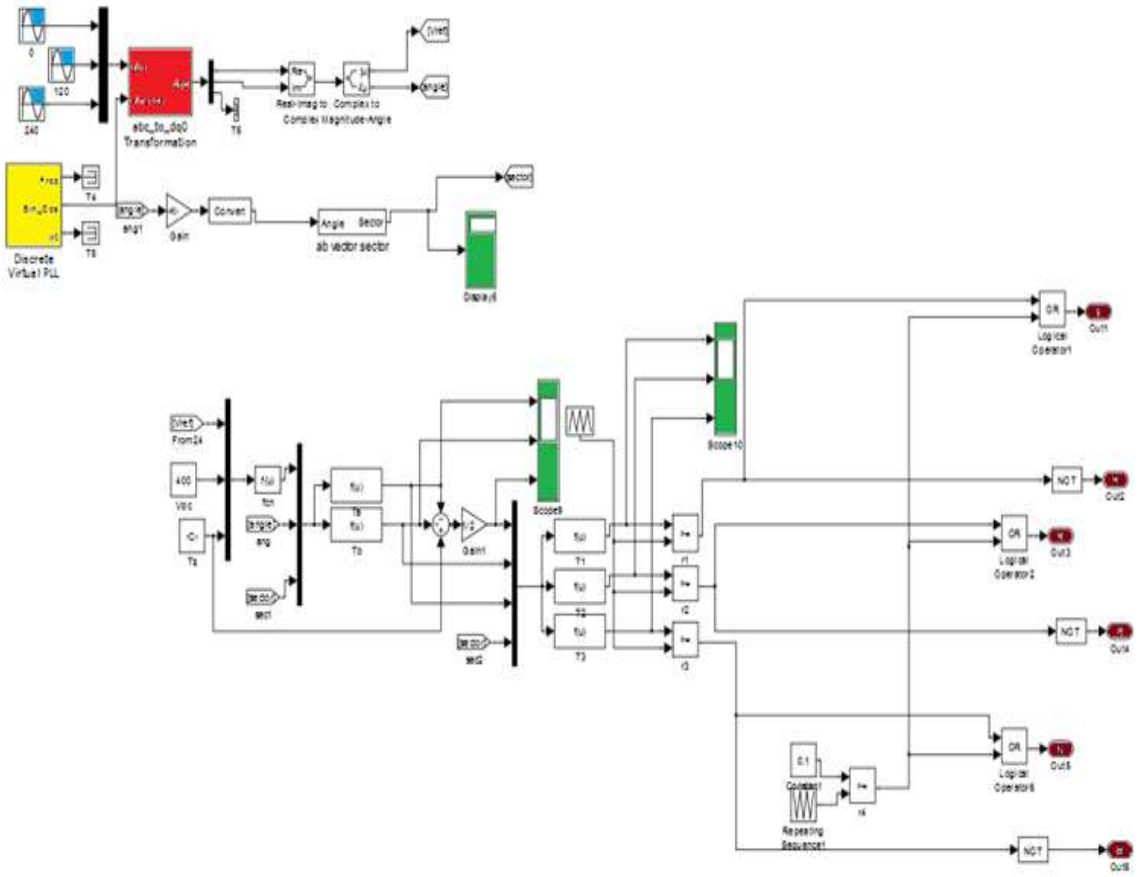

Figure 9. Sub system of SVM

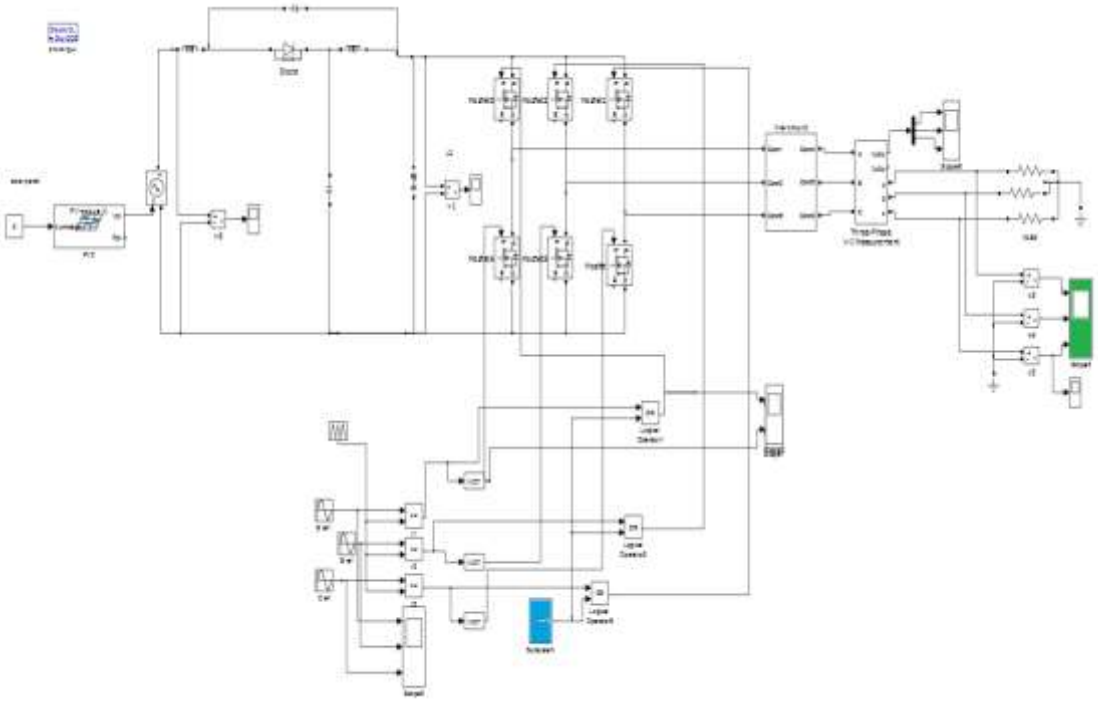

Figure 10. Quasi Z Source Inverter using SPWM

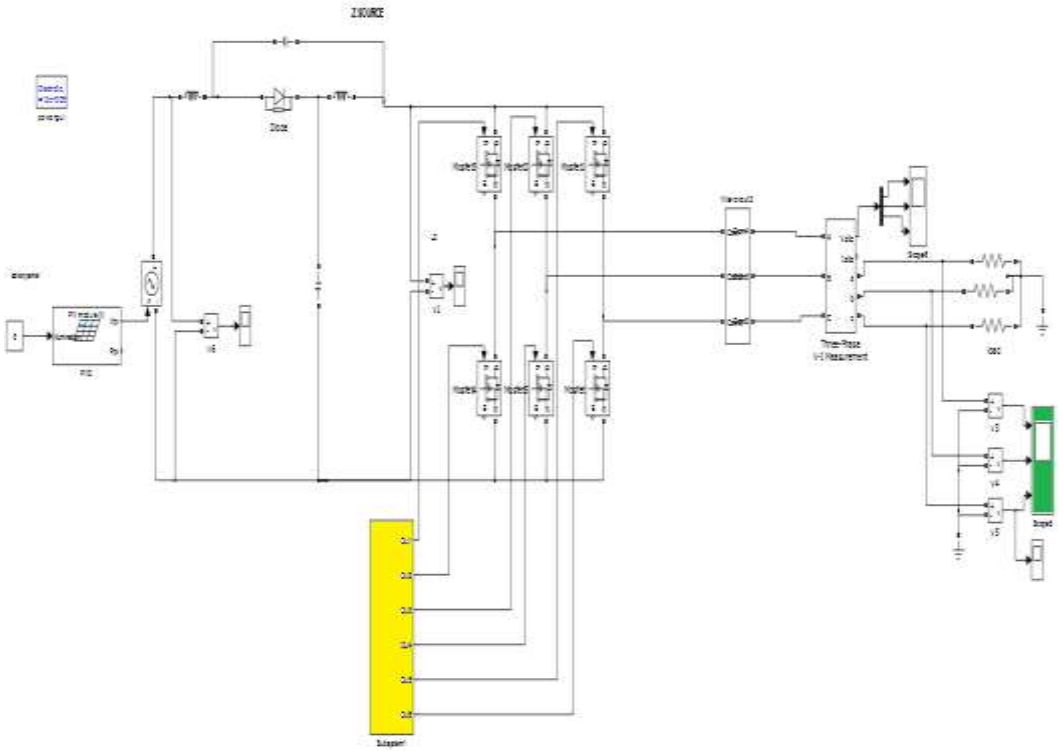

Figure 11. Quasi Z-Source Inverter using SVM

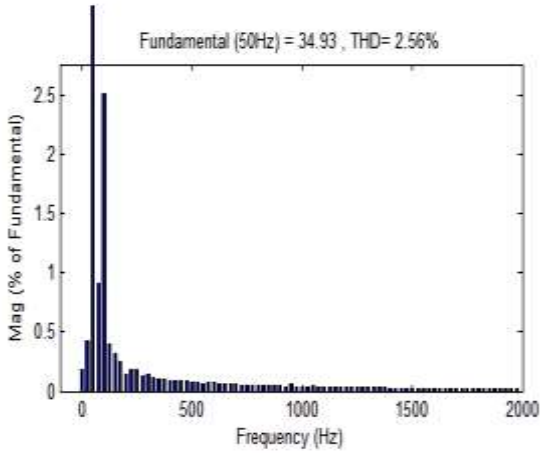

Figure 12. FFT Analysis of SPWM

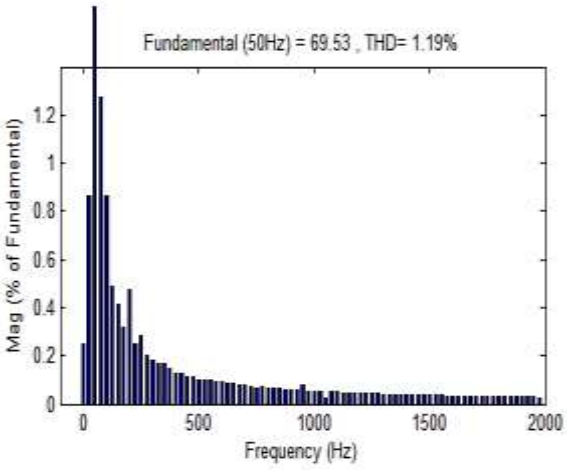

Figure 13. FFT Analysis of SVM

Table 3. Comparison of Modulation

Modulation	THD
SPWM	2.56%
SVM	1.19%

6. CONCLUSION

This paper compared at the execution of Quasi Z source inverter by using SPWM and SWM system. The total consonant mutilation in the yield voltage is seen to be diminished using Space vector modulation framework. The theoretical examination, multiplication results presented in this work clearly display the proposed QZSI inverter with SVM strategy The QZSI is prepared for dealing with broad assortment of data voltage changes. It gives the enhanced single stage power change topology and higher steadfastness. QZSI is most proper interface for sun based photovoltaic structure and could end up being exceptionally viable, when executed with the improved control frameworks proposed.

REFERENCES

[1] Sobhan Dorahaki. New Methods for Reducing the Problems of Photovoltaic Systems. *TELKOMNIKA Indonesian Journal of Electrical Engineering*. 2015; 16(1): 13-18
