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Design and Implementation of Seven-level Energy Stored Quasi Z-Source Cascaded Multilevel Inverter For PV systems Using Fuzzy logic controller

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***Abstract*: -- This Paper represents PV based seven-level Quasi Zsource inverter (QZSI). PV is mathematically modelled along with maximum power point tracking (MPPT).The quasi-Z-source cascade multilevel inverter (qZS-CMI) presents many advantages over conventional CMI when applied in photovoltaic (PV) power systems. For example, the qZS-CMI provides the balanced dc-link voltage and voltage boost ability, saves one-third modules, etc. However, the qZS-CMI still cannot overcome the intermittent and stochastic fluctuation of solar power injected into the grid. This paper proposes an energy stored qZS-CMI-based PV power generation system. The system combines the qZS-CMI and energy storage by adding an energy stored battery in each module to balance the stochastic fluctuations of PV power. This paper also proposes a control scheme using Fuzzy logic for the energy stored qZS-CMI-based PV system. The proposed system can achieve the distributed maximum power point track for PV panels, balance the power between different modules, and provide the desired power to the grid. The method of controller parameters is disclosed, Simulations of the circuit have been executed in MATLAB/Simulink and the results were verified using the fuzzy logic controller.**

***Keywords* — Quasi-Z source inverter (QZSI), Maximum Power Point Tracking (MPPT), Cascade Multilevel Inverter (CMI), energy storage, photovoltaic (PV) power generation.**

I. INTRODUCTION

Due to increasing scarcity of the conventional energy resources, there is an alarm for finding out the renewable energy resources all over the world. One such important renewable source is solar energy. Several researches are going on to improvise the trapping of solar energy. Here, the proposed topology uses PV source for each of the bridges in the seven-level cascaded QZSI. Under continuously varying insulation and temperature, it becomes essential to track the highest power point of the PV. So, Perturb and Observe algorithm is used to find out the maximum power point tracking of the PV source as it is the simplest of all MPPT algorithms and easily implementable with the requirement of measuring only a few parameters. H-Bridge seven-level inverter with Quasi-impedance network is considered here to obtain both inversion and boost capability in a single stage. The QZSI is the sub topology and has all the advantages of Z-source inverter. In addition to that, it has continuous input current characteristic which makes it more suitable for the PV applications. Due to the capability of bearing the shoot through due to impedance network, this five level QZSI can produce boosted output voltage with reduced THD. Several modulation strategies are available for generation of shoot through states. For the proposed topology, maximum constant boost control technique is used as it has constant shoot through duty ratio. The details are provided in the upcoming section NOWADAYS, applying multilevel inverters to photovoltaic (PV) power systems is gaining more attention. Among the typical multilevel inverter topologies, the cascade multilevel inverter (CMI) is more widely used due to its attractive features, such as achieving the distributed maximum power point tracking (MPPT) and high voltage/high power grid tie without a transformer. However, each module is a buck inverter in the conventional CMI-based PV power system, and each module's PV voltage variation will cause the whole system's dc-link voltages to be imbalanced. Considering the unique features of the Z-source inverter (ZSI) and quasi-Z source inverter (qZSI), i.e., implementing voltage boost/buck and inversion in a single stage the Z-source/quasi-Z-source cascade multilevel inverter (ZS/qZS-CMI)-based PV power systems have been proposed in to overcome the aforementioned disadvantages of the conventional CMI-based PV system. The conclusion was that the qZS-CMI PV system saved one-third of the modules than the traditional CMI-based PV system. In addition, solar power presents intermittent and stochastic characteristics, so energy storage is added in the PV systems to obtain smooth power. Energy stored qZSI was proposed for PV system application in to achieve the same

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purpose in the simple way, where the focus was mainly on three phase two-level energy stored qZSI-based PV power generation systems, and they presented system modeling, control schemes, and controller design for the three-phase two-level system. The literature of the three-phase two-level energy stored qZSI and the qZS-CMI provides effective references for the energy stored qZS-CMI-based PV system, For example, the three-phase two-level energy stored qZSI only has one.

inverter with one energy storage, while the energy stored qZS-CMI needs to manage the operation of several modules and consists of many inverter modules with many energy storages; the qZS-CMI did not have an energy storage, which achieved the balanced dc-link voltages and resulted in all PV powers being injected into the grid even with fluctuation. The energy stored qZS-CMI can have balanced and smooth power injected into the grid, where each module's energy storage will absorb redundant PV power and/or supply absent power to the grid. Therefore, the energy stored qZS-CMI requires different control methods from those existing in the three-phase two-level energy stored qZSI and qZS-CMI.

II. PV BASED QUASI Z SOURCE INVERTER

Fig. 1 shows the PV based seven-level cascaded H-bridge QZSI. It consists of PV sources and impedance networks separately in each of the H-bridges. The QZSI extends several advantages over the ZSI such as continuous current from the input DC source, cut down component ratings, and enhanced reliability.

