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Fuzzy Current Control of Voltage Source Converter Connected to the Grid with Solar Energy

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Abstract: This work deals with the comparison of the fuzzy current controller with the PI and PR controller for the PV system connected to the Grid, maximum power is extracted from panel by means of Boost convert and Pulses are generated from Perturb and observed method is used as maximum power point tracking algorithm (MPPT). The output of the boost converter is given to the 3-phase inverter which is connected to the grid. The Fuzzy Current Control strategy is implemented to control the inverter. In this control technique Load current is taken as reference current and grid current is taken as actual current. Error in *d*-axis and *q*-axis current are given to the fuzzy controller which generates the reference voltage in *d*-*q* frame. These are transferred into the ABC frame and Compared with the carrier signal, generates pules to the inverter which are given to the inverter. The Fuzzy current control method switches the power device in the inverter such that minimizes the error between the grid currents and the load current. It is compared with the PI and PR controllers. Fuzzy controller has given better performance in terms of the THD value of grid current. This is implemented through the MATLAB simulation.

Keywords: Fuzzy Controller, Three phase voltage source inverter, PV system, Proposal controller (PI), Proposal Resonant Controller (PR).

1. INTRODUCTION

Renewable energy resources are an interesting alternative to that of the non-renewable energy sources because they can be used on a large scale without polluting the environment. Photovoltaic (PV) power generation is a concept of converting solar energy into direct current electricity using semiconductor materials. A PV system includes a solar panel which consists of a number of solar cells which are used to generate the required solar power. These renewable energies can be used efficiently with power electronic converters. When power converters are placed in the system, harmonics are generated due to the switching process, which may cause disturbances in the distribution grid, so these harmonics should be filtered, which requires the usage of filters like 'L, LCL, LC' has to make the THD in the grid current should be less and also should satisfy the international standards [1-2].

PI controller gaines are tuned by meanes of fuzzy for the adaptive control stratigy has given the fast transient response and better performance under varioues parameteric condationes of 1.Ph. inverter connected to the grid [3]. Comaprision of the classical PI and fuzzy logic PI current controller of PWM recifier implimented based on field orintation control has given better performance [4]. Fuzzy current controller used in the innner current contol loop and fuzzy controller used in the outer voltage loop to controll the power flow between the fuelcel and batter system connected to gride has given the better performance in terms of the THD value of the grid current under the diffent parametric condationes[5]

2. FUZZY DESIGN AND PR CONTROLLER

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2.2.1. Fuzzy Design

The architecture of this controller is shown in Figure 6, it has three unites fuzzifier unit and interface unit and defuzzifier at the out terminals. It has input and output variables. Error and change in error currents are inputs whereas voltage is output variable. The current error means difference between the load current $I_l(k)$ and grid current $I_{g(k)}$ and process output is reference voltage $y(k)$. Change in error current means difference between the current values two successive sample periods. Which are defined in (1) & (2) respectively. In this work seven membership functions are defined as High Negative (HN3), Moderate Negative (MN2), Small Negative (SN1), Zero (Z), Small Positive (SP1), Moderate positive (MP2), High Positive Big (HP3) are shown in the Table 1. The input variables are processed by membership functions. Commonly triangular or trapezoidal functions are used.

$$e_i(k) = I_1(k) - I_g(k) \quad (1)$$

$$\Delta e_i = e_i(k) - e_i(k-1) \quad (2)$$

In this work two fuzzy controllers are used as shown in Figure 5. Whose membership functions are shown as Figure 2, 3 & 4.

