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Performance Analysis of QZSI for PV Integrated Grid System

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ABSTRACT

In PV based grid connected system, grid interfaced inverter plays a vital role. The quality of output power of the grid mainly depends upon the operation of PV grid interfaced inverter. Hence, to optimize the control of qZSI based grid interfaced PV inerter, this work proposed a fuzzy controller. Thus the superiority of the proposed topology is verified using MATLAB simulation. This in turn can reduce the steady state error and also results in reduced harmonics at the grid side current.

Key words: PV, Grid Interfaced Inverter,qZSI, FLC.

1. INTRODUCTION

The vast development in technology has increased the greats demand for power. This has made the world to move towards renewable energy system (RES) for power generation. Now a days, PV is becoming more popular in power generation due to its low cost, excellent performance, flexibility and easy installation. However, it is limited by two factors namely

(i)Interfacing with converter system

(ii)Variability in the output in accordance with seasonal variation.

This variation in temperature and irradiation widely varies an output voltage of a PV cell. But a conventional inverter (VSI) cannot operate with these wide variations. As a result of this, converter (DC/DC) is introduced in between PV unit and inverter. However, this type of arrangement will increases the cost of the system. Hence, to reduce the cost and to make it more economical, ZSI has been formulated [1-6]. But, under boost mode, this ZSI exhibits discontinuous input current. Thus, it requires large filters at the input side[7].

Thus, to overcome this problem, qZSI was introduced. Thus, this work analyses the application of qZSI in PV generation system.

While implementing this topology, the inverter can draw a Constant Current (CC) from PV array. This will result in increased capability of handling wide range of input voltage of an inverter. As a result, the stress over the components can be reduced. Thus the advantages of qZSI over PV system are as follows

1) As qZSI draws a CC from PV, filters are eliminated.

2) The component rating is very low when compared to ZSI

3) It reduces the ripple in the PV system causes reduction in ripple current.

In this regard, Yushanet al (2014) formulated a qZSI with CMLI based grid interconnection for PV system. Li et al (2013) formulated a qZSI for distribution and generation system. All these studies exhibit various topology of qZSI for different applications.

The control strategy of qZSI mainly includes PI controller[8]. But, it seems to be more complex for qZSI as it is tedious to achieve error free output. Hence, to overcome this advantages, AI based controller are implemented [9-14]. Thus, this work, a fuzzy based qZSI for PV is formulated. It is demonstrated by both theoretical analysis and simulation.

II. CONFIGURATION OF THE PROPOSED QZSI STRUCTURE

The figure 1 depicts the grid connected PV system using a QZSI.

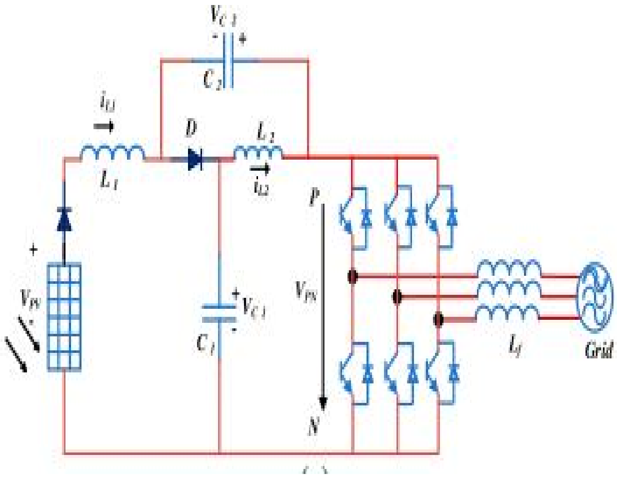


Figure 1: PV fed qZSI

qZSI functions under two modes namely[17]:
i) Shoot-through state (ST)
ii) Non-shoot-through state (NST)
The NST at to the time interval (T_1)is depicted in figure 2 and its operation is explained below

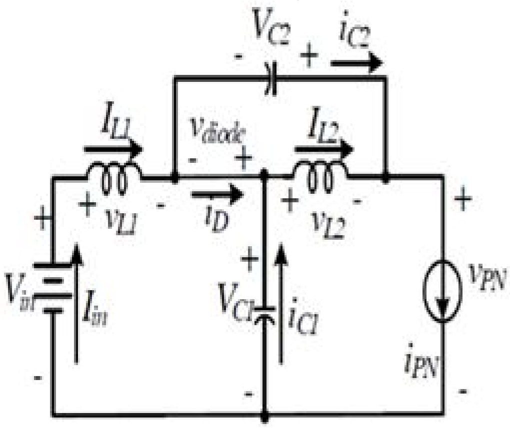
$$V_{L1} = V_{in} - V_c V_{L2} = -V_c \quad (1)$$

