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Fuzzy Based Improvement of Power Quality in 1-Φ Grid-Connected PWM Voltage Source Inverter

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Abstract- The Distributed generated system originated due to the demand of electrical energy and keen scarcity of conventional energy sources. The main problem is the harmonization of the DG to the utility grid. Usually, for synchronizing the utility grid with DG source current regulated PWM voltage-source inverters (VSI) are used in order to meet the following objectives: 1) To improve grid stability 2) To control active and reactive power through voltage and frequency control 3) Improvement of power quality, etc. By using Fuzzy with hysteresis controller enhancement of power quality is made by diminishing current error at higher band width. This system is modeled and simulated in the MATLAB/Simulink model and the results obtained are compared with conventional hysteresis controller.

Index Terms- Hysteresis current controller, Fuzzy logic controller, Point of common coupling (PCC), distributed generation (DG), utility grid and Power quality.

I. INTRODUCTION

To meet the future energy demand of electricity DGs are the viable option as because it can provide a 1) secure and diversified energy options, 2) increase the generation and transmission efficiency, 3) reduce the emissions of greenhouse gases, and 4) improve the power quality and system stability. In spite of the several advantages, the main technical challenge is the synchronization of the DGs with the utility grid according to the grid code requirements [1].

In most of the cases power electronics converter, especially current controlled PWM-VSI are used for the integration of the DGs with utility grid. However, the converter performance is largely depends on the applied current control strategy. Very extensive research work has been done besides current control techniques and is available in the literature. [2].

The common strategies of current controllers can be classified as ramp comparator, hysteresis controller, and predictive controller amongst which the hysteresis controllers are widely used because of their inherent simplicity and fast dynamic response [3]. The main objectives of the control of grid connected PWM-VSI is to 1) ensure grid stability 2) active and reactive power control through voltage and frequency control 3) power quality improvement (i.e. harmonic elimination) etc. In this paper fuzzy with hysteresis controller is proposed to enhance the power quality by diminishing current error at higher band width. The studied system is modeled and simulated in the MATLAB/Simulink environment and the result obtained is compared with the conventional hysteresis controller.

The paper is organized as follows –Single-phase grid connected VSI is described in Section II. Analysis of hysteresis and hysteresis with fuzzy current controller is explained in the section.III. Section IV. Dedicated to results and discussion, followed by conclusion in Section V.

II. SINGLE PHASE GRID-CONNECTED VSI

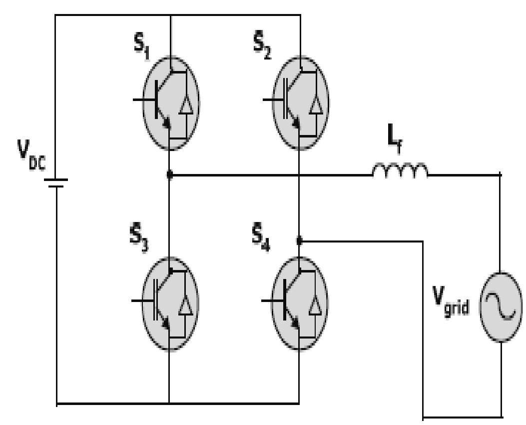

Figure 1. Single phase inverter connected to utility grid

The single-phase grid connected inverter shown in Fig.1.Which is composed of a dc voltage source (VDC), four switches (S1-S4), a filter inductor (Lf) and utility grid (Vg).

In inverter-based DG, the produced voltage from inverter must be higher than the Vg in order to assure power flow to grid. Since Vg is uncontrollable, the only way of controlling the operation of the system is by controlling the current that is following into the grid.

III. ANALYSIS OF HYSTERESIS AND FUZZY WITH HYSTERESIS CURRENT CONTROLLER

A. *Hysteresis band current controller*

In spite of several advantages, some drawbacks of conventional type of hysteresis controller are limit cycle oscillations, overshoot in current error, sub-harmonic generation in the current and uneven switching [4].In case of hysteresis controller as shown in fig.2 the error is directly fed to the hysteresis band.