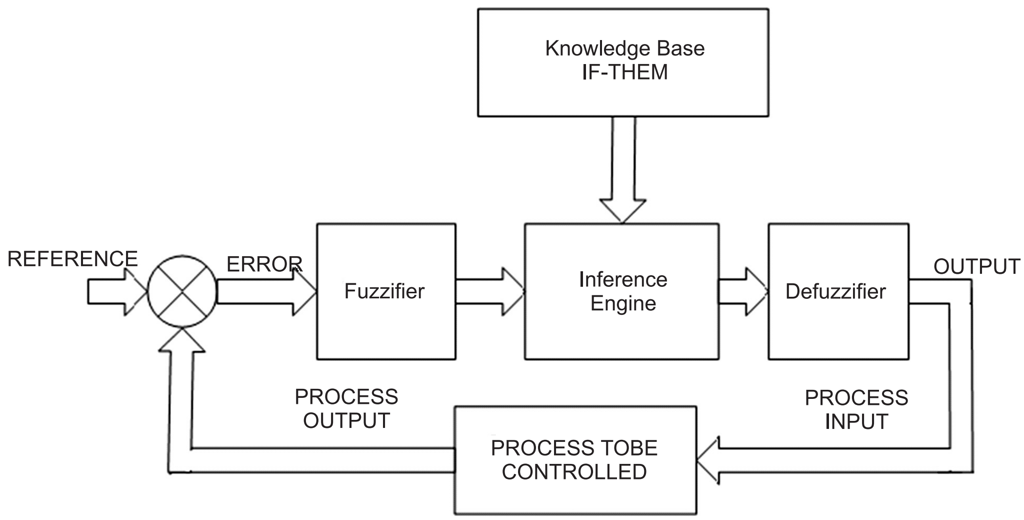

Figure 1: Architecture of fuzzy controller

Membership functions for I_d, I_q & output voltage

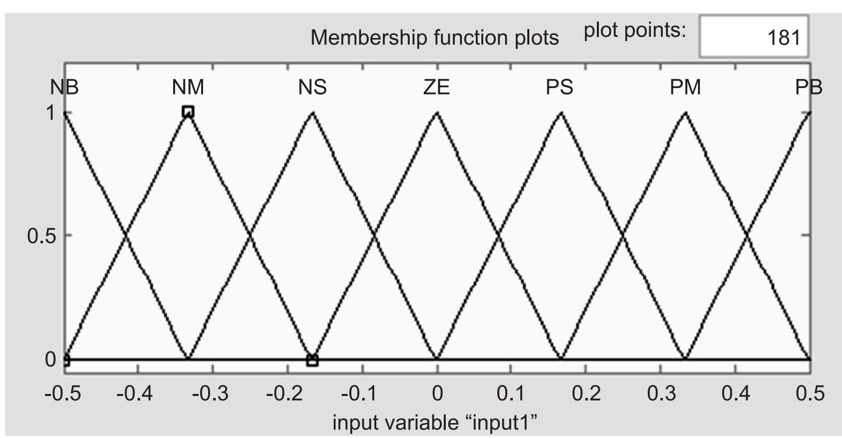

Figure 2: Membership function for error Current

Rules represented given below

Rule 1: 'error(ei)' is HN3 and error in change '(Δei)' is HN3 then Δu is HN3

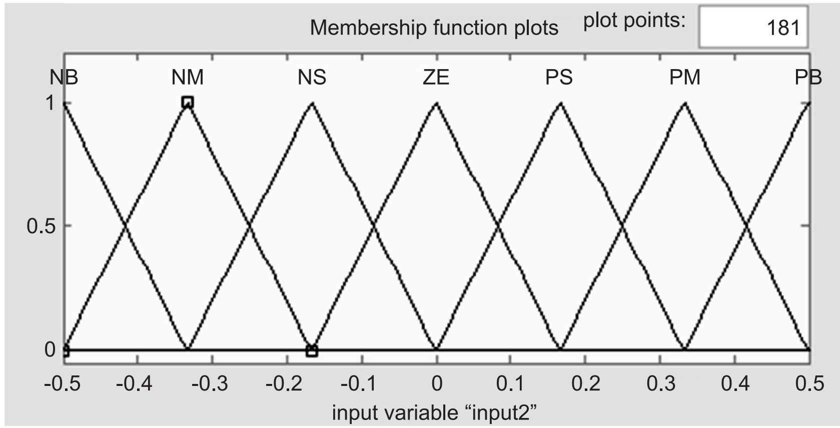

Figure 3: Membership function for change in error Current

Table 1
Rule matrix table

Error / Δerror	HN3	MN2	SN1	Z	SP1	MP2	HP3
HN3	HN3	HN3	SN1	SN1	SN1	SN1	Z
MN2	HN3	MN2	NM	NS1	SN1	Z	SP1
SN1	MN2	MN2	SN1	NS1	Z	SP1	SP1
Z	MN2	SN1	N1	Z	SP1	SP1	MP2
SP1	SN1	SN1	Z	SP1	SP1	MP2	MP2
MP2	SN1	Z	SP1	SP1	MP2	MP2	HP3
HP3	Z	SP1	SP1	MP2	MP2	BP3	HP3

