Single-Phase Quasi-Z-Source Inverter with ANFIS Controller

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Abstract:

In the modern days quasi z source inverters plays an important role and so many advantages. The utilization of proposed inverter gives grid connected applications like lower component rating, single stage operation, and continuous input current and DC rail. In the project evaluating the performance of single phase grid connected quasi z source inverter by using anfis controller. Sliding mode control (SMC) and Adaptive neuro fuzzy interference system (ANFIS) using To obtain a rapid and complex reaction for large variance in input and output, it was proposed for capacitor voltage regulation. Obtaining steady state performance and dynamic state performance by using the proposed converter. The performance of SMC with anfis based proposed converter obtaining the results using Matlab Simulink.

Keywords: Z-Source-Quasi Inverter; Sliding Control mode; DC rail ; Adaptive neuro Fuzzy interference system (Anfis); ANFIS controller; PI Controller.

1. INTRODUCTION :

The advantages of renewable energy sources are better than the non-renewable energy sources. In the renewable energy sources are like solar energy (PV), wind energy, Hydro energy. In the different types of renewable energy sources solar power generation gives popularity, high efficiency, simple construction, low operation cost, non-contamination in the energy sources. Solar energy generates the power depends on sun irradiation and temperature. The type of generation in the solar DC energy and convert the power dc to ac using inverter to the grid. In the solar power generation mppt techniques plays an important role. The conversion stages in the solar to grid two conversions required in the conventional methods. To get the inverter initial volt within the necessary limit, the necessary DC-DC converter worked. In traditional methods, the conversion stages produce the convolution of the entire network, loss power, and price. Connecting the step up transformer is alternate route to reduce the conversion stages. to raise the output volt on the ac side. Too many drawbacks, such as device size and the expense of the transformer, are used by the step up transformer. So the no of conversion stages reduced by using z source inverter (ZSI) [1].This project incorporates an impedance source power converter (Z-fount converter) to reduce the problems of traditional methods. It operates as dc to ac, ac to dc, ac to ac, and dc to dc power conversion operating in the z-source converter. The proposed converter gives a unique impendence network to combine the main circuit to the power source and load for giving unique features that cannot be obtained in the conventional methods. The z source inverter schematic circuit diagram consists of two inductors and two capacitors connected to the inverter input. With a single stage configuration, ZSI would be able to increase or decrease the output voltage in the converter operation with passive components. The oscillation girth pitch (PWM) using to control the inverter in the ZSI are analyzed different approaches [2]-[4]. The ZSI used in so many applications in dc power generation side areas like solar power generation, battery based vehicles, dc related drives. [5]- [7]. Several methods searched among related to the ZSI which will reduce the pressure in the switches and improve the system rating [8] - [9].Quasi Z source inverter (QZSI) obtained by integrating the performance of ZSI in different versions [10] – [11]. Application of a Distributed Generation (DG) Quasi Z Source Inverter. The proposed inverter is capable of regulating a wide range of input voltages by supplying constant current from an input source. Continuous current inverter output uses input current and lees tension in the switches. In the two condensers, the capacitor voltage value is the same, so the voltage stress around the capacitor would be the same. But in qZSI, the condensers have different voltage ratings, so lower voltage stresses. By comparing the voltage stress and ratings of the converter qZSI gives better results comparing to the ZSI [12]. The performance of the qZSI gives better performance in the grid connected configuration. The main advantage of the

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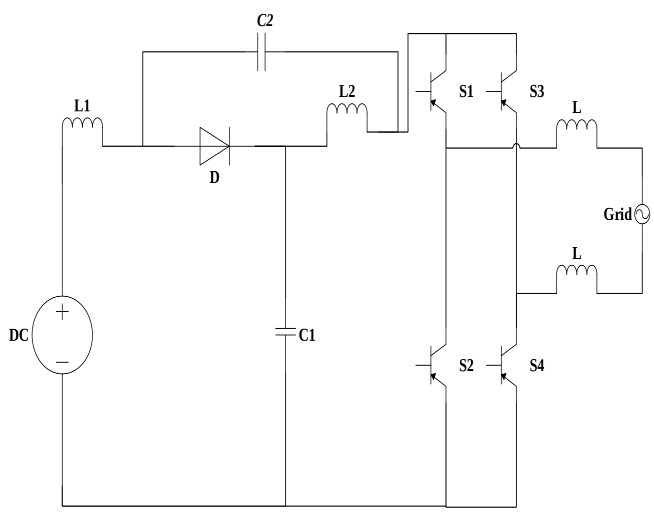
qZSI gives reduce the complexity because of dc rail between source and inverter. So the effect of electromagnetic interference (EMI) also very less. The input voltage boost up by using shoot through signal, during the shoot the top and down buttons are ON via the flag. Hence, capacitor volt can be compensate by shifting the shot via duty time in the initial control objective. To improve the dynamic response of capacitor voltage control, several different control topologies are suggested [11]-[13]. A variable structure system discussed initially in the Sliding mode controller (SMC) [14]. The benefits of SMC as input variations, output variations, and indecisions of parameters. The power converter is an integral variable structure with a switching feature. The changing sass of the SMC-based device controller implemented in this project should be improved. However, the downside of the SMC as a restriction of the power converter switching frequency is preferably not useful[16]-[17]. Paper [18] discussed about SMC in ZSI. In [19] the battery charging current control to the object nicely explained as SMC in qZSI. In this project discussed about qZSI with SMC based Anfis controller implemented and evaluating the results using Matlab/Simulink.