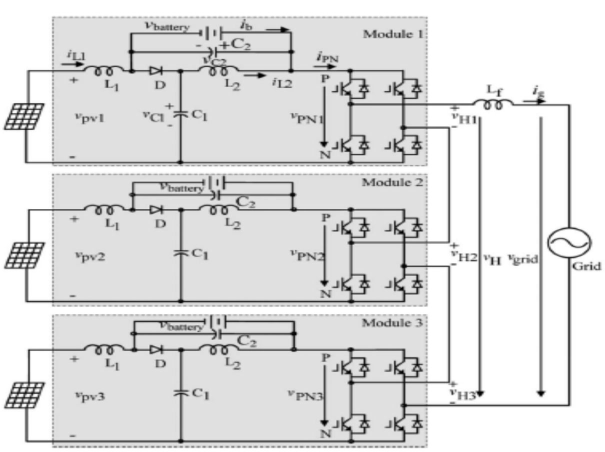

Fig. 1. PV based seven level QUASI-Z-SOURCE Inverter

This paper proposes an energy stored qZS-CMI applied in a PV power system. With the proposed control scheme, the energy stored qZS-CMI-based PV system can achieve the distributed MPPT for all PV panels; moreover, it can provide the desired power to the grid with the balanced module power. A seven level cascaded converter consists of three DC sources and three full bridge converters. Minimum harmonic distortion can be obtained by controlling the conduction angles at different converter levels. By switching the MOSFETS at the appropriate firing angles, we can obtain the seven level output voltage. MOSFET is preferred because of its fast switching nature. The switching angles can be chosen in such a way that the total harmonic distortion is minimized [3]. One of the advantages of this type of Seven level inverter is that it needs less number of components comparative to the Diode clamped or the flying capacitor, so the price and the weight of the inverter is less than that of the two types. However, the elementary concept of a multilevel converter to achieve higher power is to use a series of power semiconductor switches with several lower voltage dc sources to perform the power conversion by synthesizing a staircase voltage waveform. Capacitors, batteries, and renewable energy voltage sources can be used as the multiple dc voltage sources. The commutation of the power switches aggregate these multiple dc sources in order to achieve high voltage at the output; however, the rated voltage of the power semiconductor switches depends only upon the rating of the dc voltage sources to which they are connected. Each single DC sources is associated with a single Hbridge converter. The AC terminal voltages of different level converters are connected in series. Through different combinations of the four switches, S1-S4, each converter level can generate three different voltage outputs, +Vdc, -Vdc and zero. The AC outputs of different full-bridge converters in the same phase are connected in series such that the synthesized voltage waveform is the sum of the individual converter outputs. The number of output waveform is the sum of the individual converter Outputs. In this topology, the number of output-phase voltage levels is defined by

$$m=2N+1,$$

where N is the number of DC sources.

Topology of Proposed System

Quasi Z-Source Inverter:

The QZSI extends several advantages over the ZSI such as continuous current from the input DC source, cut down component ratings and enhanced reliability. Figure 2 shows the basic topology of QZSI.

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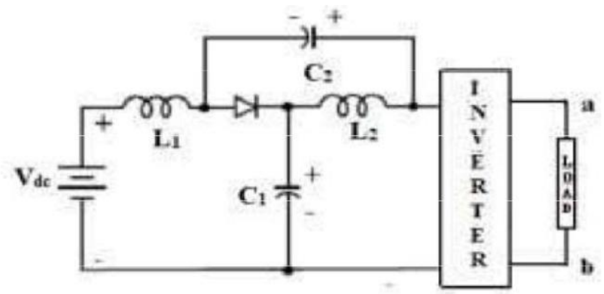

Fig2: Basic topology of QZSI

Modes of Operation and Circuit analysis:
The two modes of operation of a quasi z-source inverter are:

- Non-shoot through mode (active mode).
- Shoot through mode.

Active Mode: 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, which makes the QZSI behave similar to a VSI. During the interval of the non-shoot-through states, T1

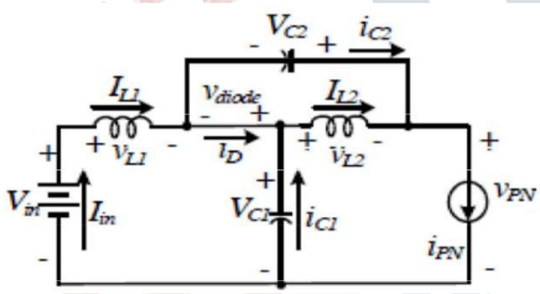

Fig3: Active mode of QZSI

VL1 = Vin – VC1,V L2 = -VC2

V_{PN} = 0,Vdiode= V_{C1} + V_{C2}

Shoot Through Mode:
In the shoot through mode, switches of the same phase in the inverter bridge are switched on simultaneously for a very short duration. The source however does not get short circuited when attempted to do so because of the presence LC network, while boosting the output voltage. The DC link voltage during the shoot through states, is boosted by a boost factor, whose value depends on the shoot through duty ratio for a given modulation index.

