Power Quality Improvement of Single Phase Grid Connected PWM Inverter Using Fuzzy With Hysteresis Current Controller

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Abstract

Abstract: *The ever mounting demand of electrical energy and the scarcity of conventional energy sources lead to the development of distributed generation (DG) system. The main problem is the harmonization of the DG to the utility grid. Generally current regulated PWM voltage-source inverters (VSI) are used for synchronizing the utility grid with DG source in order to meet the following objectives like: to ensure grid stability, active and reactive power control through voltage and frequency control and power quality improvement (i.e. harmonic elimination) etc. In proposed project hysteresis current control technique will be used as inverter control technique, which is one of the feedback control scheme. In addition to hysteresis current controller fuzzy will be used in order to improve performance. The proposed project is modeled using MATLAB/SIMULINK. The proposed project will be studied under two cases. The results obtained are compared with the conventional hysteresis controller.*

Key words: Hysteresis current controller, Fuzzy logic controller, distributed generation (DG), utility grid, Power quality.

1. Introduction

Ever mounting demand for the electrical energy leads to installation of more number of generation plants. But the installation of bulk power plants includes several socio-economic factors. At the same time non conventional energy sources are the emerging technology in the present .Unlike to conventional production of energy, non conventional production is not bulky and less efficient. Due to environmental aspects the non conventional power generation is encouraged. Conventional generation is done at remote places and through transmission and distribution power is fed to load centers. But most of the nonconventional power generation is onsite generation. And also the non conventional generation is done preferably in dc form. The generated power is tied to existing system to meet the demand. But the existing system for load is ac. Thus there is a need to convert this dc to ac by maintaining synchronism with the grid. For this purpose inverters are used. There are various types of inverters are available. Based on the conditional requirement the appropriate inverter is chosen.

In DC/AC conversion there is now a general preference to use voltage-source rather than current-source inverters. This trend, which grew in the last two decades, is mainly justified by the introduction of power devices with self turn-off capability and by the advantages of a capacitive DC storage, over an inductive one, in terms of weight, cost and efficiency. Additional advantages are determined by the fact that this kind of converters is well matched with the inductive characteristic of usual AC loads, without the need of output filter capacitors, and the majority of modern power devices have anti-parallel free-wheeling diodes, deriving from their physical structure or included in the package. As a result, voltage source inverters (VSI) have become a simple and reliable solution.

On the other hand, motors and other AC loads which are usually fed by converters exhibit in general better performance and faster response if they are current-fed rather than voltage-fed**.** In AC motors, current control reduces the dependence on stator parameters and allows an immediate action on the torque delivered by the machine. In other AC loads, such in the case of UPS, current control results in an increased stability of the control loop and in an intrinsic short-circuit protection. These requirements can be fulfilled, while keeping the advantages of the VSI power structure, by a closed-loop regulation of the AC currents produced by the inverter. This solution ensures several additional advantages. Among them, it gives the control of the current waveform within the AC period, which compensates also for load transients and nonlinearities and for commutation delays. The feedback loop results also in some limitations: fast-response voltage modulation techniques must be employed, such as Pulse Width Modulation (PWM) or Discrete Pulse Modulation (DPM).

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When the conversion takes place from dc to ac the output of the inverter is to be ensured that it should not disturb the existing system at any cost. However the output of the inverter consists of harmonics which causes the grid to unstable. Generally wide range of filters are designed to filter these harmonics. Though the filters are designed the harmonic content is not reduced to zero. Thus variety of control strategies are available for the control of inverter. In the proposed project the inverter control strategy used is hysteresis current controller. Which is feedback control of the inverter and also one of the techniques of pulse width modulation techniques (pwm). In the proposed project the single phase grid connected inverter is controlled with hysteresis current controller with fuzzy. The proposed project is studied under two conditions. Namely step changes in load, changes in the grid voltage phase angle. Some of the basic terminology is reviewed below.

