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Power Quality Improvement of 1-Φ Utility Grid Connected PWM Inverter using Back Propagation Nueral Network with Hysteresis Current Controller

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Abstract

Artificial neural-networks (ANN) are one of those words that are getting fashionable in the new era of technology. Current regulated PWM voltage source inverters used for synchronizing the utility grid with distributed generation source. Using ANN application with hysteresis current controller improving grid stability, active and reactive power control through voltage and frequency control etc., to the utility grid. ANN hysteresis current controller results are compared with conventional hysteresis controller. The studied system is modeled and simulated in the MATLAB.

Keywords— ANN controller, Hysteresis current controller, Distribution generation & active and reactive powers, single phase grid connected

Introduction

DGs are the future demands to really meet their desires of supply of electricity the viable option providing different thing like grid stability, power factor improvement making unity, increase the generation and transmission efficiency and controlling of reactive power in the grid [1]. In most of the cases power electronics converter, especially current controlled PWM-VSI is used for the integration of the DGs with utility grid. 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 a) power quality improvement (power factor unity and harmonic elimination) b) To made grid stability c) To control active power and reactive power through voltage and frequency control In this paper ANN with hysteresis controller is proposed to enhance the power quality by diminishing current error at higher band width and compare the results with conventional hysteresis current controller.

The paper is organized as follows – Analysis of hysteresis and hysteresis with ANN current controller is explained in the section. II. Single phase grid connected PWM inverter in section III. Section IV is results and discussion, conclusion in section V.

ANALYSIS OF HYSTERESIS AND ANN HYSTERESIS CURRENT CONTROLLER

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.1 the error is directly fed to the hysteresis band.

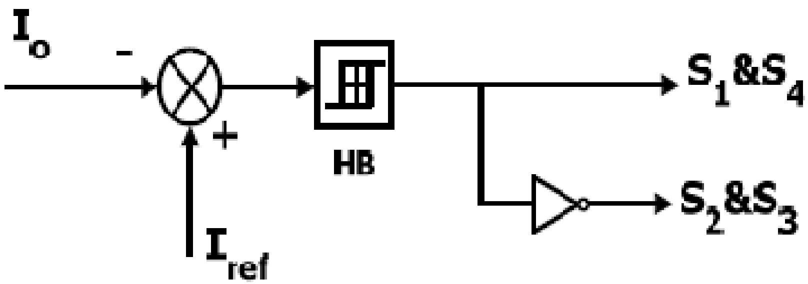


Fig 1. Hysteresis –Band Current Controller

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.

$$e = i_0 - i_{ref} \tag{1}$$

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 power computed as:

$$P_L = \frac{1}{n}\sum_{j=1}^{n} v_s(j) i_L(j) \tag{2}$$

Using Torrey and Al-Zalmel [5] methodology, the reference source current is computed as

$$i_{ref} = K v_g \tag{3}$$

Where k is the scaling factor and computed as

$$k = \frac{2p_L}{V_m{}^2} \tag{4}$$

The switching frequency calculated as

$$V_{dc} = L_f \frac{di_0}{dt} + V_g \tag{5}$$

From equation (1)

$$i_0 = i_{ref} + e \tag{6}$$

By arranging equation (5 and 6) we can calculate as

$$T_{ON} = \frac{2L_f HB}{V_{dc} - V_g} \tag{7}$$

And

$$T_{off} = \frac{2L_f HB}{V_{dc} + V_g} \tag{8}$$

$$\frac{1}{f_s} = T_s = T_{ON} + T_{OFF} \tag{9}$$

$$f_s = \frac{(V_{dc}^2 - V_g^2)}{4V_{dc} L_f HB} \tag{10}$$

Hence, the switching frequency varies with the dc voltage, grid voltage, load inductance and the hysteresis band [6].

The ANN with hysteresis current controller

The main drawback of conventional hysteresis current controller has acoustic noise for uneven switching frequencies and difficulty for 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 ANN is used along with hysteresis current controller as shown in fig.2.