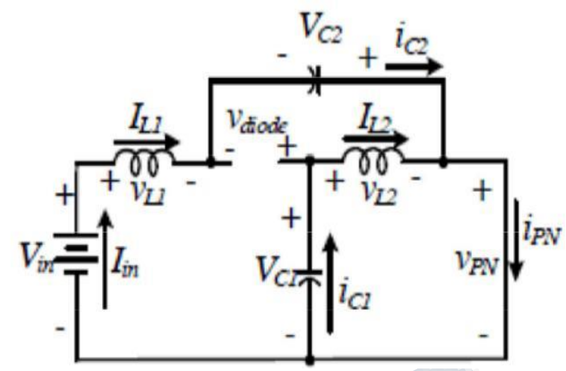

Fig4: Shoot through mode of QZSI

Assuming that during one switching cycle, T, The interval of the shoot through state is T_0 ; The interval of non-shoot-through states is T_1 ;

Thus one has $T = T_0 + T_1$ and the shoot-through duty ratio, $D = T_0 / T_1$.

During the interval of the non-shoot-through states, T_1

$V_{L1} = V_{in} - V_{C1}$,
$V_{L2} = -V_{C2}$ (1)

During the interval of the shoot-through states, T0,

$V_{L1} = V_{C2} + V_{in}$,
$V_{L2} = V_{C1}$ (2)

$V_{PN} = 0$,
Vdiode=VC1+VC2 (3)

At steady state, the average voltage of the inductors

over one switching

cycle is zero.

VPN = VC1 – VL2 = VC1 + VC2,

Vdiode = 0

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Modeling of Proposed System

In this paper, the two capacitors of each module have the same capacitance, and the two inductors of each module have the same inductance, The reasons are

1) Different capacitances will cause different current behaviors of the two inductors. In particular, there will be larger inductor current second harmonic (2ω) ripple when compared to the case with the same capacitance. Large inductor current 2ω ripple will result in large loss and high current stress of inductors.

2) Our design also aims to obtain constant inductor current without 2ω ripple. For this case, two capacitors will have the same 2ω current ripple.

Two capacitors with equal capacitance will result in the same 2ω voltage ripple, so the 2ω ripple of dc-link voltage is divided into two equal parts—half on the capacitor C_1 and half on the capacitor C_2. Otherwise, if the capacitor C_2 has smaller capacitance than the capacitor C_1, the capacitor C_2 will have higher 2ω voltage ripple, which will result in higher 2ω ripple of the battery current.

3) A similar situation will occur if the two inductors have differing inductances. The modeling and controller design will also be complicated if C_1 _= C_2 and L_1 _= L_2.

According to the operating principle of energy stored qZSI the state space equation of each module is

$$\dot{x}_n = \begin{bmatrix} 0 & 0 & \frac{D_n - 1}{L} & \frac{D_n}{L} \\ 0 & 0 & \frac{D_n}{L} & \frac{D_n - 1}{L} \\ \frac{1 - D_n}{C} & \frac{-D_n}{C} & 0 & 0 \\ \frac{-D_n}{C} & \frac{1 - D_n}{C} & 0 & 0 \end{bmatrix} x_n + \begin{bmatrix} \frac{1}{L} & 0 & 0 \\ 0 & 0 & 0 \\ 0 & \frac{D_n - 1}{C} & 0 \\ 0 & \frac{D_n - 1}{C} & \frac{1}{C} \end{bmatrix} u_n$$

Where the subscript n denotes the nth module, n {1, 2, 3}; $\mathbf{x}_n$ is the state vector, $\mathbf{x}_n = [x_{1n}\ x_{2n}\ x_{3n}\ x_{4n}]^T = [i_{L1n}\ i_{L2n}\ v_{C1n}\ v_{C2n}]^T$; D_n is the shoot-through duty ratio of the n^{th} module and $0 < D_n < 0.5$; $\mathbf{u}_n = [u_{1n}\ u_{2n}\ u_{3n}]^T = [v_{pvn}\ i_{PNn}\ i_{bn}]^T$; and the battery current is

$$i_{bn} = \frac{v_{bn} - v_{C2n}}{r_{bn}}$$

Where v_{bn} is the battery open-circuit voltage, r_{bn} is the battery resistance, and v_{C2n} is the voltage of capacitor C_2. For v_{bn} at the determined battery state of charging (SOC), battery current i_{bn} depends on the voltage v_{C2n}.

For the grid side, the dynamic equation is

$$\frac{di_g}{dt} = \left[v_H - v_g - r_f i_g\right] / L_f$$

Where L_f and r_f are the inductance and parasitic resistance of the filter, respectively, v_g and i_g are the grid voltage and current, respectively, and v_H is the output voltage of the energy stored

qZS-CMI, i.e.,

$$v_H = v_{H1} + v_{H2} + v_{H3}$$

The equilibrium point of the system can be solved as

$$\bar{x}_n = \frac{\bar{D}_n \cdot \bar{v}_{pvn}}{1 - 2\bar{D}_n}$$

Where the symbol "–" above the variables denotes their equilibrium terms.