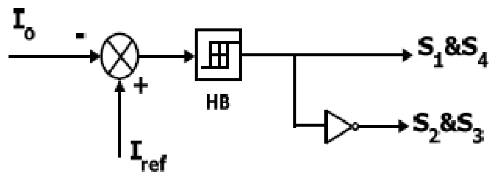

Figure 2. Hysteresis –Band Current Controller

As given by equation (1) the reference line current of the grid connected inverter is referred to as iref and difference between io and iref is referred to as error (e). The hysteresis band current controller assigns the switching pattern of grid connected inverter.

$$e = i_o - i_{ref} \qquad (1)$$

The switching logic is formulated as follows:

If e >HB then switch S1 and S4 is on
If e <-HB switch S2 and S3 is on

The average load power is computed as:

$$p_L = \frac{1}{n}\sum_{i=1}^{n} V_s(j) i_L(j) \qquad (2)$$

Using Torrey and Al-Zalmel [6] methodology, the reference source current is computed as:

$$i_{ref} = kV_g \qquad (3)$$

Where k is the scaling factor and computed as

$$k = \frac{2p_L}{V_m^2} \qquad (4)$$

The switching frequency of the system can be calculated as

$$V_{dc} = L_f \frac{d_{io}}{dt} + V_g \qquad (5)$$

From equation (1)

$$i_o = i_{ref} + e \qquad (6)$$

By rearranging equation (5 and 6) we can calculate

$$T_{OFF} = \frac{2L_f HB}{V_{dc} + V_g} \qquad (7)$$

((7)

And

$$T_{ON} = \frac{2L_f HB}{V_{dc} - V_g} \qquad (8)$$

$$\frac{1}{f_s} = T_s = T_{ON} + T_{OFF} \qquad (9)$$

$$f_s = \frac{(v_{dc}^2 - v_g^2)}{4v_{dc} L_f HB} \qquad (10)$$

Hence, the switching frequency varies with the dc voltage, grid voltage, load inductance and the hysteresis band [7].

B. The fuzzy with hysteresis current controller

The main drawback of hysteresis current controller is uneven switching frequency which causes acoustic noise and difficulty in designing input filters during load changes. The switching frequency can be reduced by reducing the band width of the hysteresis band but at the same time the current error will increase which produce more distortion in the output current.

To eliminate drawback up to certain extent fuzzy is used along with hysteresis current controller as shown in fig.3 [5].

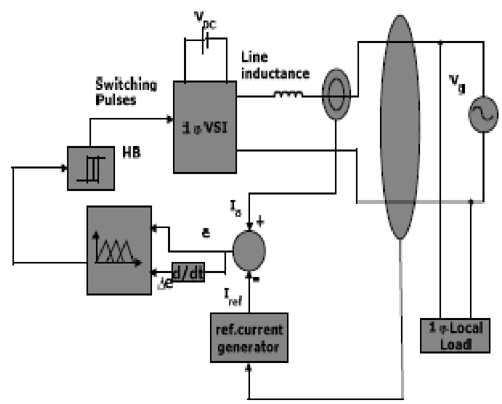

Figure 3. Block diagram for fuzzy with hysteresis current control for single phase grid-connected VSI

The structure of fuzzy logic controller is given below in fig 4.

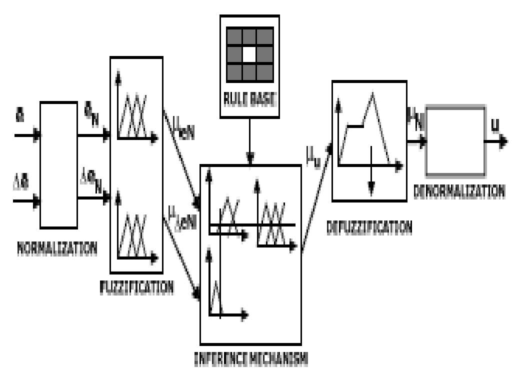

Figure 4. Structure of Fuzzy logic controller

Here the membership function is chosen as triangular as shown in fig 5. The input is taken as error (e) and the change in error (Δe) .Total 49 rules are taken into account as given in table -1.

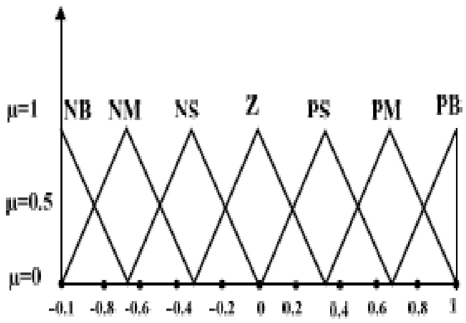

Figure 5. Membership function

For Example:

If e is negative small (NS) and
Δe is positive big (PB)

Then output is positive medium (PM).