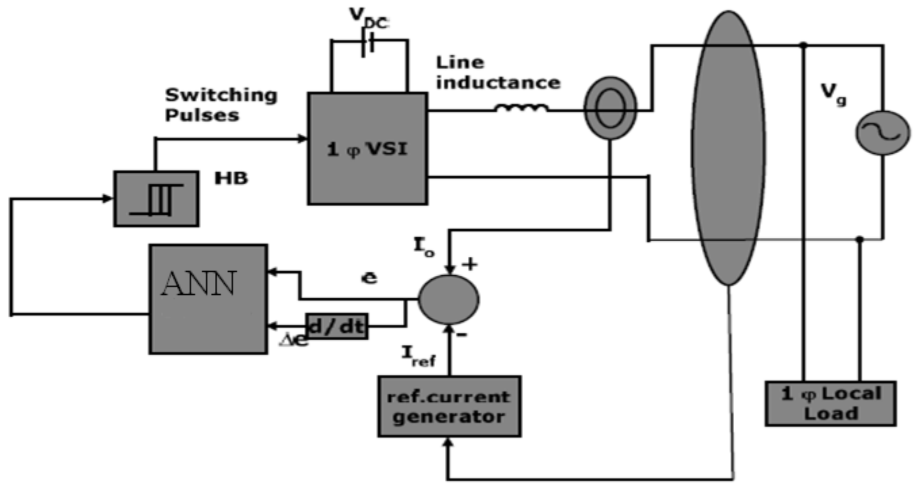
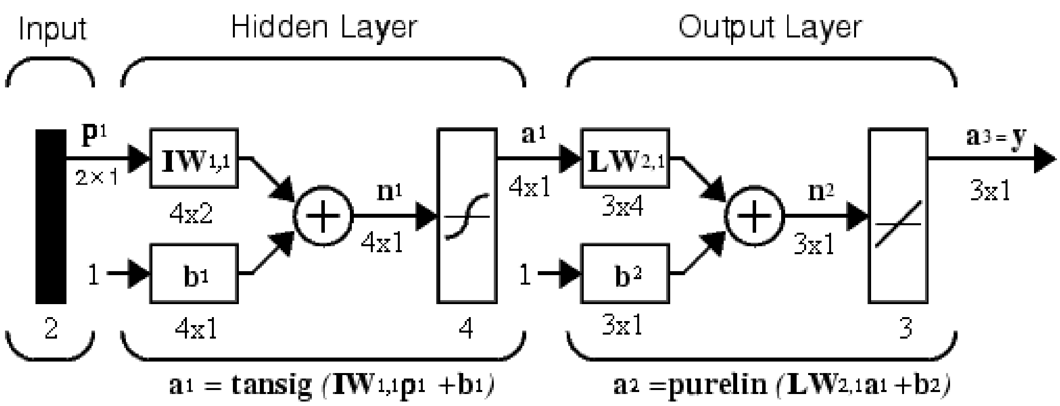


Fig2 Simulation Block diagram for ANN with hysteresis current control for single-phase grid-connected VSI

Artificial neural networks are models of biological neural structures. In this case we are using artificial neural network as shown in Fig3. In our case, we will only describe the structure, mathematics and behaviour of that structure known as the back propagation network. This is the most prevalent and generalized artificial neural network currently in use.

The structure of ANN is given below in fig3



Input is given to the hidden layer i.e., the sum of the weighted inputs and the bias forms the input to the hyperbolic tangent sigmoid transfer function and hidden layer output is given to the output layer of linear transfer function. Finally output is given to the hysteresis band current controller.