The dc-link voltage envelope of the n^{th} module is

$$\hat{v}_{PNn} = \bar{v}_{C1n} + \bar{v}_{C2n} = \frac{1}{1-2D_n}\bar{v}_{pvn}$$

The currents and powers of the n^{th} module meet

$$\bar{i}_{L1n} - \bar{i}_{L2n} = \bar{i}_{bn};$$
$$P_n - P_{pvn} = P_{bn}$$

Where P_{pvn}, P_n, and P_{bn} are the PV power, the load power (positive in going to the load), and the battery power (positive in discharging) of the n^{th} module, respectively.

From (7), the energy stored qZSI module will perform the following.

1) If $P_{pvn} < P_n$, $P_{bn} > 0$, $i_{bn} > 0$, and the battery is discharging.

2) If $P_{pvn} > P_n$, $P_{bn} < 0$, $i_{bn} < 0$, and the battery is charging.

3) If $P_{pvn} = P_n$, $P_{bn} = 0$, $i_{bn} = 0$, and the battery is neither discharging nor charging.

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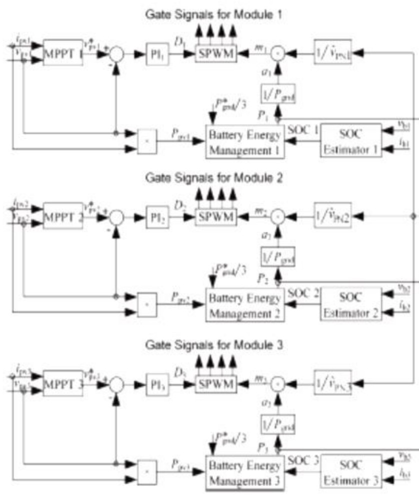

Fig.5.Control scheme for the proposed system.

Control scheme

It shows the proposed control scheme for the energy stored qZS-CMI-based PV power generation system. Each module has its own MPPT and battery energy management to ensure.The grid power control is used to transmit the three modules' power to the grid and keep the whole system operating at unity power factor.

Battery Energy Management of Each Module:

If the total grid power reference is P^*_{grid}, each module power reference can be set at $P^*_{grid}/3$. For each module, there are three operating cases.

Case 1) The nth module battery operates within a safe range, i.e., SOC min < SOC < SOC max, and the n^{th} module output power can match its power reference, i.e., $P_n = P^*_{grid}/3$, n = 1, 2, 3, no matter how much power is from the nth module's PV panel.

Case 2) when the n^{th} module battery SOC reaches SOC min, this module battery cannot be discharged any further. The output power of the n^{th} module depends on the comparison of its PV power P_{pvn} and the module power reference $P^*_{grid}/3$. If $P_{pvn} < P^*_{grid}/3$, the n^{th} module battery will operate in neither charging nor discharging state, and the n^{th} module outputs entire PV power, i.e., $P_n = P_{pvn}$; if $P_{pvn} \geq P^*_{grid}/3$, the nth module battery will be charged, and the nth module provides the desired power $P_n = P^*_{grid}/3$.

Case 3) when the nth module battery SOC reaches SOC max, this module battery cannot be charged any more. The output power of the n^{th} module depends on the comparison of its PV power P_{pvn} and the module power reference = $P^*_{grid}/3$. If $P_{pvn} < = P^*_{grid}/3$, the nth module battery will operate in discharging state, and the nth module outputs the desired power $P_n = = P^*_{grid}/3$; if $P_{pvn} \geq = P^*_{grid}/3$, the n^{th} module battery will be in neither charging nor discharging state, and the n^{th} module outputs its entire PV power, i.e., $P_n = P_{pvn}$.

Grid Power Control:

The magnitude of the grid current reference is calculated by

$$\hat{i}_g = \frac{2P_{grid}}{\hat{v}_g}$$

Where P_{grid} is the total grid-injected power of the three modules and $\hat{v}_g$ is the magnitude of the grid voltage.

The module power ratio a_n can be expressed by

$$a_n = \frac{P_n}{P_{grid}}$$

Grid Current Loop:

The grid-current control block diagram is shown in A PR regulator is employed to track the sinusoidal reference of the grid current.

The transfer function of the PR regulator is

$$G_{PR}(s) = \frac{k_p s^2 + k_r s + k_p \omega_0^2}{s^2 + \omega_0^2}$$

Moreover, a grid voltage feed forward control is introduced to compensate the disturbance of the grid voltage and achieve the fast dynamic response.