Table-1-Rule base for fuzzy controller

e \ Δe	NB	NM	NS	Z	PS	PM	PB
NB	NB	NB	NB	NB	NM	NS	Z
NM	NB	NB	NB	NM	NS	Z	PS
NS	NB	NB	NM	NS	Z	PS	PM
Z	NB	NM	NS	Z	PS	PM	PB
PS	NM	NS	Z	PS	PM	PB	PB
PM	NS	Z	PS	PM	PB	PB	PB
PB	Z	PS	PM	PB	PB	PB	PB

IV. RESULTS & DISCUSSION

The section reveals the simulation results for fuzzy with hysteresis current control algorithm applied to single-phase mains connected inverter system and also the result is compared with conventional hysteresis controller on the basis of current error and harmonic distortion. The studied model has been developed and simulated in the MATLAB/Simulink environment. For simulation, the Dc-link voltage is taken 400V, and the grid voltage is 240V, the inductance of the line is 5mH and the utility grid frequency is 50Hz.

A. Simulation results under steady state conditions

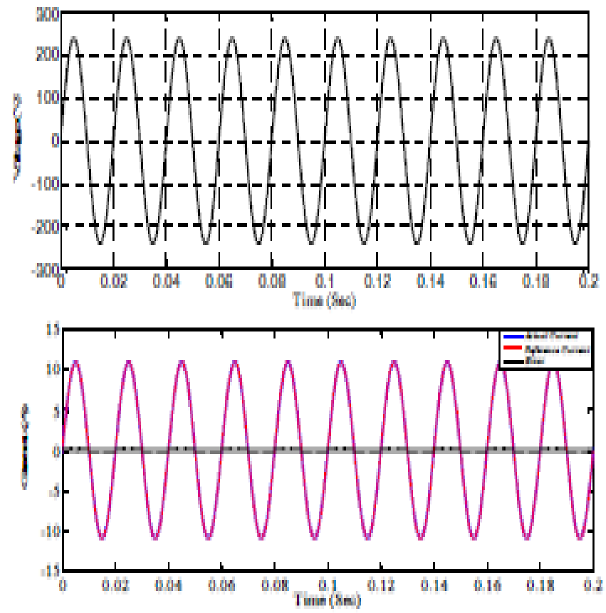
Figure 6. Simulation results of the fuzzy with hysteresis current controller for steady state (a) grid voltage (Vg) (b) reference current, actual current and current error.

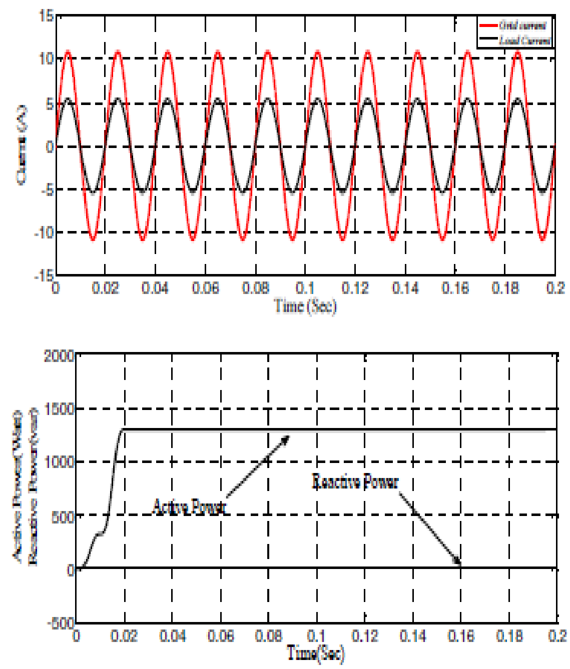

Fig 7 shows that that the proposed controller is able to control the active and reactive power independently.

B. Simulation results during Transient condtions

1) Response with Step changes in the load

To analyze the performance of the hysteresis and fuzzy with hysteresis controller the load is changed between the period 0.06 and 0.14 sec.