SINGLE PHASE GRID CONNECTED VOLTAGE SOURCE INVERTER

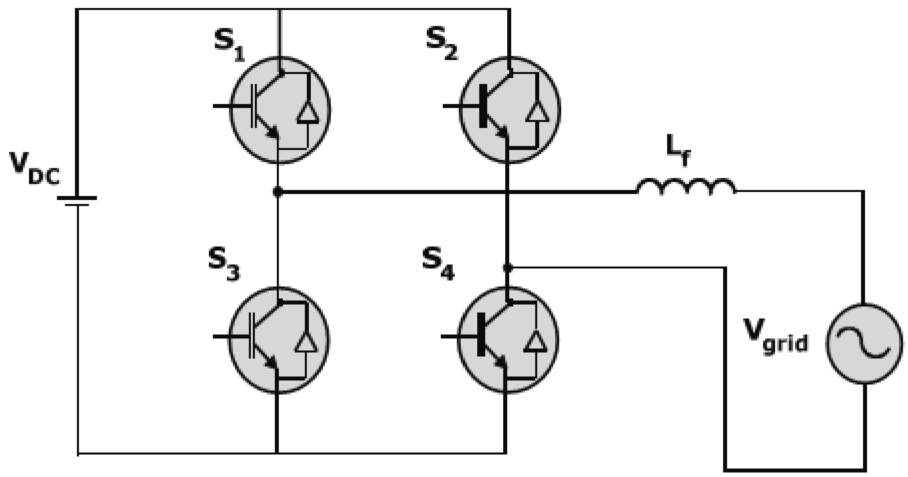


Fig4. Voltage source inverter connected to utility grid

Single phase grid connected voltage source inverter is shown in fig.4. Here four switches (S_1-S_4), a dc voltage source, inductor filter and utility grid. In this circuit voltage produced from voltage source inverter must be higher than the V_g in order to power flow to grid. This is only way of controlling operation of the system by controlling current that following into grid.

RESULTS & DISCUSSION

This section is discussion about results of ANN hysteresis current controller connected to single phase grid connected voltage source inverter system and also discussion about results compared with conventional hysteresis current controller on basis of current error and harmonic distortion. This model is studied in MATLAB simulation environment. For simulation DC link is taken 400V, the grid voltage is 220V, the inductance line is 5mH and utility grid frequency is 50 HZ.

Simulation results under steady state conditions

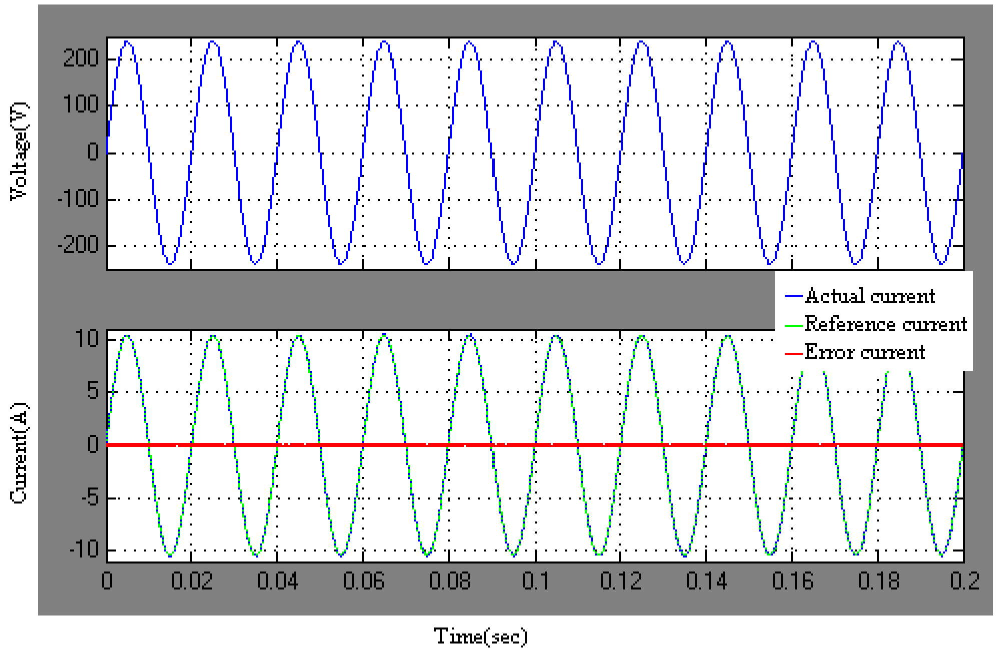


Fig.5 Simulation results of the ANN with hysteresis current controller for steady state grid voltage (Vg), reference current, actual current and current error