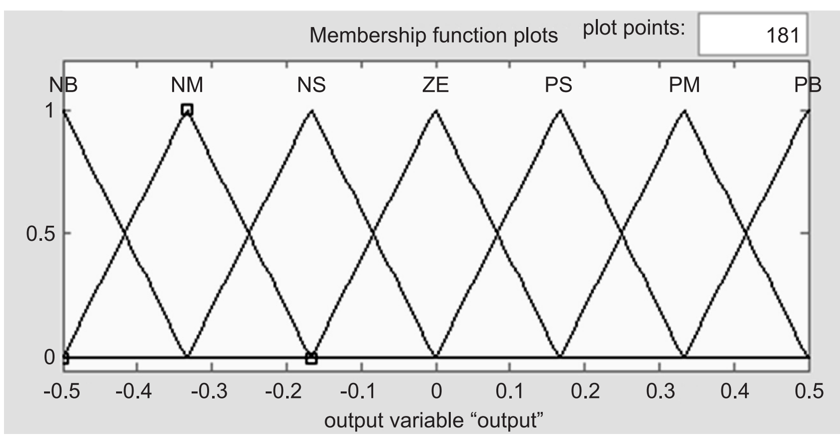

Figure 4: Membership function for output voltage

Rule 2: 'error(*ei*)' is HN3 and error in change '(Δ*ei*)' is MN2 then Δ*u* is HN3

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Rule 49: 'error(*ei*)' is HP3 and error in change '(Δ*ei*)' is HP3 then Δ*u* is HP3.

2.2.2. PR Controller

Proportional Resonant Controller (PR) is the second order generalized integrator (GI). Equation (3) presents an ideal PR controller which gives the stability problems because of an infinite gain. To avoid this condition, the PR controller can be treated as non-ideal by introducing damping as stated Equation (4). The K_P is the proportional gain which is controls the steady state error and K_r is the integral gain term control the dynamics of the system. By using the PR controller, the tracking capability of the reference current is enhanced compared to the conventional Proportional Integral controller.

$$G_{PR}(s) = K_P + K_R \frac{S}{S^2 + \omega_O^2} \tag{3}$$

$$G_{PR}(s) = K_P + K_R \frac{2\omega_C S}{S^2 + 2\omega_C S + \omega_O^2} \tag{4}$$

Overall block diagram of the system.

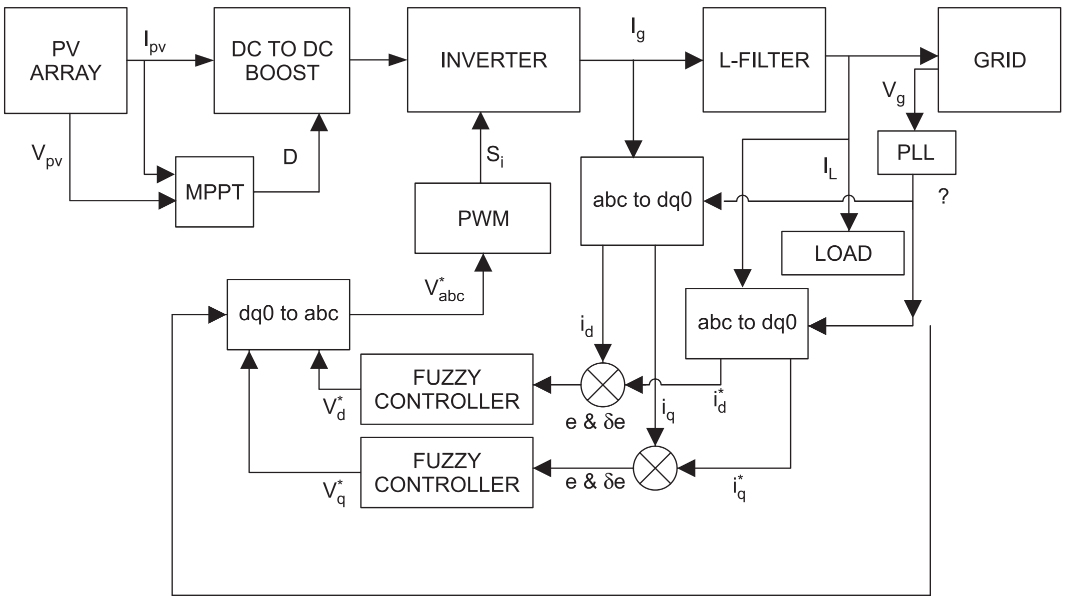

Figure 5: Overal Block Diagram of the System

PV array which converters the solar energy into the DC current by means of MPPT, maximum power is extracted from PV array and also increase to the required voltage given to the inverter which converter the DC Power to the AC power connected to the Grid. In this work fuzzy controller is used to supply required power with less transients and improved power quality in terms of the THD value of the grid currents for Fuzzy controller, error in current and change in error current are inputs and generates the reference voltage in DQ frame which are converted back to the ABC frame given to the PWM Modulator where reference voltage is compared to the triangular (10KZ) carrier wave produce pules to the three phase inverter connected the grid are shown in overall block diagram Figure 5.