2. Fuzzy Logic Controller

The real world is complex. Fuzzy logic extends Boolean logic to handle the expression of vague concepts. Complexity in the world generally arises from uncertainty in the form of ambiguity. In reasoning about a complex system, human reason approximately reveals about its behavior; thereby maintaining only a generic understanding about the problem the closer lood at the problem reveals the "FUZZY" is the solution.

As we learn more and more about the system, its complexity decreases and our understanding increase. As complexity decreases, the precision afforded by computational method become more useful in modeling the system. For systems with little complexity hence little uncertainty closed form mathematical expressions provide descriptions of the systems.

For systems that are a little more complex but for which significant data exists model free methods, such as artificial neural networks, provide a powerful and robust means to reduce some uncertainty through learning, based on problems in the available data. Fuzzy reasoning provides a way to understand system behavior by allowing us to interpolate approximately between observed input and output situations.

Imprecision in fuzzy model is generally quite high. Fuzzy system can implement crisp inputs and outputs, and can produce a non-linear functional mapping and algorithm. Fuzzy systems can focus on modeling problems characterized by imprecise information.

Fuzzy set theory provides a mean for representing uncertainties. Historically, probability theory has been the primary tool for representing uncertainty in mathematical model. Now fuzzy set theory is a marvelous tool for modeling the kind of uncertainty associated with vagueness, with impression, and/or with a lack of information regarding a particular element of the problem at hand.

2.1 General fuzzy system:

A fuzzy system is a static non-linear mapping between its inputs and outputs. The inputs and outputs and 'crisps'- that is , they are real numbers, not fuzzy sets.

The universe of discourse is the universe of all variable information on a given problem. Defining of universe enable to define certain events on this information space. The mathematical abstraction of these events is itself universe.

2.2 Membership functions:

Membership is an idea of mapping from an element in one universe to one of the other element in another universe. Figure 2.1 shows the typical membership functions.

Let u_i denote universe of discourse and A_i denote a specific linguistic value for a linguistic variable u_i , the function speed associated with A_1^J that maps to u_i to (0,1) is called membership function.

For example, if u_i =(-150,150) u_i = "speed" and A_i^j = "positive large" then speed may be triangular shape that peaks at one at $u_{i\,=}$ 75 and is near zero.

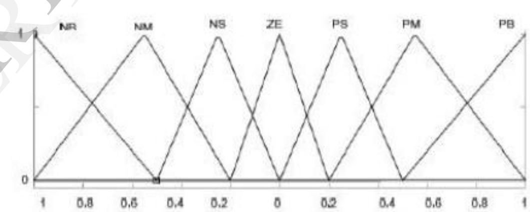

Fig 2.1:
Membership function

When u_i<50 or u_i>100, this membership function describes the "certainty" that an element of $u_{i.}$

2.3 Block diagram of FLC:

There are specific components characteristic of a fuzzy controller to support a design procedure. In the block diagram the controller is between a preprocessing block and a post-processing block. Figure 3.2 shows the block diagram of basic FLC.

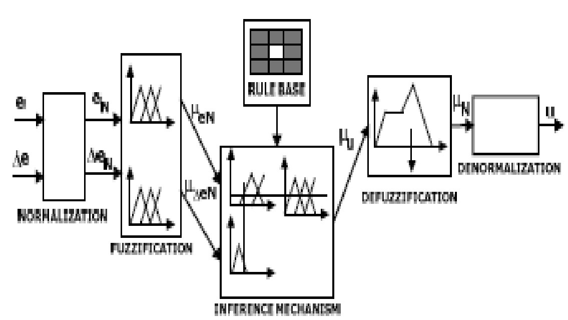

Fig 2.2: Block diagram of fuzzy logic controller

3. Proposed Inverter Topology

3.1 Proposed project topology:

In spite of several advantages, some drawbacks of conventional type of hysteresis controller are sub-harmonic generation in the current and uneven switching.

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 upto certain extent fuzzy is used along with hysteresis current controller as shown in figure 4.1.