In this project way of pattern as follows, in section 2 discussing about introduction of ZSI and power generation, in Section 3, discussing about structure of qZSI, in section 4 discussing about proposed control strategy. In section 5 explains about steps and inquiry of SMC. Section 6 discusses about the simulation results of existing network and conclusions, reference as discussed.

2. Structure of quasi-z- source inverter:



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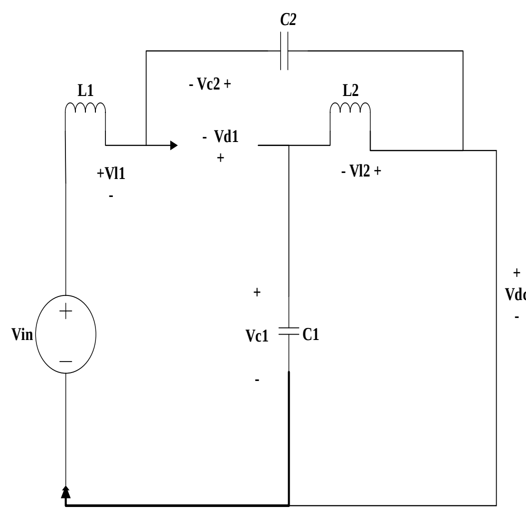

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Fig. 1. 1-Ph grid connected qZSI.

Fig. 2. Equivalent qZSI circuit in state shooting (u=1)

The schematic diagram of the conventional based single-phase grid connected qZSI shown in fig. 1. In the quasi z source inverter working as a single stage conversion and it has impedance network allied to the grid. The urged process consists of two L1 and L2 inductors and two C1 and C2 capacitors. In the proposed system, as shoot thorough state, and non-shoot through state, it operates in two states in continuous conduction mode. Referencing that T is the whole switching cycle time, T0 is switching time in the first state and T1 is non-shoot through cycle time. So the task ratio is expressed as D = T0 / T in terms of shooting through. The presumption of a symmetrical qZS network modelling network. When the system running shoot through state, the DC connexion short circuited of the top & down buttons of the inverter occurred. The schematic diagram shown in Fig 2 of the qZSI in the shot via state. U=1, as the state of the single button, is reprehend. Shooting via the corresponding circuit below,

$$V_{L1} = V_{c2} + V_{in}$$

$$V_{L2} = V_{c1}$$

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$$i_{C1} = -i_{L2}$$

$$i_{C2} = -i_{L1} \quad (1)$$

When the diode acts as a non-shoot via state status, and the inverter acts as an inverter of the traditional voltage source. The non-expel via the agnate whirl trim on view in Fig. 3.U=0 represents as off state of the single switch. The identical diagram of the non-shoot laid out below,

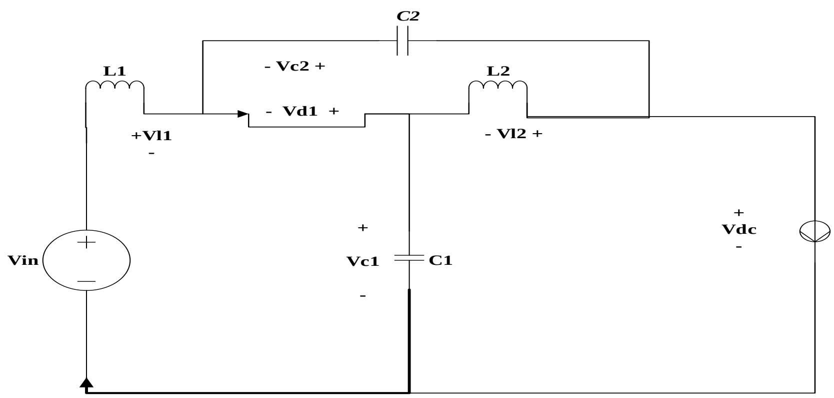

Fig. 3. Identical diagram of Q-ZSI in shoot-via state (u=0)