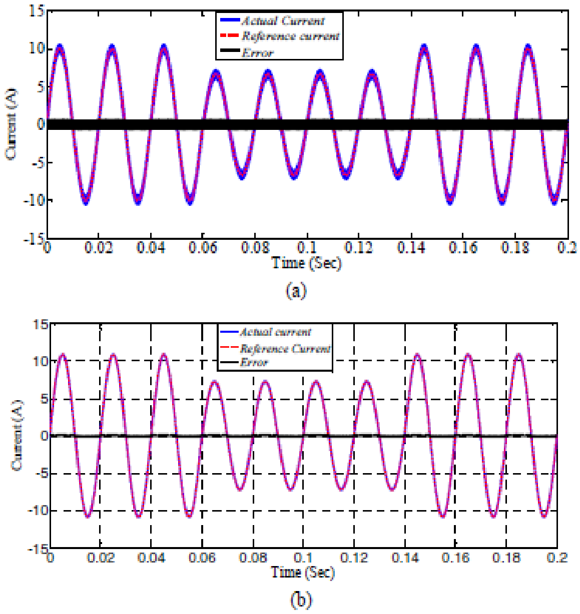

Figure 8. Simulation results of reference current, actual current and error for change in load (a) hysteresis (b) fuzzy with hysteresis current controller

From fig 8(a) we can observed that the current error is more in case of conventional controller. In the proposed controller the distortion in the inverter current is less and hence the error is less as shown in fig 8(b).

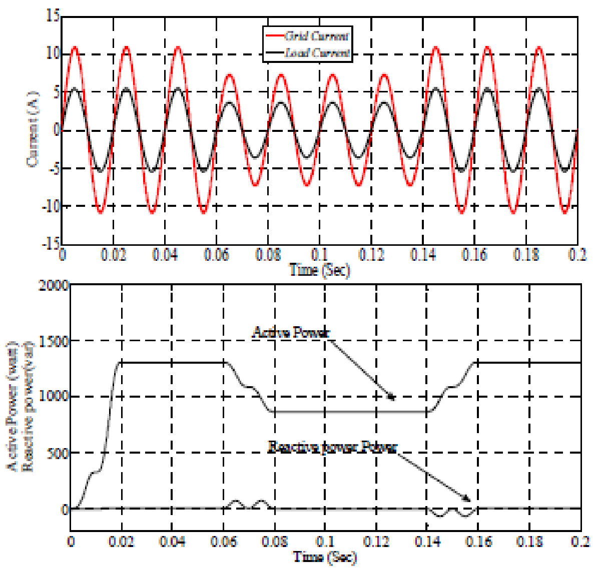

Figure 9. Response of grid parameters (a) load current and grid current (b) active power and reactive power.

Fig.9 shows the change in active power, load, current and grid current during the load transient which shows that the dynamic response faster of the proposed controller.

2) Effect of changes in the hysteresis band-width

In this case the hysteresis band width is changed at time t= 0.1 sec from HB=1 to HB=3

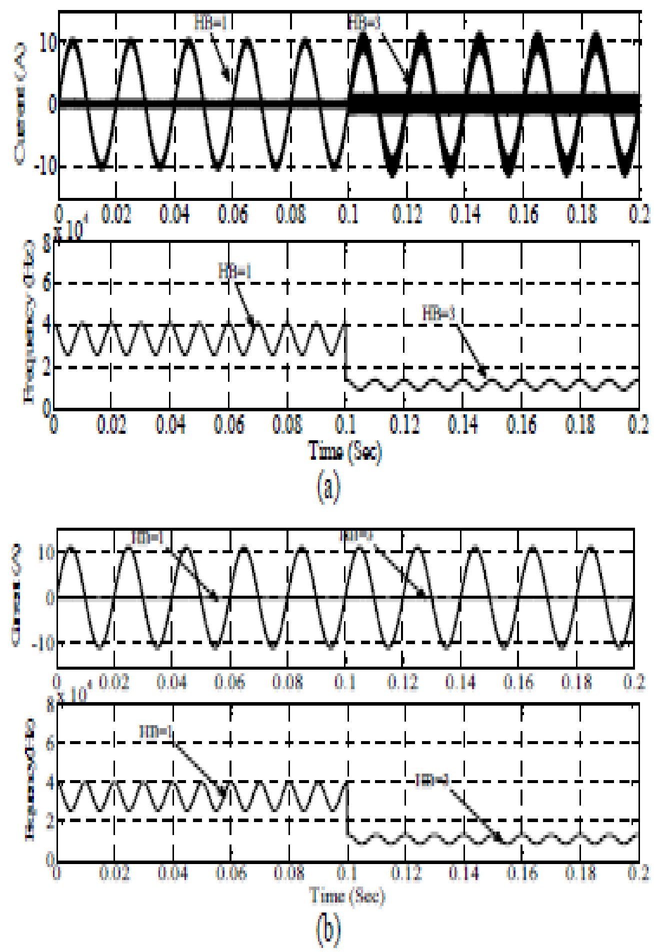

Figure 10. Simulation result of grid current ,error and switching frequency (a) for hysteresis controller (b) fuzzy with hysteresis controller.