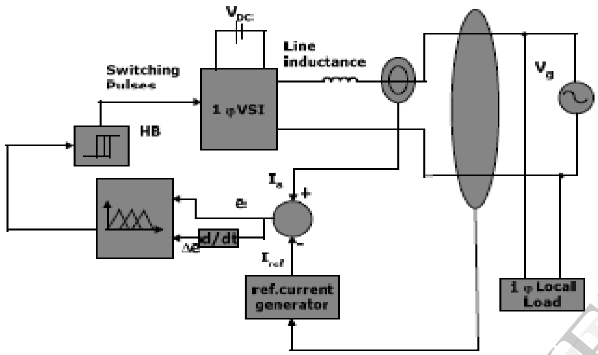

Fig 3.1 : Block diagram for fuzzy with hysteresis current control for singlephase grid-connected VSI

3.2 Reference current generation:

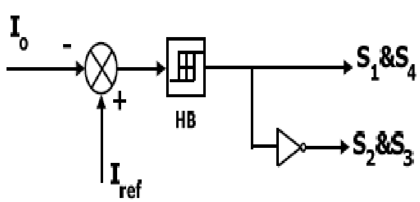

Fig 3.2: Hysteresis –Band Current Controller

As given by equation 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. Figure 4.2 represents reference current generation scheme.

As given by equation 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 = io –iref

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:

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

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

$$i_{ref} = k v_g$$

Where k is the scaling factor and computed as frequency of the system can be calculated as

$$k = \frac{2P_L}{V_m^2}$$

The switching frequency of the system can be calculated as

$$V_{dc} = L_f \frac{di_o}{dt} + V_g$$

$$i_o = i_{ref} + e$$

By rearranging the equations, we get

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

And

$$T_{OFF} = \frac{2L_f HB}{V_{dc} + V_g}$$

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

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

The proposed project is studied under two cases namely

- Step changes in the load
- Changes in the phase of grid voltage

On the basis of harmonic distortion and current error. The results are compared with the conventional hysteresis controller.

4. Implementation of Proposed Project

4.1 Circuit diagram of proposed project:

By connecting all the above implemented blocks we get the simulink diagram of proposed project. The results of simulation of this circuit is presented in the results chapter. The steady state parameters are observed in figure 6.1 to 6.3. Figure 4.1 shows the siulink model of proposed project.

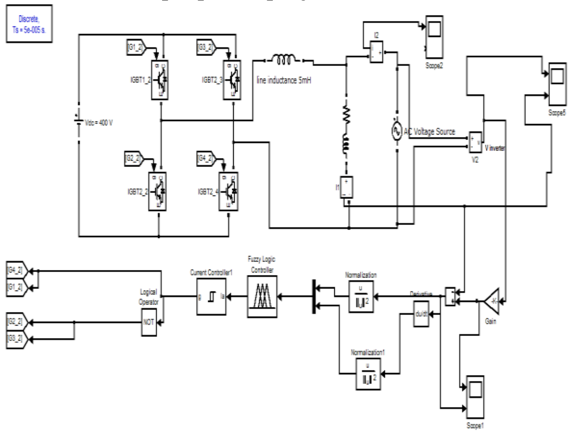

Fig 4.1: simulink model of proposed project

Now the proposed project is studied under two cases.

4.1.1 Case 1: Step Changes in the Load

Step changes in the load means there is sudden change in load (either removal or additional). To create step changes in load two loads are used. At specific time one load is disconnected there by created the step changes in load. This can be achieved by using circuit breaker block in the simulink shown in figure 4.2

4.1.2 Circuit breaker:

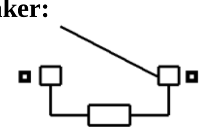

Fig 4.2: simulink model of circuit breaker

The breaker is set to open initially when the initial state parameter is set to zero. Then we have to give the closing and opening times within the square braces. By the time entered the circuit breaker opens and closes accordingly.

The simulink diagram of this case with fuzzy is shown in figure 4.3. Fuzzy results are compared with conventional circuit results in figure 5.6. The results are presented in the results chapter.