$$V_{L1} = -V_{c1} + V_{in}$$

$$V_{L2} = -V_{c2}$$

$$i_{C1} = i_{L1} - i_{DC}$$

$$i_{C2} = -i_{L2} - i_{DC} \quad (2)$$

From (1) and (2),

$$V_{L1} = (-V_{c1} + V_{in}) + (V_{c1} + V_{c2})u$$

$$V_{L2} = (-V_{c2}) + (V_{c1} + V_{c2})u$$

$$i_{C1} = (i_{L1} - i_{DC}) + (i_{DC} - i_{L1} - i_{L2})u$$

$$i_{C2} = (i_{L2} - i_{DC}) + (i_{DC} - i_{L1} - i_{L2})u \quad (3)$$

In view of inductor currents and capacitor voltages in state variables of the system as,

$$X = [i_{L1} \quad i_{L2} \quad v_{C1} \quad v_{C2}]^T \quad (4)$$

The qZSI for the state space averaged model conveyed as,

$$\dot{X} = AX + Bu \quad (5)$$

Where,

$$A = \begin{bmatrix} \frac{1}{L_1}(-V_{c1} + V_{in}) \\ \frac{-V_{c2}}{L_2} \\ \frac{1}{C_1}(i_{L1} - i_{DC}) \\ \frac{1}{C_2}(i_{L2} - i_{DC}) \end{bmatrix} \qquad B = \begin{bmatrix} \frac{1}{L_1}(V_{c1} + V_{c2}) \\ \frac{V_{c1} + V_{c2}}{L_2} \\ \frac{1}{C_1}(i_{DC} - i_{L1} - i_{L2}) \\ \frac{1}{C_2}(i_{DC} - i_{L1} - i_{L2}) \end{bmatrix}$$

3. Procedure for Control:

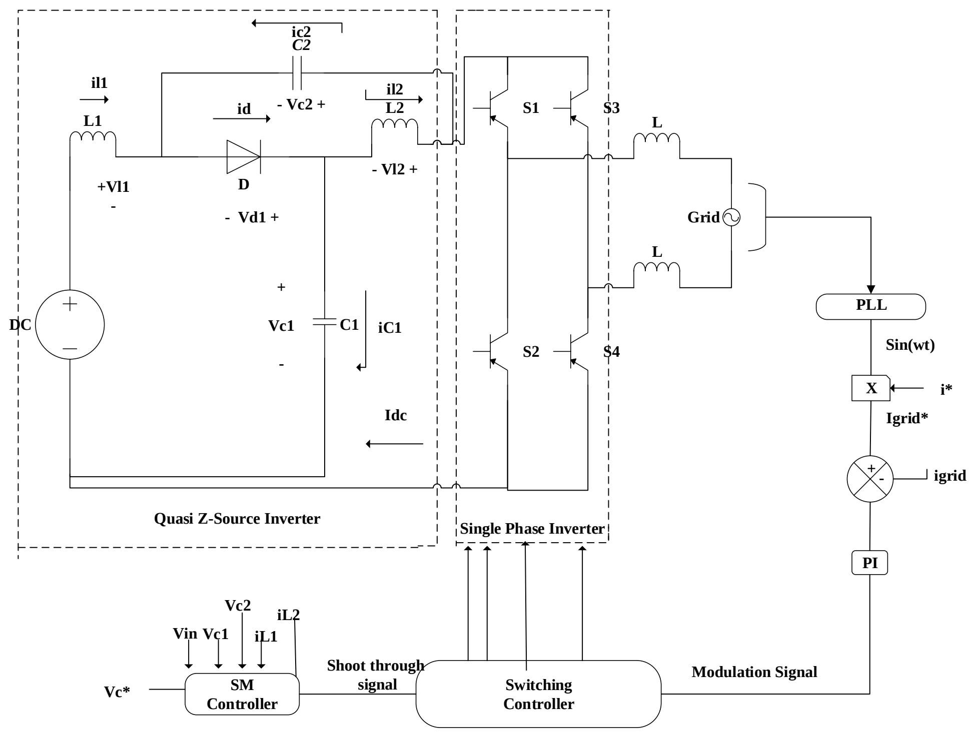

Fig. 4. Closed loop control based grid connected quasi-Z-Source Inverter

Operating two control loops in the proposed methodology. In the first loop, the voltage of the capacitor is controlled via the shoot-through duty ratio D in the qZSI network. In the second loop, control operates via the modulation index M in the AC side voltage or current. The different type of control strategies in the closed loop control analyzed in the section I. the way of closed loop control based grid connected qZSI shown in fig. 4. To improve the transient response implementing the closed loop grid connected system. Transient reaction improves very dramatically in the grid linked condition. There is no disturbance in the difference of the input volt & output current grid. The variation of load shift and shift in the reference grid current is based on the benefit in the same way. The aspect locked ring (PLL) is worn by the current sway process to sway the ac side converter to synchronise the inverter performance.