For the system shown in , each module's modulation signal m_n will be

$$m_n = \frac{P_n \cdot v_H^*}{P_{grid} \cdot \hat{v}_{PNn}}$$

From (3), the energy stored qZS-CMI-based grid-tie PV system has the transfer function

$$G_L(s) = \frac{I_g(s)}{V_H(s) - V_g(s)} = \frac{1}{L_f s + r_f}$$

Fig.6. Simplified block diagram of the grid current loop.

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Leakage current suppression:

Leakage current suppression is a concern in transformer-less PV power systems. For utility-scale PV farms, due to high voltage level, PV panels have to be mounted on a structure with insulation, which also avoids the leakage current to the ground. For small-scale PV power generation systems, such as residential PV systems, the leakage current may flow to the ground because of the requirement of grounding PV panels, so it will require a special design to limit the leakage current within a specified range. The same situations exist for the proposed energy stored qZSCMI- based PV power system. For utility-scale application, the PV panels' high voltage insulation from the ground has to be taken into account, and hence, there is no leakage current issue. In residential applications, special approaches are necessary to handle the leakage current issue.

Fuzzy Logic Controller:

Fuzzy logic control uses non-mathematical decision based algorithms that use operator's experiences. This type of control strategy is well suited for non-linear systems. Fuzzy logic control is developed in this work to obtain desired output voltage of the chosen multi-level inverter.

In order to obtain the fuzzy control surface for non-linear, time varying and complex dynamic systems, there are a number of steps to be followed as discussed below. The block diagram of fuzzy logic control scheme developed for the chosen single phase seven level inverter is shown in Fig. The FLC is divided into five modules: fuzzifier, database, rule base, decision maker and defuzzifier. The computational structure of fuzzy logic control scheme is composed of the following.

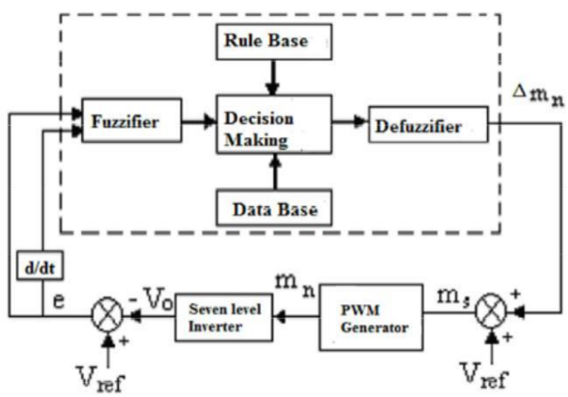

Fig7 : Fuzzy logic control scheme for Quasi Z-source

III. SIMULATION CIRCUITS

A. Control structure for closed loop

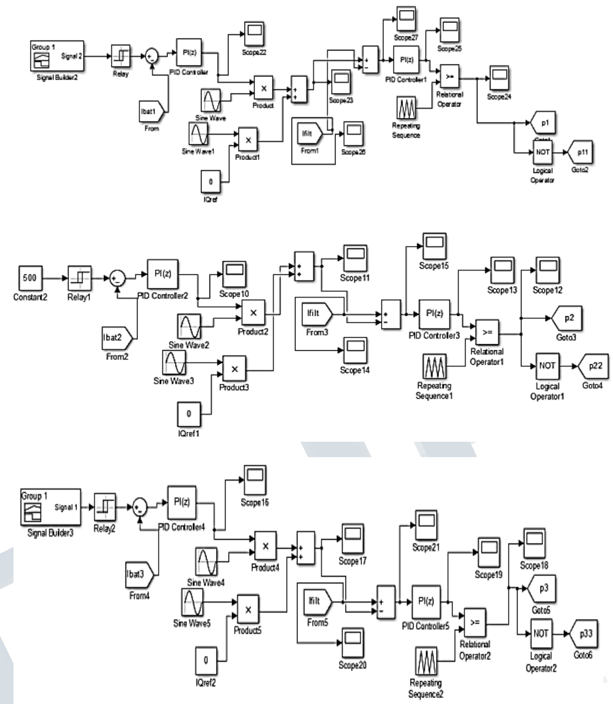

Fig.8. Control circuit without fuzzy controller.

B. Control structure for closed loop including Fuzzy logic controller

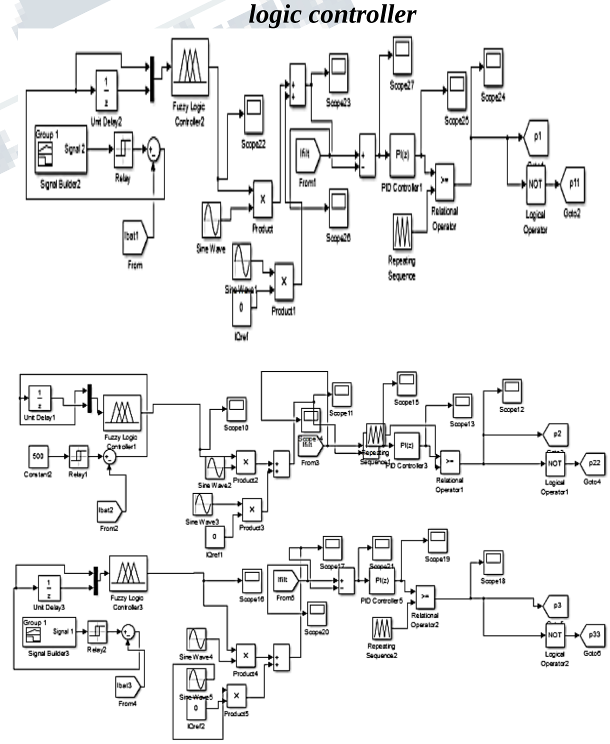

Fig.9. Control circuit with fuzzy controller.