3. SIMULATION RESULTS

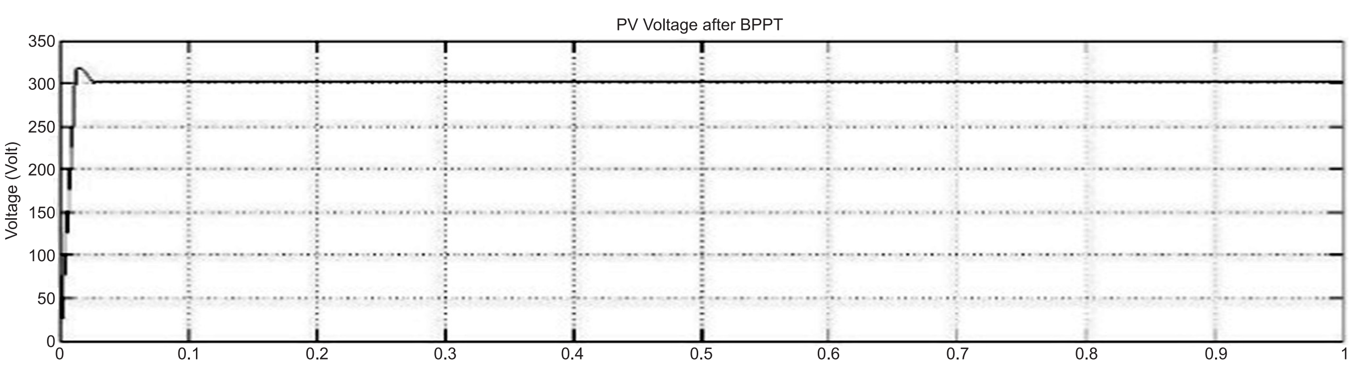

Figure 6: PV voltage After MPPT

In this work, PV array is designed for a power of 12 KW with an output of 150 Volts. By means of the buck-boost converter, the output voltage is increased to 300 Volts, as shown in Figure 6, which acts as an input to the three phase inverter circuit. The pulses generated by fuzzy controller given to the 3-Ph. Inverter Connected to the grid. The output voltage of the Inverter is shown in Figure 7.