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4. Sliding Type Monitor:

In this sliding type monitor (SMC) gives the many advantages like input, output variations and parameters variations, stability of the system. The drawback of the controller it doesn't operating as ideally because of the power converter has limited switching frequency. It is possible to operate power converters as quasi-sliding mode controllers. SMC was primarily used as a buck boost converter, boost converter, buck converter, and cuk converter to power the dc to dc converters. In renewable energy applications, such as input and output variations, the converter is applicable. In this project, SMC worked to sway and level the dc output volt of the qZSI impedance network linked with the grid. The main objective of the sway procedure is to boost the steady state and the efficiency of the transient state. The final condition of achievement can be fulfilled by the required function of chance switching.

4.1 Surface Sliding:

The original condition should be victorious in the move arise of the say curve. It is necessary to satisfy the hitting condition by selecting the switching function. The switching function can reflect the power switches of the logic states.

$$u = \frac{1}{2}\left(1 + sign(s)\right) \qquad (6)$$

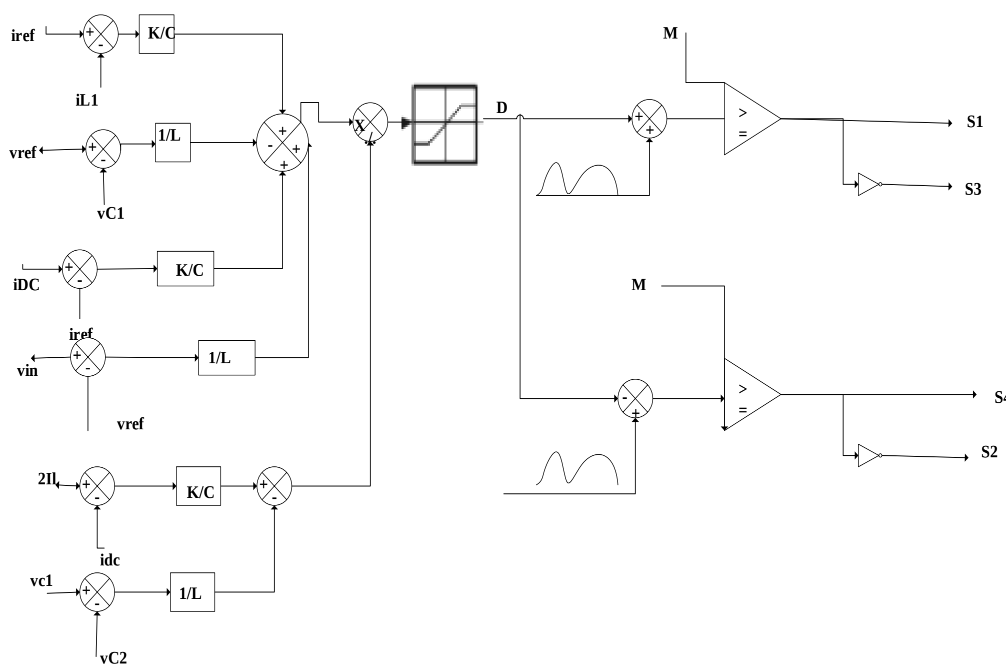

Fig. 5. Logic control for SMC implementation

Here, S=say shifty curve

S=0 is representing move arise of the network.