$$V_{PN} = V_{C1} - V_{L2} = V_{C1} + V_{C2} = 0 \quad (2)$$

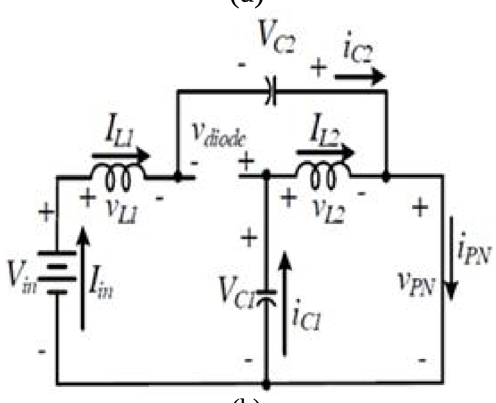
The figure 2b shows ST states at the time interval (T_0) .Thus,

$$V_{L1} = V_{C2} - V_{in} V_{L1} = -V_{C1} \quad (3)$$

$$V_{PN} = 0\ Diode\ voltage = V_{C1} + V_{C2}$$



(a)



(b)

Figure 2: a) qZSI NST b) ST state

Using the above equations, the voltage through the capacitors (V_{C1}& V_{C2}) is about

$$V_{C1} = \frac{T_1}{T_1 - T_0} V_{in} \ (5)$$

$$V_{C2} = \frac{T_0}{T_0 - T_1} V_{in} \ (6)$$

Similarly, average current through the inductors (L1&L2) are found as

$$I_{C1} = I_{C2} = I_{PN} - I_{L1} \ (7)$$

$$I_D = 2I_{L1} = I_{PN} (8)$$

Thus, the proposed qZSI which works under boost conversion mode for PV input its inversion can be obtained as

$$\tilde{V}_{PN} = V_{C1} + V_{C2} = \frac{T}{T_1 - T_0} V_{in} = \frac{1}{1 - 2\frac{T_0}{T}} V_{in} = B_{Vin} (9)$$

Where
B - Boost Factor.

IIa.Inductor Design

While in normal operating condition, both the capacitor and input voltage are equal in magnitude. Hence, the voltage across the inductor is zero. During ST, the inductor current (I_L) increases and hence the V_L=V_C [14]. Thus the I_{Lavg}can be defined as,

$$I_L = P/_{V_{dc}} \quad (10)$$

Where
P - Power
V_{dc} - DC link voltage.
However, the ripples in current remains high, when I_L and ST is maximum. Normally, only 30% of ripple through L is allowed. Hence, for f_s about 10kHz, the V_{Cavg} is calculated as

$$V_c = \left(1 - {T_0}/_T\right) * V_{dc} / (1 - {2T_0}/_T) \quad (11)$$

Thus by replacing the values in this equation, the V_{Cavg}andinductance is calculated

IIb.Design of a Capacitor

The capacitor is mainly inserted for voltage ripple reduction and it also maintain a voltage at Constant value. Thus, during ST, $I_L = I_C$. Hence, the capacitor value can be calculated using the formula

$$V_C = I_{L(avg)} TS/C \quad (12)$$

III. INVERTER CONTROL STRATEGIES

The main purpose of the inverter design is to reduce the level of harmonics and maintain AC and maintain AC output at the desired level. This can achieve by executing a suitable control techniques. In this work, an AI based fuzzy logic controller is implemented as controller [18,19]. Figure 3 depicts the general concept of controller for the proposed system. In this, control signal generated on the basis of the error signal determines the ON/OFF duration of switching devices.

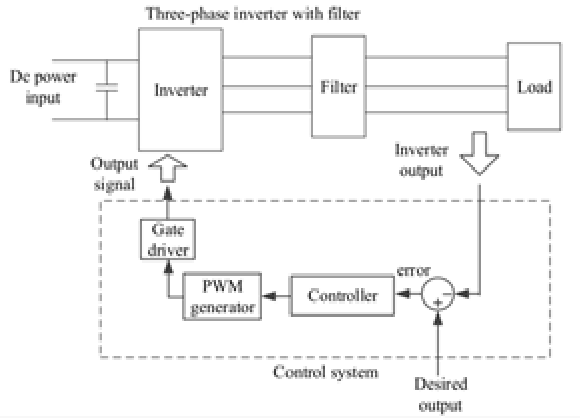


Figure 3: General concept of an inverter closed-loop control system

IV. DESIGN OFFLC

FLC implemented in this proposed topology is characterized by the following methodology.