As the band width of the hysteresis controller is increasing the switching frequency decreases but the current error increase so also the distortion in the grid current increases as shown in fig.10 (a).

In the proposed controller even if the band width increases the distortion in grid current and change in error is very less as shown in fig 10(b), It implies that the switching frequency can be decreased without hampering the power quality.

3) Effect of Phase changes in the grid voltage

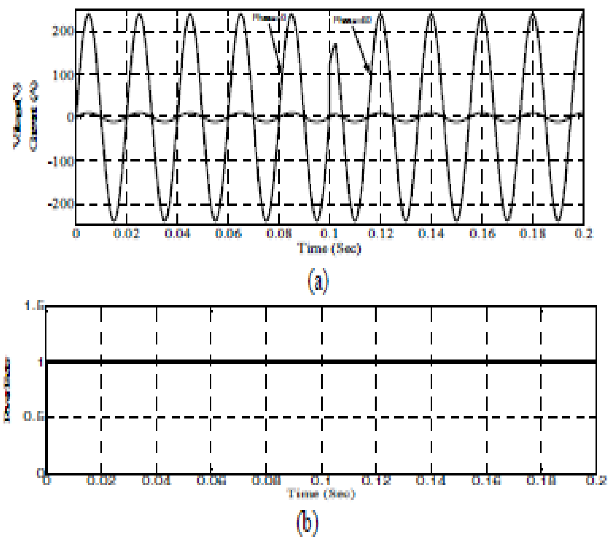

Figure 11. Simulation result of (a) grid voltage and inverter current frequency (b) power factor

In studied current control scheme the inverter is also able to inject the current in phase with the grid voltage.fig 11. (a) Shows that the current is in phase with the voltage even if the there is a phase change in the grid voltage at 0.1 sec. Fig 11. (b) Indicates the power factor of the grid current which is unity.

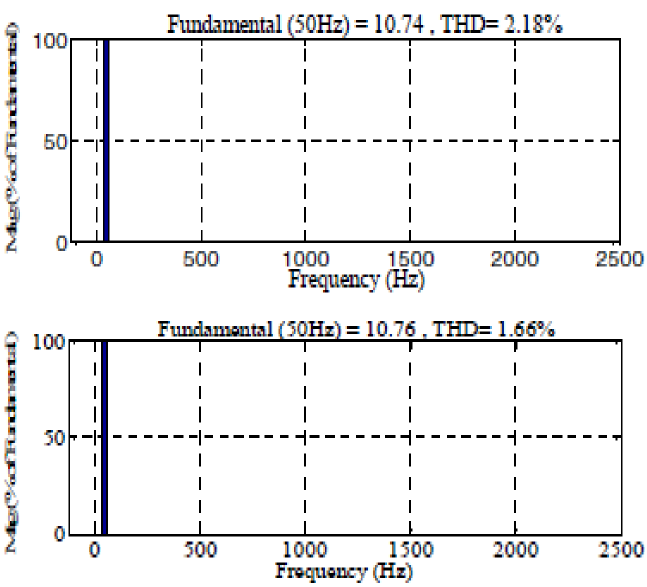

Figure 12. THD of grid current (a) Hysteresis current controller (b) fuzzy with hysteresis current comptroller

The THD of the proposed controller is considerably less 1.66% as shown in fig.13 as compared to conventional hysteresis controller which is found to be 2.18% as in fig.14.

V. CONCLUSIONS

The paper presents the control grid connected PWM VSI using fuzzy with hysteresis controller in the control loop. From the study we observed that, fuzzy with hysteresis current controller can able to enhance the power quality of the grid system as it is enable to reduce switching frequency even if the band width increased without any significant increase in the current error. As a result, the THD level of grid current is considerably reduced as compared to conventional hysteresis current controller. Moreover, switching frequency of the inverter system has been reduced, in that in turn, switching losses are also reduced to certain extent.

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