The capacitor volt misstep and input inductor current misstep can be described in the proposed SMC as regulated state variables as below.

$$x_1 = v_{ref} - v_{C1}$$

$$x_2 = i_{ref} - i_{L1} \qquad (7)$$

The fine union of the say shifty in the move arise of the proposed controller can be defined as below

$$S = \alpha_1 x_1 + \alpha_2 x_2 = GX \qquad (8)$$

Here α_1, α_2=sliding coefficients

G=sliding coefficients of the vector

Therefore the standard form of the state space equation can expressed as below

$$\dot{X} = AX + Bu + D \qquad (9)$$

$$A = \begin{bmatrix} 0 & \frac{1}{C} \\ -\frac{1}{L} & 0 \end{bmatrix}, B = \begin{bmatrix} \frac{2i_L - i_{DC}}{C} \\ \frac{v_{C1} + v_{C2}}{L} \end{bmatrix}, D = \begin{bmatrix} \frac{i_{DC} - i_{ref}}{C} \\ \frac{v_{in} + v_{ref}}{L} \end{bmatrix}$$

4.2 Equivalent Control :

The two conditions must meet the existence condition to satisfy

$$S(x,t) = GX = 0 \qquad (10)$$

$$\dot{S}(x,t) = G\dot{X} = 0 \qquad (11)$$

Combining (9) and (11)

$$\dot{S}(x,t) = G\dot{X} = GA + GBu_{eq} + D = 0 \qquad (12)$$

Hence, the equivalent control signal can executed as,

$$u_{eq} = -[GB]^{-1}[GAX + GD]$$

Where, $k = \frac{\alpha_1}{\alpha_2}$ are constant gain variables, along with typically, u_{eq} lies '1' & '0' still as Q-ZSI, the duty scale of the shoot via is 1-D, so the value of u_{eq} is limited to 0.4.

$$0 < u_{eq} < 0.4 \qquad (14)$$

The designed sliding surface obtained from the average moving motion.

4.3 State of Presence:

The sliding surface should include the state trajectory and the approach to its symmetry trace in the execution of the sliding surface condition. To ensure the prior operation of the SM, the conditions set out below must be met

$$\lim_{s\to} S\dot{S} < 0 \qquad (15)$$

The inequality equations are

$$S_{S\to 0+} = GAX + GBu_{S\to 0+} + D < 0$$

Assuming the constant values of the inductors and capacitors the conditions as come after.

Type-I:$S_{S\to 0+}, S < 0$ u = 1 in e-16,

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$$S_{S\to 0+} = k\frac{i_{L1}}{C} - \frac{v_{C2}}{L} + \frac{v_{in}}{L} < 0 \qquad (17)$$

Type-II: $S_{S\to 0-}, \dot{S} > 0$ u = 0 in e-16,

$$S_{S\to 0-} = k\frac{i_{L1}}{C} - \frac{v_{C1}}{L} + k\frac{i_{DC}}{C} - \frac{2v_{ref}}{L} + \frac{v_{in}}{L} > 0 \qquad (18)$$

The above equation of inequality is used for the L and C verification parameters of the Q-ZS network parameters used. As a number of experimental values of V in, from the resulting equation of the above, so that Q-ZS is verified in the boost mode, so that the inequality rule can be slaked. The sliding coefficient values can be determined by using the equations above.

4.4 State of Stability:

The substitution of u in to the board signal model of qZSI by identical control $u_{eq,}$ it transforms the discontinuous network into an ideal continuous sliding mode network, expressed as equation 19 below

$$\frac{d}{dt}\begin{bmatrix} i_{L1} \\ i_{L2} \\ V_{C1} \\ V_{C2} \end{bmatrix} = \begin{bmatrix} \frac{1}{C_1}(-V_{C1} + V_{in}) \\ \frac{V_{C2}}{L_2} \\ \frac{1}{C_1}(i_{L1} - i_{DC}) \\ \frac{1}{C_2}(i_{L2} - i_{DC}) \end{bmatrix} + \begin{bmatrix} \frac{1}{L_1}(V_{C1} + V_{C2}) \\ \frac{1}{L_2}(V_{C1} + V_{C2}) \\ \frac{1}{C_1}(i_{DC} - i_{L1} - i_{L2}) \\ \frac{1}{C_1}(i_{DC} - i_{L1} - i_{L2}) \end{bmatrix} u_{eq} \qquad (19)$$

5. CONTROLLER IMPLEMENTATION USING ANFIS CONTROLLER:

Takagi-Sugeno fuzzy inference based system type of artificial neural network in the adaptive neuro fuzzy inference system or adaptive network based fuzzy inference system. This technique established in 1990s. Since it combines both fuzzy logic controller and neural network controller. In the anfis controller is using FIS type parameters used to integrate the parameter variation. In the anfis controller if then rules implemented capability to approximate nonlinear functions.

In the Anfis controller input as error and change in error and output as one membership function. In the input membership functions 7 triangular based member functions implemented and output as 7 linear constant terms implemented. These total membership functions can be integrated by rules 49 iterations. The structure of anfis model shown below and the structure define the rules with input and output. The anfis controller placed in the place of PI controller. The schematic diagram of proposed qZSI with anfis controller shown below.