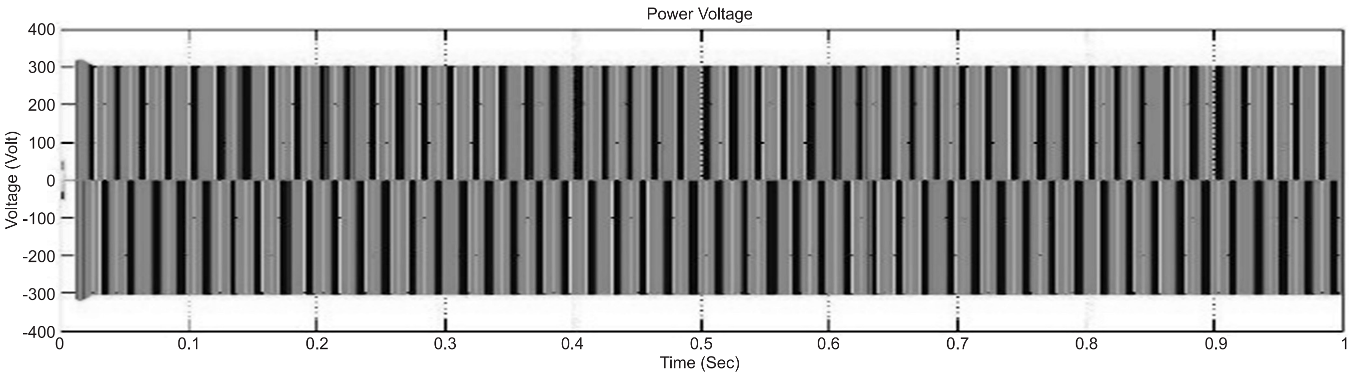

Figure 7: Three phase inverter output voltage

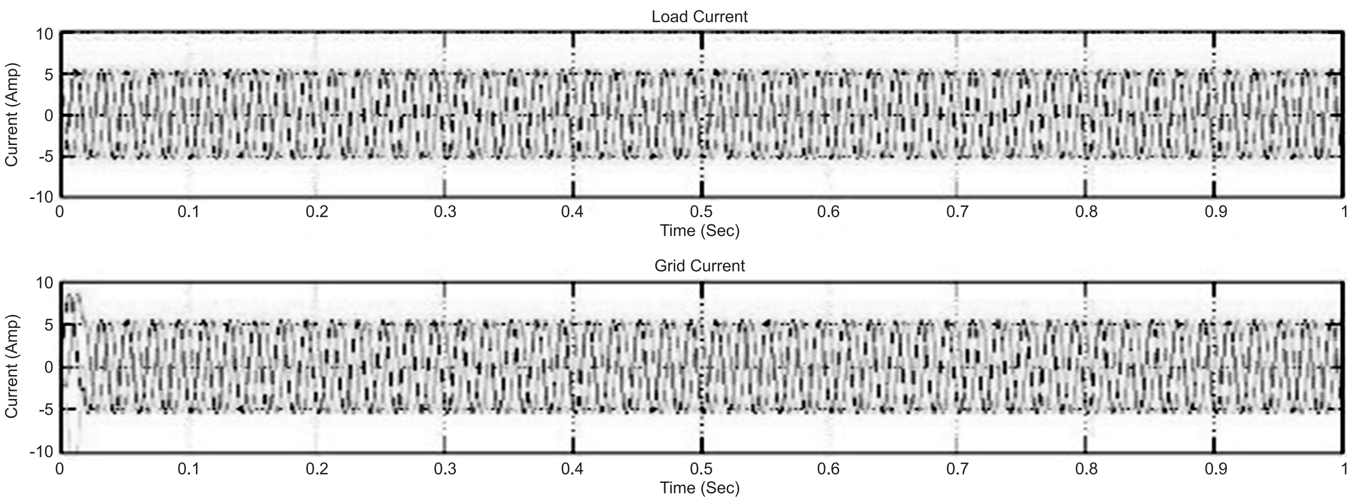

Figure 8: Load current And Grid Current

At PCC static load connected which draws a peak current of 5A, first wave in Figure 8 which is compared with grid current and precessed through fuzzy controller to generate the referance voltage by means of which generate pules which are apllied to the inverter to suplly the some amount of current as shown in the Figure 8. This controller has less transint behavier and transient current is 9 A also with in the limit. THD of the grid current as shown in Figure 9 has very less value is 0.99, with improves the power quality.

Table 2
Comparison of THD Value With Different Controller

Controller	*THD Value of Grid Current*
PI Controller	2.11
PR Controller	1.77
Fuzzy Controller	0.99

4. CONCLUSION

This work presented the Fuzzy current controller for a PV system connected to the grid. It is taken the input as error in current and change in error current gives the reference voltage to the PWM modulator. Pulse are produced which are applied to the grid connected inverter. This controller produced balanced grid current is same as the load current with less THD value compared to the PI and PR Controller and low transient behavior. It is simple current control and implementation without sacrificing quality and accuracy of the Grid Current.

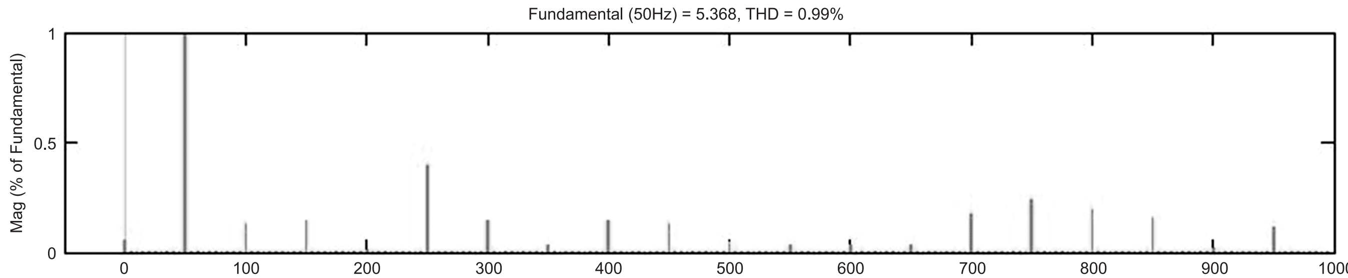

Figure 9: Analysis of Grid Current

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