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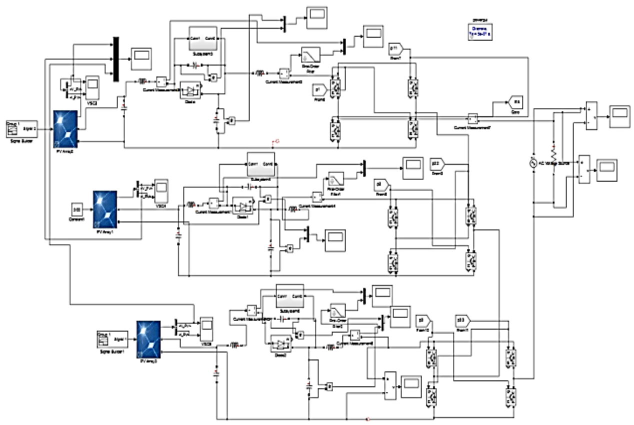
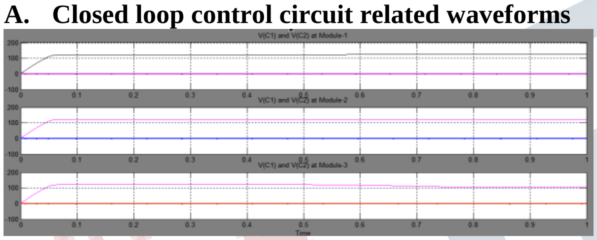
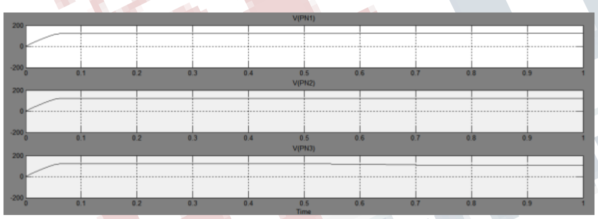


Fig.10. Considered PV system SIMULINK circuit.

IV. RESULTS AND WAVEFORMS

A. Closed loop control circuit related waveforms





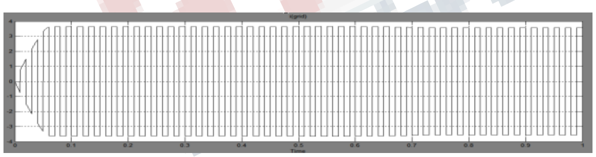


Fig Vrms output waveform

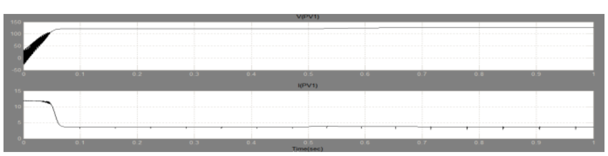
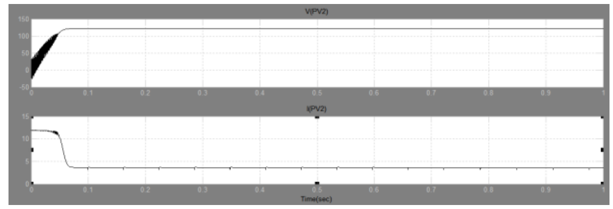


Fig: V(pv) closed control waveform



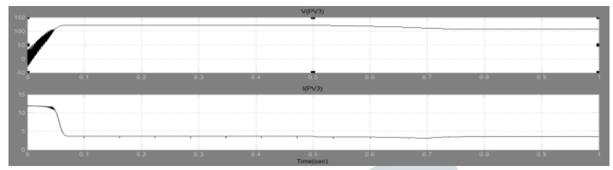
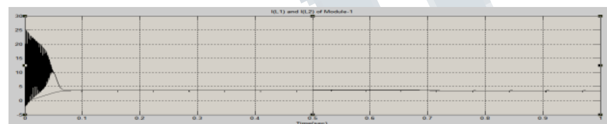
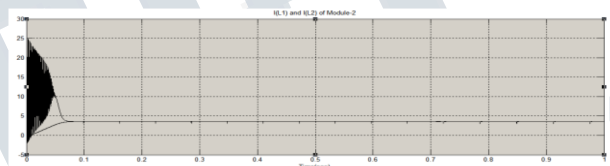