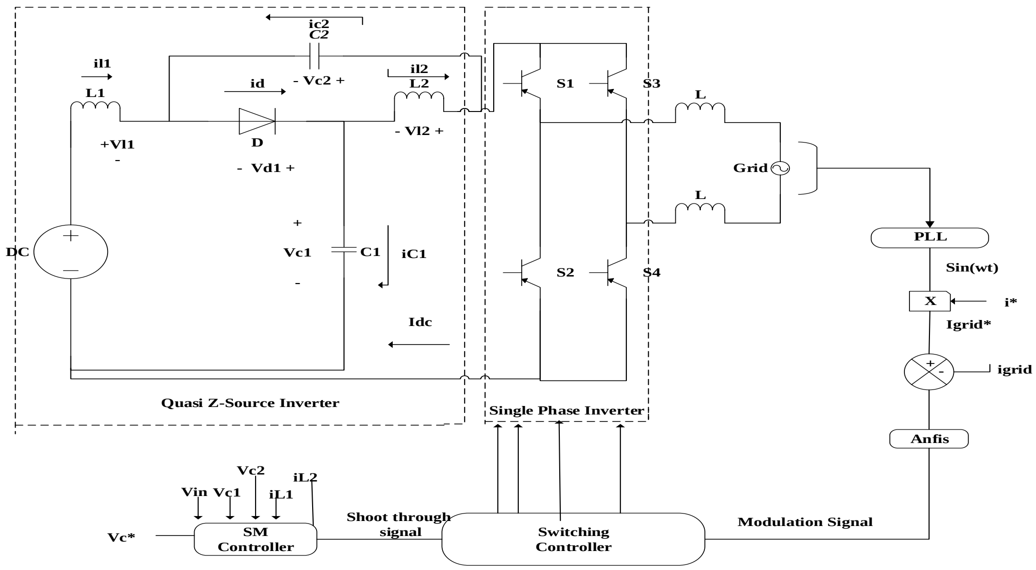

Fig. 6. Closed loop control based grid connected quasi-Z-Source Inverter by using Anfis controller

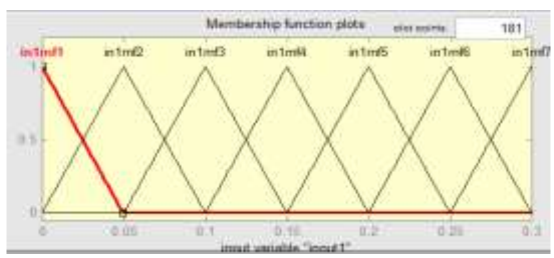

Fig. 7. Input membership function-1

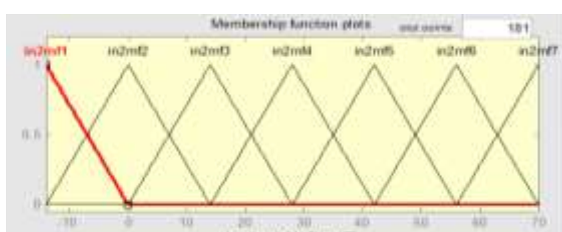

Fig. 8. Input membership function-2

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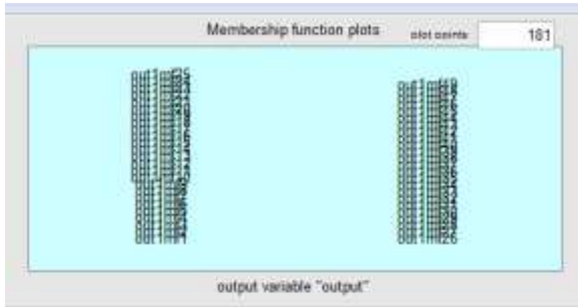

Fig. 9. Output membership function

e/Ce	NB	NM	NS	ZE	PS	PM	PB
NB	NB	NB	NB	NB	NM	NS	ZE
NM	NB	NB	NB	NM	NS	ZE	PS
NS	NB	NB	NM	NS	ZE	PS	PM
ZE	NB	NM	NS	ZE	PS	PM	PB
PS	NM	NS	ZE	PS	PM	PB	PB
PM	NS	ZE	PS	PM	PB	PB	PB
PB	ZE	PS	PM	PB	PB	PB	PB