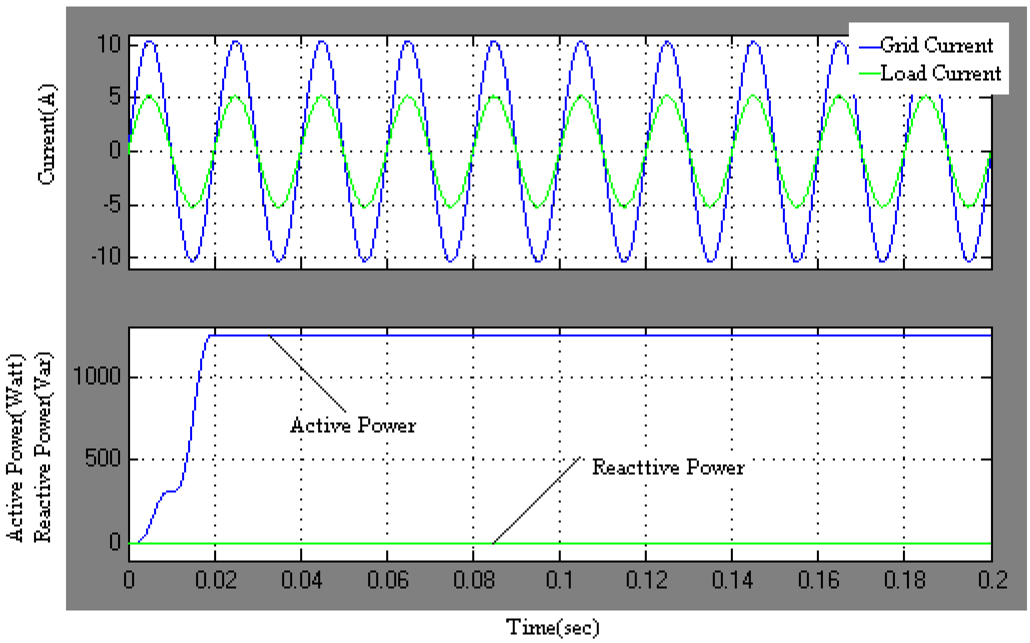
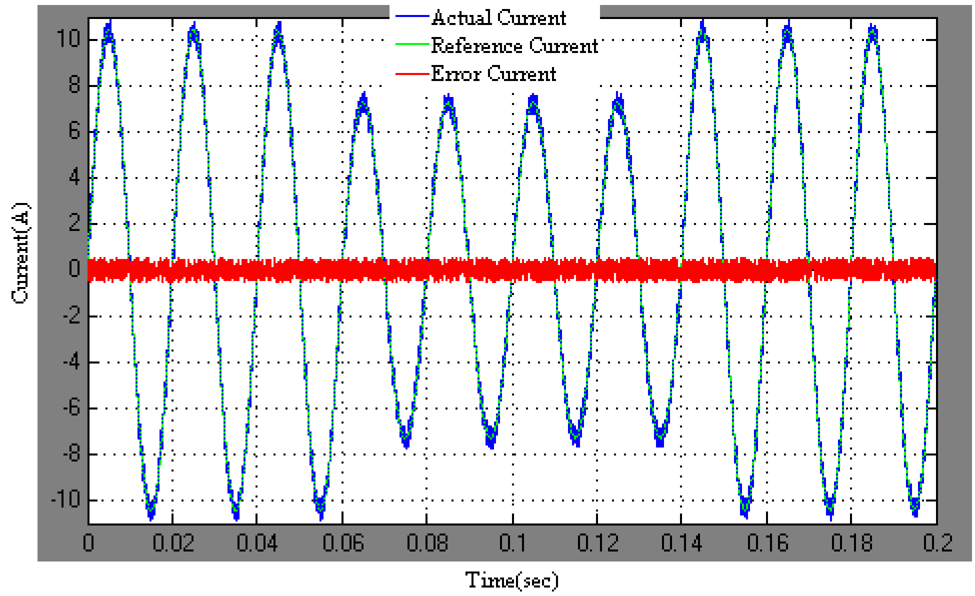