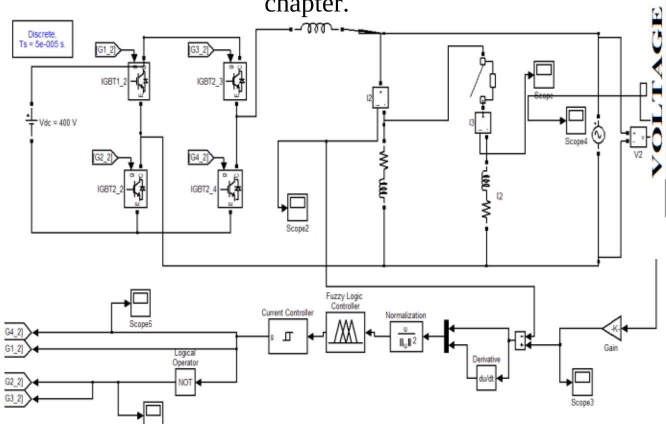

Fig 4.3: simulink model of case 1

4.1.3 Case 2:phase changes in the grid volage:

Initially the phase of the grid voltage is set to zero. At specific time the first voltage source is disconnected and a vlotage source of 60 degree phase shift is inserted in to the circuit with the help of circuit breaker which is shown in figure 4.4. The reults with fuzzy and with out fuzzy are compared. The results are presented in the results chapter and is shown in the figures 5.7 to 5.9.

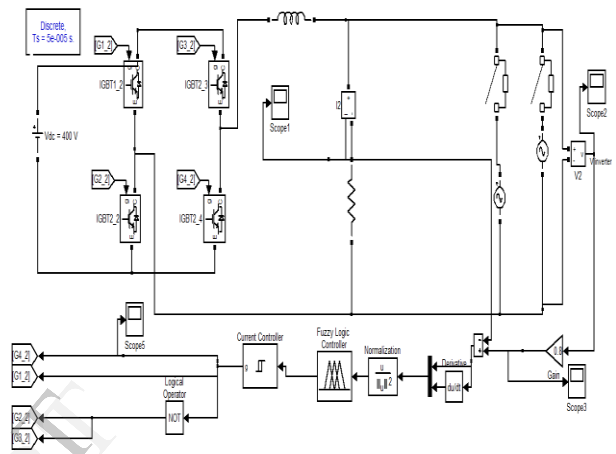

Fig 4.4: simulink model of case 2

5. Results and Discussion

Basic circuit:

The steady state results of the basic single phase grid connected inverter with fuzzy with hysteresis current controller is obtained by running the simulink model presented in the previous chapter. The grid voltage, load current, reference current, error and active and reactive power wave forms are obtained and shown in figures 5.1 to 5.3.