Table: 1. ANFIS

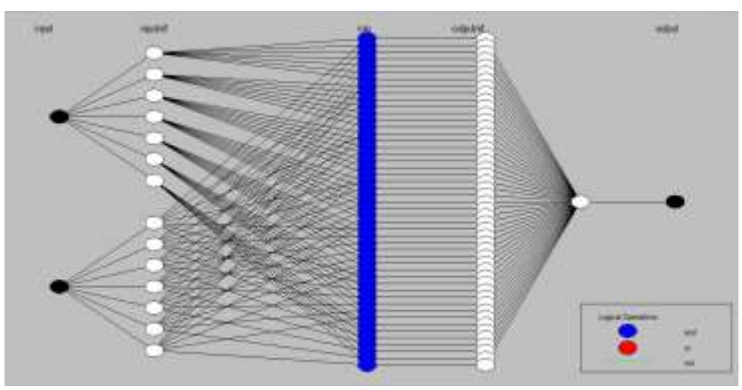

Fig: 10 ANFIS model based structure

6. SIMULATION RESULTS

In the proposed method executing the results as pi controller based and anfis controller based method explained below. To improve the steady state performance and dynamic performance can be analyzed by using Matlab/Simulink the results of the simulation can be defined below as input voltage, voltage based on capacitor and grid current and grid voltage as shown below.

6.1 Simulation results using PI controller:

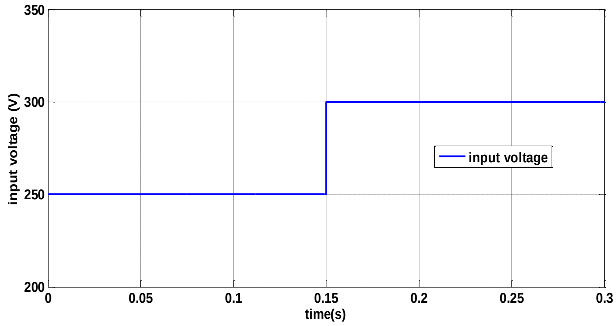

Fig. 11. Input voltage

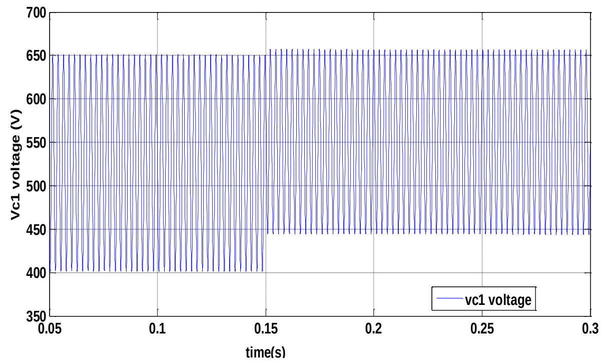

Fig. 12. Voltage across Vc1

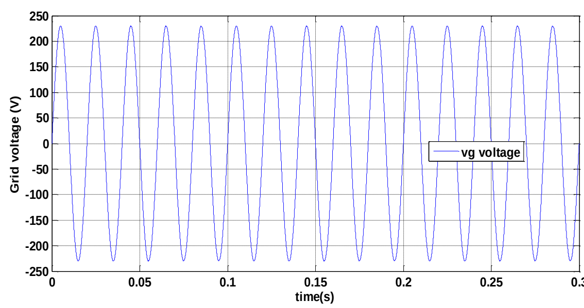

Fig. 13. Grid voltage

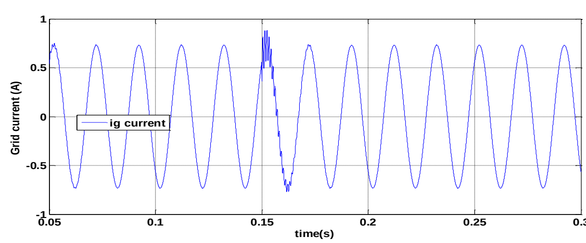

Fig. 14. Grid current

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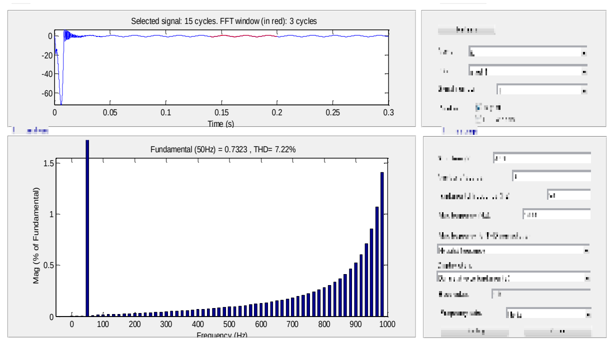