1. 7 sets for both input and output.
2. TF is tailored.
3. UOD is implemented for fuzzification process.
4. Implications are carried using 'min' process.
5. 'Centroid' is incorporated for defuzzification process.

Figure 4a, 4b and 4c shows the triangular MF for the input and output variables respectively.

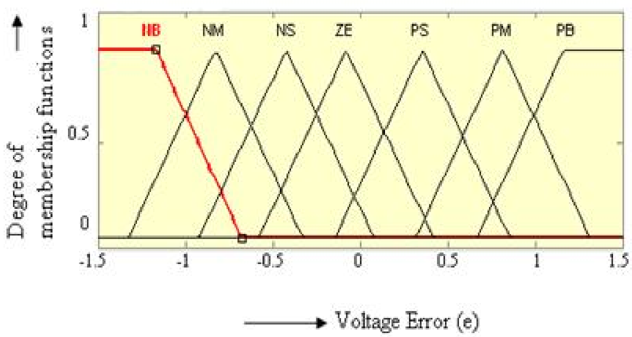


Figure 4a: MF (e)

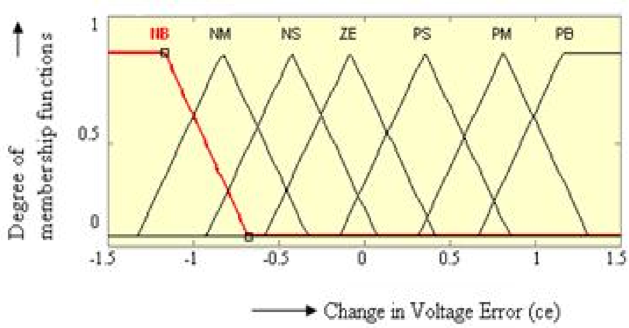


Figure 4b: MF (Δe)

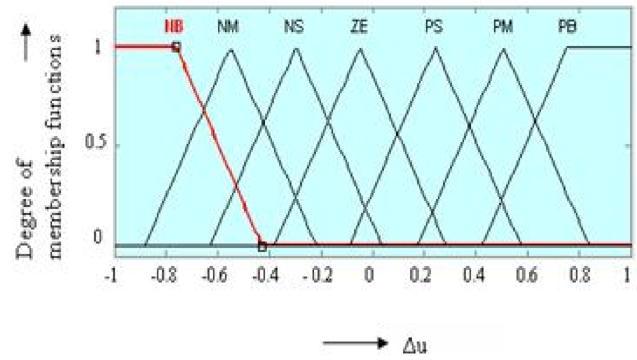


Figure 4c: MF (Δu)

The fuzzy rule base designed for this proposed controller is depicted in table 1.

Table 1: Fuzzy Rule base

$\Delta e/e$	**NL**	**NM**	**NS**	**ZE**	**PS**	**PM**	**PL**
NL	NB	NB	NB	NM	NM	NS	ZE
NM	NB	NB	NM	NS	NS	ZE	PS
NS	NB	NM	NS	NS	ZE	PS	PM
ZE	NM	NS	NS	ZE	PS	PS	PM
PS	NM	NS	ZE	PS	PS	PM	PB
PM	NS	ZE	PS	PS	PM	PB	PB
PL	ZE	PS	PM	PM	PB	PB	PB

V.GENERATION OF PWMSIGNALS

In this topology, SPWM was implemented to generate PMW signals. In SPWM technique, sinusoidal (AC) reference is compared with the carrier wave (triangular) and the result of this, governs the switching condition of a VSI.

When $V_{ref} > V_C$, switches in the upper arm are on in 'ON' condition. If $V_C < V_{ref}$ the switching state remain vice-versa.

VI. RESULTS AND DISCUSSION

Thus the effectiveness of the suggested system is analyzed using MATLAB simulation. Table 2 depicts the parameters of the PV module.

Table.2: PV module parameters

Parameter	**value**
OpenCircuit Voltage (Voc)	37.2
Short Circuit Current (Isc)	8.65
MPP voltage (V)	30
MPP current (A)	8
No.of series array	10
No.of parallel array	2

To illustrate the steady state response of the system, the PV is operated at constant 1000 W/m^2, 25^{o}C. Figure 5 shows the simulated waveforms of $V_{pv}/I_{pv}/P_{pv}$ / V_{dc} under steady state condition. Similarly, the grid side voltage and current is depicted in figure 6.