Fig.6 Response of parameters Grid current and load current, Active power & reactive power

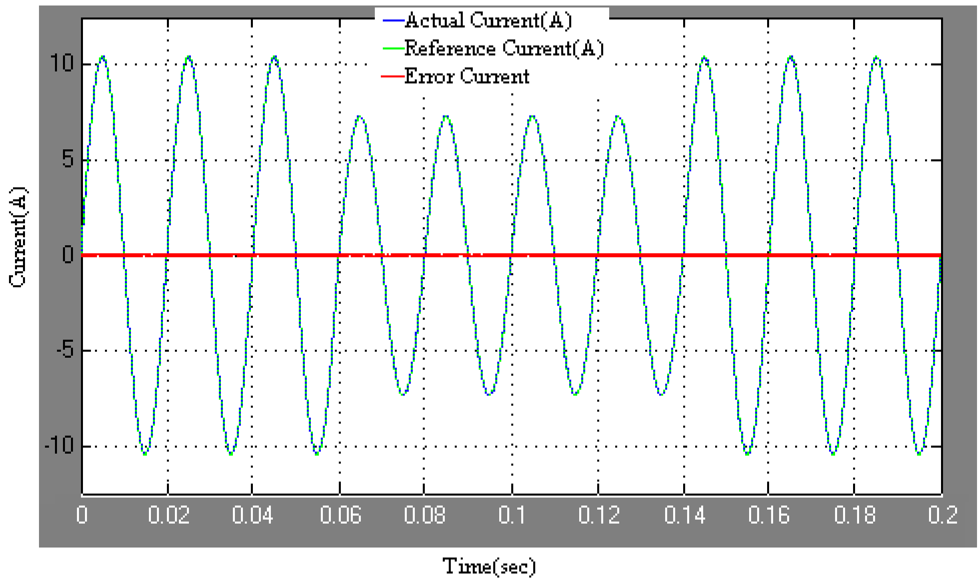
Fig.6 shows that that the proposed controller is able to control the active and reactive power independently.

Simulation results during Transient conditions
Response with Step changes in the load

To analyze the performance of the hysteresis and ANN with hysteresis controller the load is changed between the period 0.06 and 0.14 sec and error in current.



(a)



(b)

Fig .7 Simulation results of reference current, actual current and error for change in load (a) hysteresis (b) ANN with hysteresis current controller

From fig 7(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 figure 7(b).