Fig. V(pv)





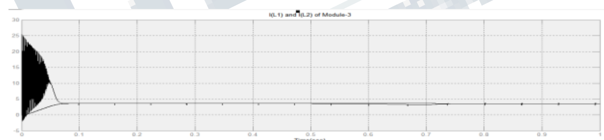


Fig: current waveforms of closed circuit

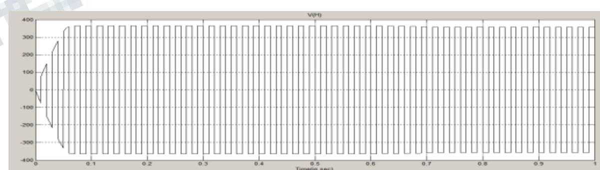
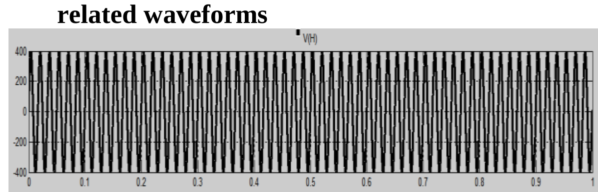


Fig.19.Vrms ouput waveform

B. Closed loop including Fuzzy logic controller related waveforms



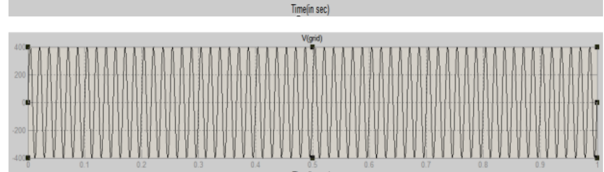


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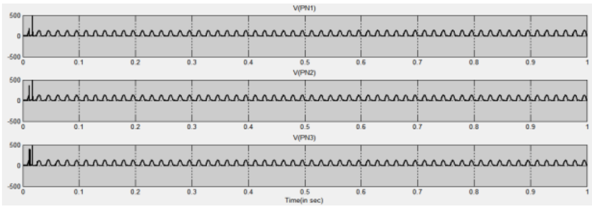
Fig.19.Vgrid waveforms



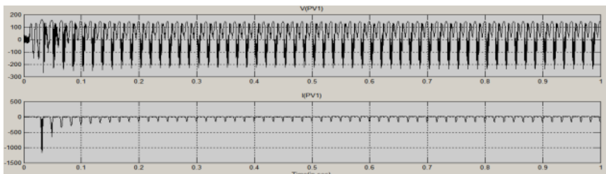
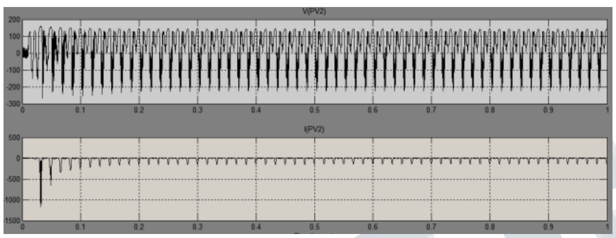


Fig:Vp1,2



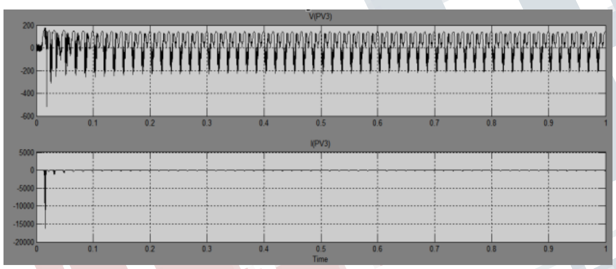
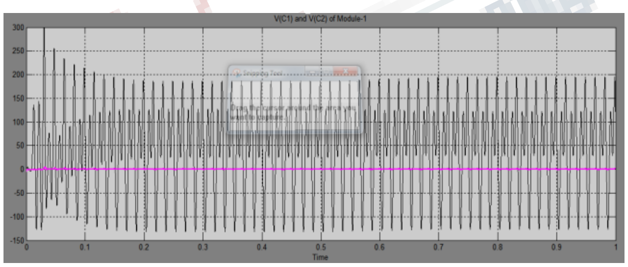
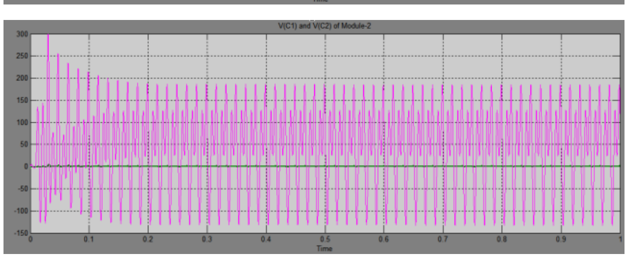