Fig. 15. Grid current Thd value

6.2 Simulation results using Anfis controller:

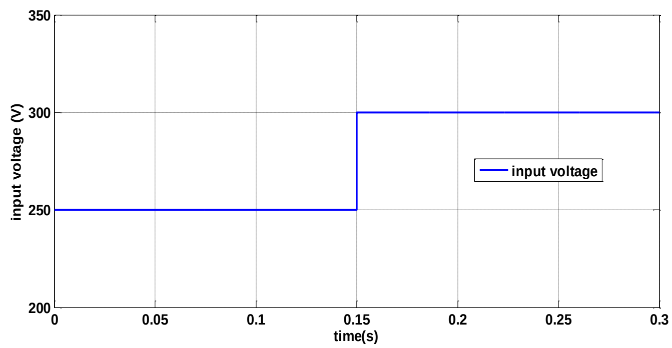

Fig. 16. Input voltage

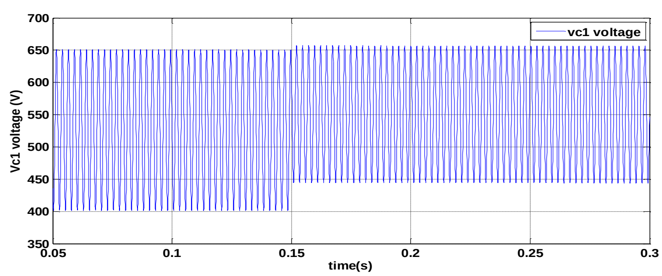

Fig. 17. Voltage across Vc1

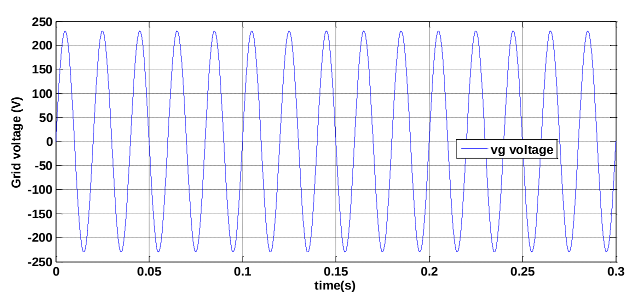

Fig. 18. Grid voltage

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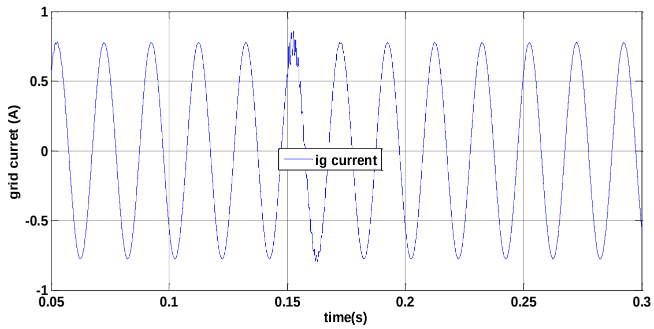

Fig. 19. Grid current

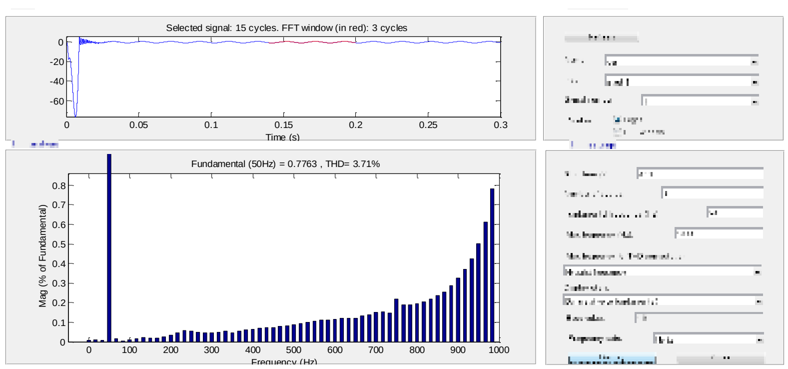

Fig. 20. Grid current Thd value

Controller	THD value
PI controller	**7.22**
Anfis	**3.71**

Table. 2. Thd comparison table

6.3 CONCLUSION:

In this paper, sliding mode controller based anfis controller for improving dynamic response in the qZSI system. The advantages of qZSI give more stability and give fast response in the performance. Different types of controller can discussed about boosting the voltage and send to the grid. In this project the steady and dynamic state performance improved better compared to the conventional method. The comparison between pi controller and anfis controller shown in as THD values. It represents that PI controller has 7.22% and implementing an anfis controller Thd value as 3.71%. The performance of qZSI based anfis controller results executed by using Matlab/ Simulink.

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