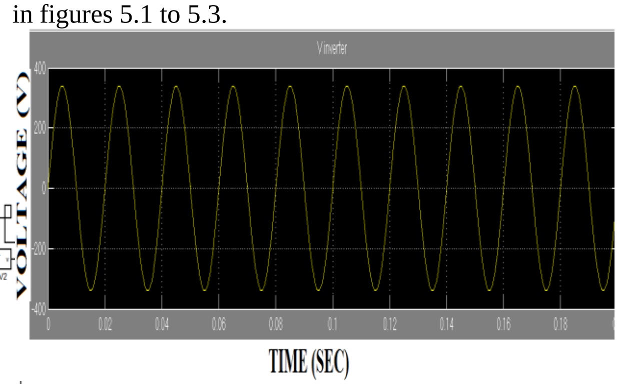

Fig 5.1: grid voltage

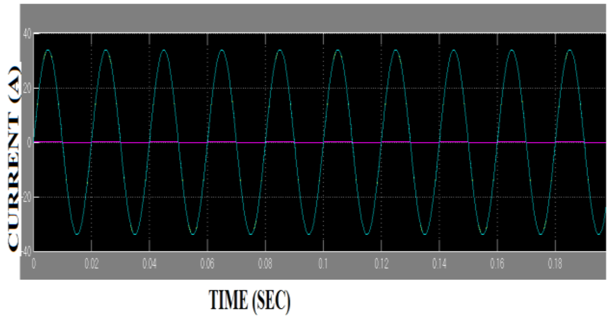

Fig 5.2: load current, reference current and error

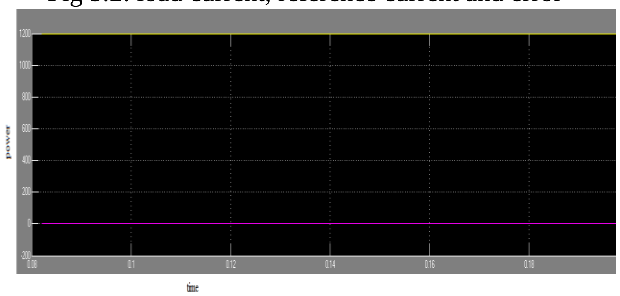

Fig 5.3 : active and reactive power

Case 1: Step changes in the load:

The results of step changes in the load with fuzzy and without fuzzy are presented. The results are compared on the basis of THD. And it is observed that the THD with fuzzy is less compared to without fuzzy. The load current, active and reactive power and THD analysis is shown in figures 6.4 to 6.6.

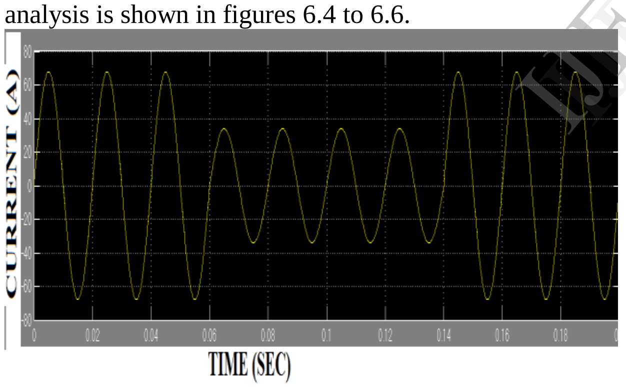

Fig 5.4 load current with step changes

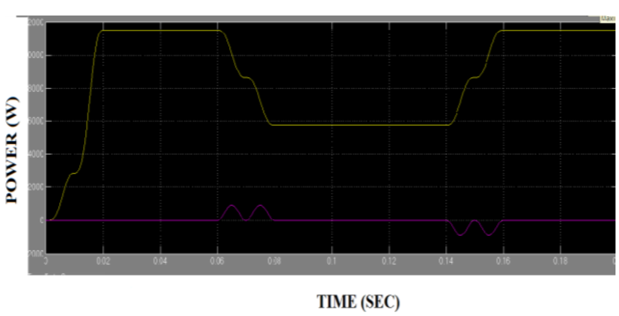

Fig 5.5: active power and reactive power with step changes

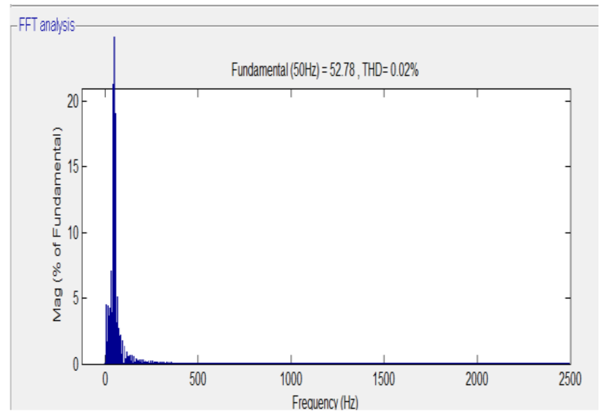

Fig (a)