[2] Ge Baoming, Peng Fang Zheng, Abu-Rub Haitham. Novel Energy Stored Single-Stage Photovoltaic Power System with Constant DC-Link Peak Voltage. *IEEE Transactions on Sustainable Energy*. 2014; 5(1): 28-35.
[3] Ge Baoming, Abu-Rub Haitham. An Energy Stored Quasi-Z-Source Inverter for Applications to Photovoltaic Power System. *IEEE Transactions on Industrial Electronics*. 2013; 60(10): 4468-81.
[4] Hamid Reza Mohammadi, Ali Akhavan. "A New Control Method for GridConnected PV System Based on QuasiZSource Cascaded Multilevel Inverter Using Evolutionary Algorithm". *International Journal of Power Electronics and Drive Systems*. 2015; 6(1): 109-120
[5] Cao Dong, Jiang Shuai and Peng Fang Zheng. Low-Cost Semi-Z-source Inverter for Single-Phase Photovoltaic Systems. *IEEE Transactions on Power Electronics*. 2011; 26(12): 3431-32
[6] Vinnikov Dmitri. Quasi-Z-Source-Based Isolated DC/DC Converters for Distributed Power Generation. *IEEE Trans-actions on Industrial Electronics*. 2011; 58(1):192-201.
[7] Shuitao Yang, Fang Z Peng. Current-Fed Quasi-Z-Source Inverter with Voltage Buck–Boost and Regeneration Ca-pability. *IEEE Transactions on Industry Applications*. 2011; 47(2): 882-92.
[8] Nguyen Minh-Khai, Lim Young-Cheol and Cho Ge-um-Bae. Switched-Inductor Quasi-Z-Source inverter. *IEEE Transactions on Power Electronics*. 2011; 26(11): 3183-91.