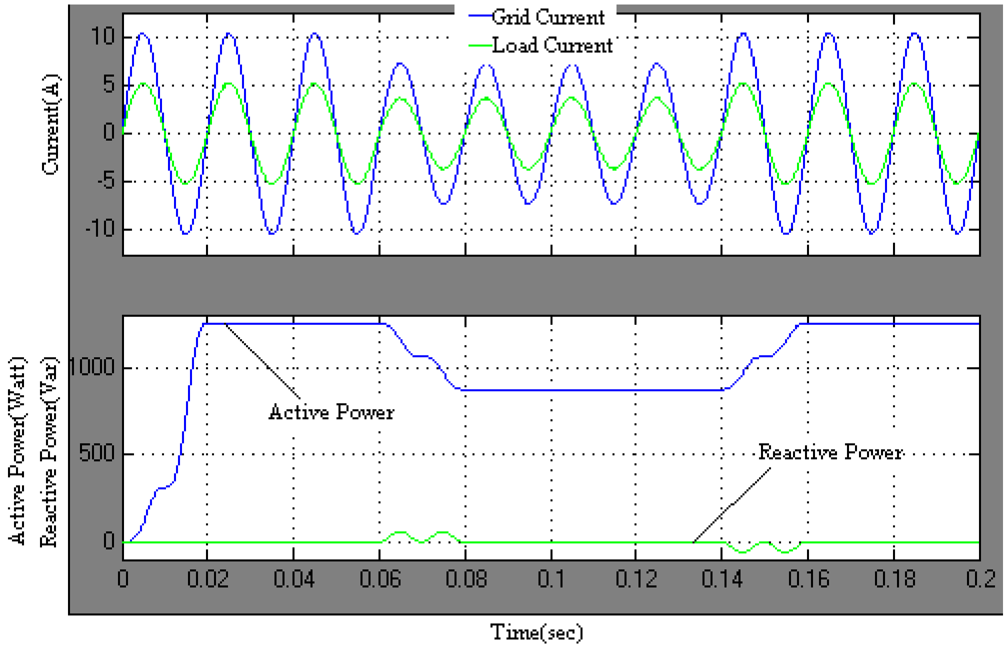
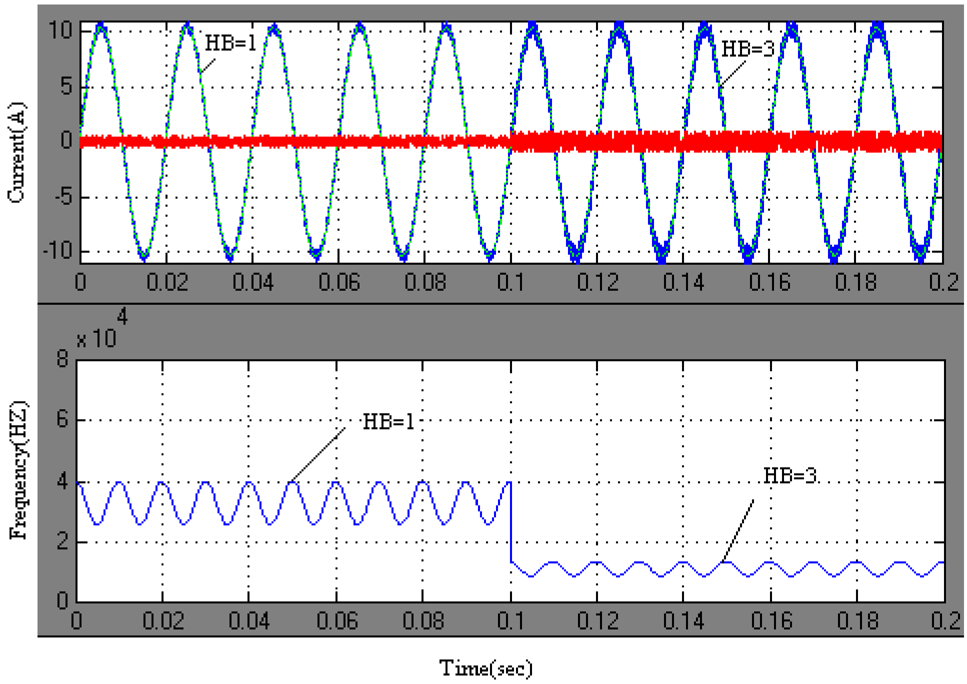


Fig.8 Response of grid parameters load current and grid current , active power and reactive power

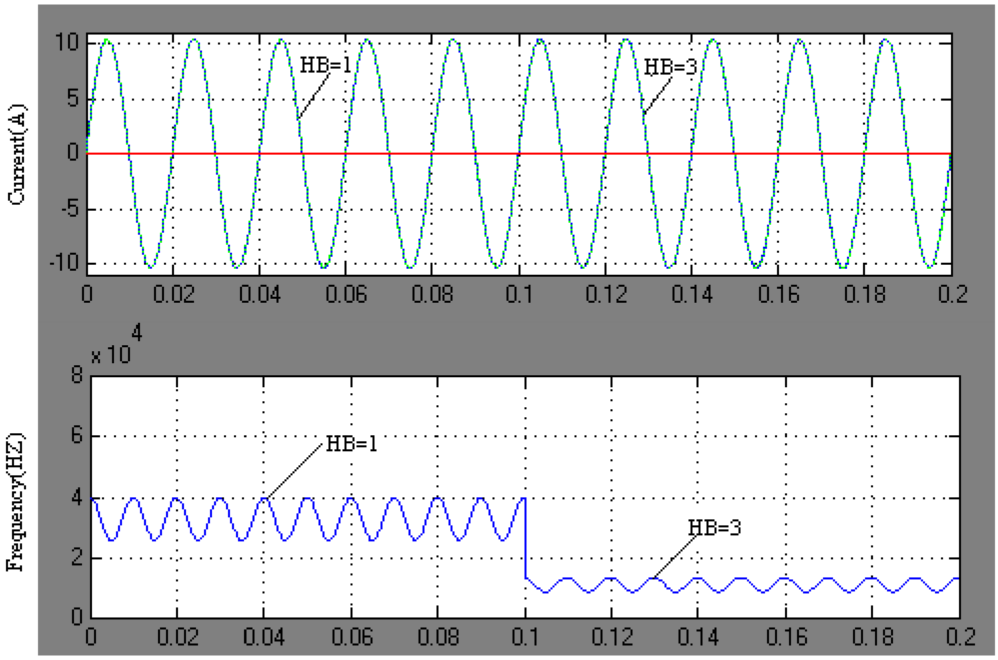
Fig.8 shows the change in active power, load, current and grid current during the load transient which shows that the dynamic response faster of the proposed controller.