Fig.19.vc1,vc2





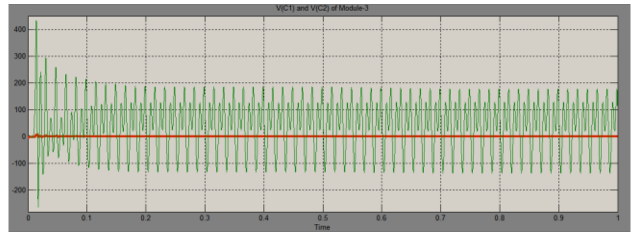
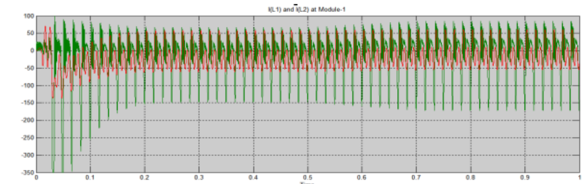
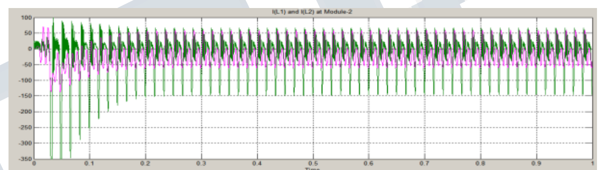
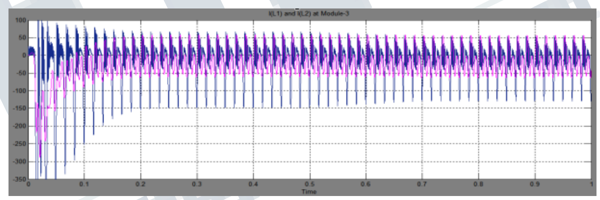


Fig.19.Vl 1,2,3 waveforms







IL 1,2,3 waveforms

V. CONCLUSION

In this research work, Quasi Z source seven level cascaded h-bridge inverter have been presented and it gives higher output voltage through its quasi Z source network. The proposed system is a combination of QZSI and multilevel topology using Fuzzy Logic Controller.. The simulation results show the effectiveness of the proposed QZS-CMI and output of the waveform was analyzed in the MATLAB/simulink. The simulation and experimental results verified the proposed energy stored qZS-CMI-based PV system and the proposed control method and control scheme using fuzzy logic controller. Leakage current suppression is an important topic that will be researched next for the proposed system.

REFERENCES

[1] G. Buticchi, D. Barater, E. Lorenzani, C. Concari, and G. Franceschini, “A nine-level grid-connected converter topology for single-phase transformer less PV systems,” IEEE Trans. Ind. Electron., vol. 61, no. 8, pp. 3951–3960, Aug. 2014.

[2] H. Abu-Rub, M. Malinowski, and K. Al-Haddad, Power Electronics for Renewable Energy Systems, Transportation and Industrial Applications. Hoboken, NJ, USA: Wiley, Jul. 2014.

[3] S. Rivera et al., “Cascaded H-bridge multilevel converter multistring topology for large scale photovoltaic systems,” in Proc. IEEE Int. Symp. Ind. Electron., 2011, pp. 1837–1844.

[4] F. Peng, M. S. Shen, and K. Holland, “Application of Z-source inverter for traction drive of fuel cell—Battery hybrid electric vehicles,” IEEE Trans. Power Electron., vol. 22, no. 3, pp. 1054–1061, May 2007.

[5] M. Shen et al., “Constant boost control of the Z-source inverter to minimize current ripple and voltage stress,” IEEE Trans. Ind. Appl., vol. 42, no. 3, pp. 770–778, May/Jun. 2006.

[6] E. Karaman, M. Farasat, and A. M. Trzynadlowski, “A comparative study of series and cascaded Z-source matrix converters,” IEEE Trans. Ind. Electron., vol. 61, no. 10, pp. 5164–5173, Oct. 2014.

[7] L. Liu, H. Li, Y. Zhao, X. He, and Z. Shen, “1 MHz cascaded Z-source inverters for scalable grid-interactive photovoltaic (PV) applications using GaN device,” in Proc. IEEE Energy Convers. Congr. Expo., 2011, pp. 2738–2745.

[8] Y. Zhou, L. Liu, and H. Li, “A high performance photovoltaic module integrated converter (MIC) based on cascaded quasi-z-source inverters (qZSI) using eGaN FETs,” IEEE Trans. Power Electron., vol. 28, no. 6, pp. 2727–2738, Jun. 2013.

[9] D. Sun et al., “A new grid-connected PV system based on cascaded H-bridge quasi-Z source inverter,” in Proc. IEEE Int. Symp. Ind. Electron.,2012, pp. 951–956.

[10] Y. Liu, B. Ge, H. Abu-Rub, and F. Peng, “Phase-shifted pulse-width amplitude modulation for quasi-Z-source cascade multilevel inverter based photovoltaic power system,” IET Power Electron., vol. 7, no. 6, pp. 1444–1456, Jun. 2014.