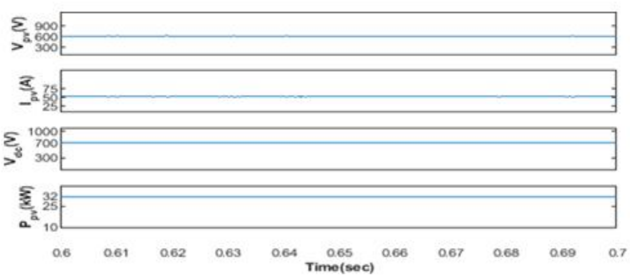


Figure 5: Steady state performance(V_{pv}/ I_{pv}/ V_{dc}/ P_{pv})

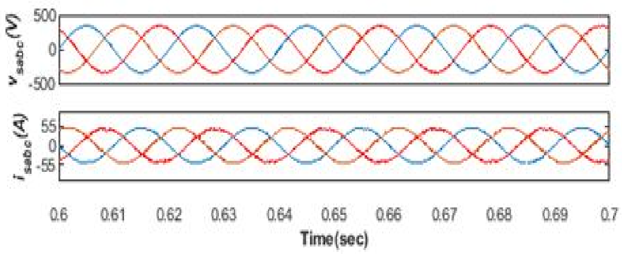


Figure 6: Steady state performance (Grid voltage and current)

From these analysis, the output current harmonic obtained using FLC is depicted in figure 7.

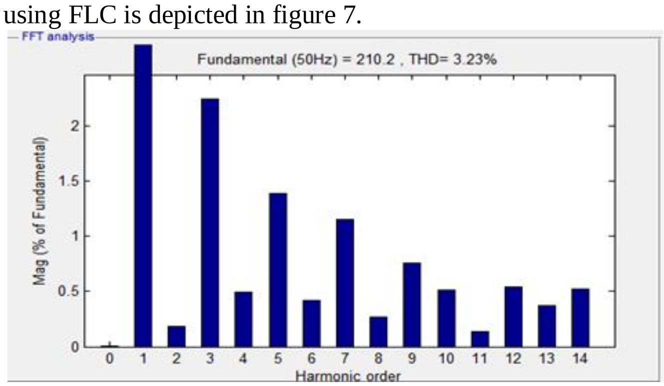


Figure 7: FFT analysis qZSI with FLC controller

VIa. Analysis of the system under insolation variation

Under this condition, the solar insolation is changed from 1000 W/m^2 to 600 W/m^2 at0.65 sec and the response of the same is depicted in figure8.

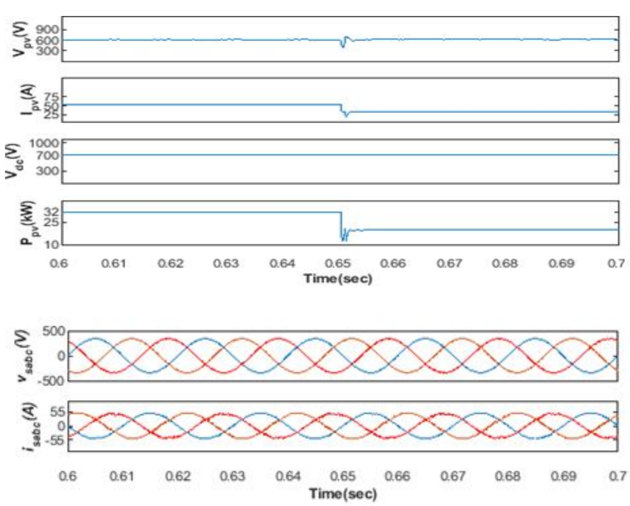


Figure 8: Performance under varying irradiation

From the figure 8, it is found that the voltage and current of the PV system gets affected due to variation in insolation. However, the FLC maintains the V_{dc} constant and maintains the grid voltage and current as the same steady state operation. Two different controllers (PI and FLC) compared in terms of THD is depicted in table 3.

Table 3: Comparative analysis

		Simulation	
S.No	**Parameters**	**PI**	**FLC**
1	THD in %	6.89%	3.23%

From the table, it is proven that replacing PI with FLC results in lower THD. Therefore, the results agree with feasibility of FLC controlled QZSI to improve the power quality.

VII. CONCLUSION

In this work, the performance of FLC based qZSI is analyzed for PV grid interconnected inverter strategy. From the analysis, the following conclusions are derived

1) The 3Φ QZS PV grid integrated inverter controlled by FLC enriches the robustness of the system thereby reducing THD.
2) Similarly, it has more resistivity to grid frequency offset and hence, the THD rate is about to 3.23% which is lower when compared to traditional controller.
3) It has more preventing effect on high-order harmonics.

Thus, it is concluded that this proposed strategy can significantly reduce the steady-state error. It also improves the robustness by easiest control structure design.

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