[9] Abu-Rub Haitham. Quasi-Z-Source Inverter-Based Photo-voltaic Generation System with Maximum Power Tracking Control Using ANFIS. *IEEE Transactions on Sustainable Energy*. 2013; 4(1): 11-20.
[10] Li Yuan, Jiang Shuai, Jorge G Cintron-Rivera. Modeling and Control of Quasi-Z-Source Inverter for Distributed Generation Applications. *IEEE Transactions on Industrial Electronics*. 2013; 60(4): 1532-41.
[11] Jianfeng Liu, Jiang Shuai, Cao Dong. A Digital Current Control of Quasi-Z-Source Inverter with Battery. *IEEE Transactions on Industrial Informatics*. 2013; 9(2): 928-37.
[12] Lei Qin, Cao Dong and Peng Fang Zheng. Novel Loss and Harmonic Minimized Vector Modulation for Current-Fed

Quasi-Z-Source Inverter in HEV Motor Drive Application. *IEEE Transactions on Power Electronics*. 2014; 29(3): 1344-57.
[13] Effah Francis Boafo, Wheeler Patrick, Clare Jon. Space-Vec-tor-Modulated Three-Level Inverters with a Single Z-Source Network. *IEEE Transactions on Power Electronics*. 2013; 28(6): 2806-15.
[14] Mahmoud Zadehbagheri, Amin Payedar. "The Feasibility Study of Using Space Vector ModulationInverters in TwoLevel of Integrated Photovoltaic System". *TELKOMNIKA Indonesian Journal ofElectrical Engineering*. 2015; 14(2): 205-214.
[15] Babita Nanda Total Harmonic Distortion of Dodecagonal Space Vector Modulation, *International Journal of Power Electronics and Drive Systems*. 2014; 4(3): 308-313.