Effect of changes in the hysteresis band-width

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



(a)



(b)

Fig.9. Simulation result of grid current, error and switching frequency (a) for hysteresis controller (b) ANN with hysteresis controller.

Here fig.9 (a) shows conventional hysteresis current controller increasing bandwidth switching frequency decreases then current error increases as well as distortion in grid current increases. In proposed controller even if bandwidth increases the distortion of grid in current and change in error is very less as shown in fig.9 (b), It implies that the switching frequency can be decreased without hampering the power quality.

Effect of Phase changes in the grid voltage

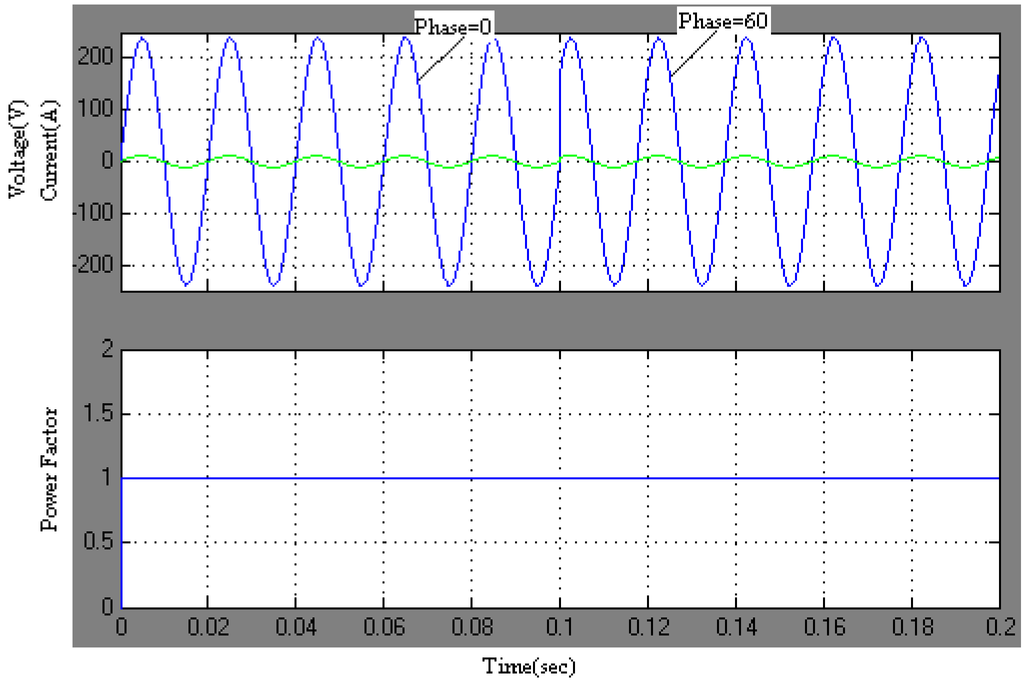
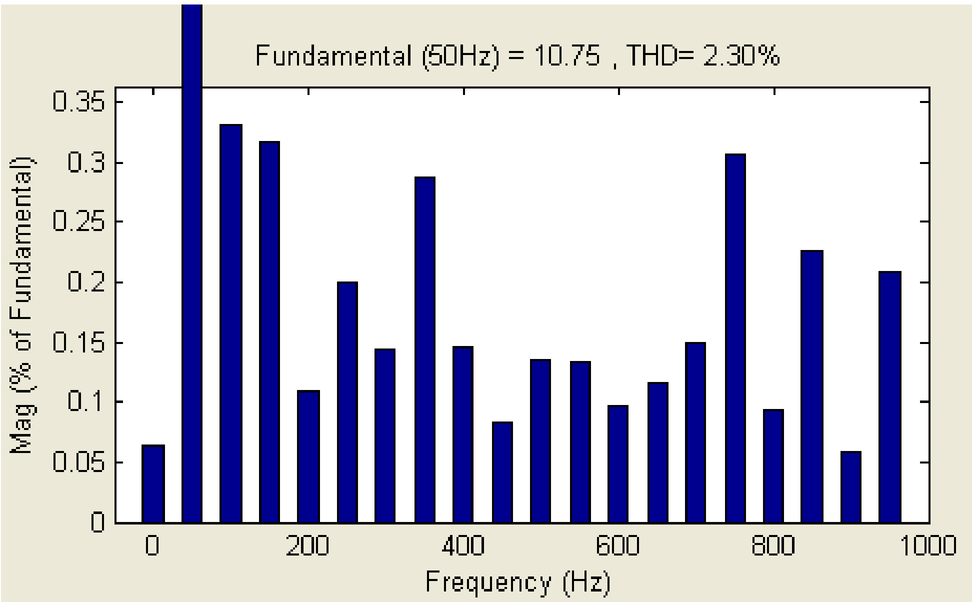
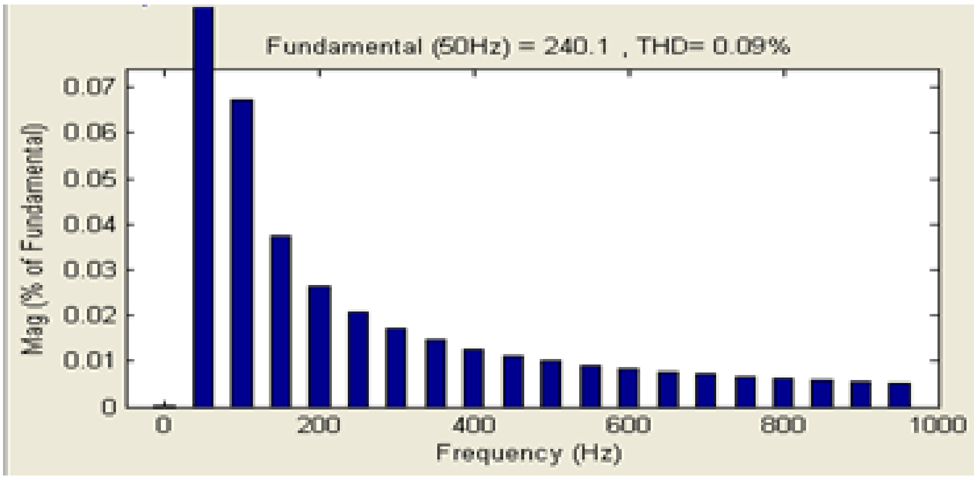


Fig.10. Simulation result of grid voltage and inverter current frequency, power factor

In studied current control scheme the inverter is also able to inject the current in phase with the grid voltage.fig 10Shows that the current is in phase with the voltage even if the there is a phase change in the grid voltage at 0.02 sec and indicates the power factor of the grid current which is unity



(a)



(b)

Fig.11. THD of grid current (a) Hysteresis current controller (b) ANN with hysteresis current comptroller

The THD of the proposed controller is considerably less 0.09% as shown in fig.11 (b) as compared to conventional hysteresis controller which is found to be 2.30% as in fig.11 (a).

CONCLUSION

From the study we observed that, ANN 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. The paper presents the control grid connected PWM VSI using ANN with hysteresis controller in the control loop 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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