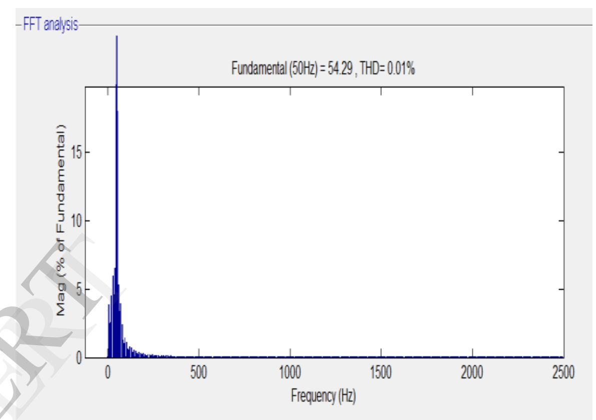

fig (b)

Fig 5.6: FFT analysis of load current a) with out fuzzy b) with fuzzy

Case 2: phase chages in the grid voltage:

The phase changes in the grid voltage circuit is simulated. The results are obtained. Results with fuzzy shows better performance than without fuzzy on the basis of THD which is shown in figure 5.7 to 5.9.

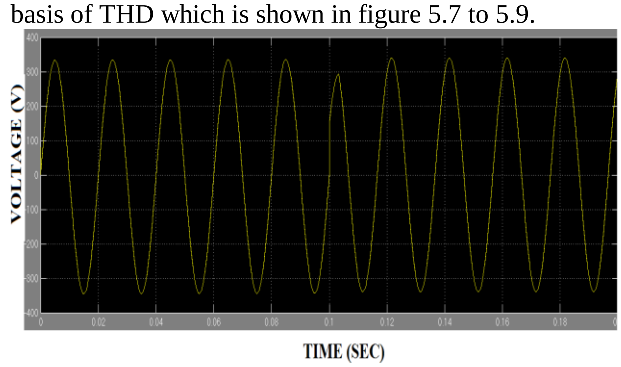

Fig 5.7: phase changes in the grid voltage

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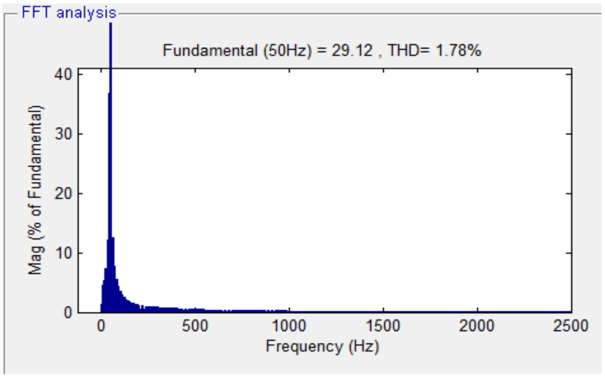

Fig 5.8: FFT analysis of grid current with out fuzzy

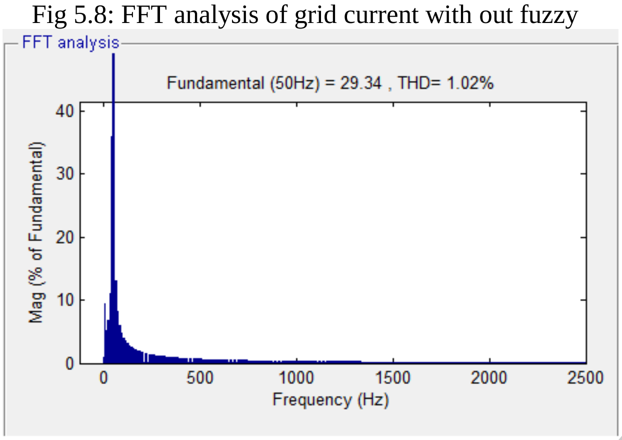

Fig 5.9: FFT analysis of current voltage with fuzzy

The THD of without fuzzy is 1.78 and with fuzzy is 1.02 percentage. Thus fuzzy gives improved performance than conventional hysteresis controller.

6. Conclusion

The proposed project 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 reduce total harmonic distortion in two studied cases. The THD level of grid current is considerably reduced as compared to conventional hysteresis current controller. Thus the proposed system provides better performance than conventional hysteresis current controller.

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