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A Fuzzy Based PV-Active Power Filter for Compensating Current for Grid Connected System

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ABSTRACT

The photovoltaic (PV) generation is increasingly popular nowadays, while typical loads require more high-power quality. Basically, one PV generator supplying to nonlinear loads is desired to be integrated with a function as an active power filter (APF) and fuzzy logic control. A three-phase three-wire system, including a detailed PV generator, dc/dc boost converter to extract maximum radiation power using maximum power point tracking, and dc/ac voltage source converter to act as an APF, is presented. The instantaneous power theory is applied to design the PV-APF controller, which shows reliable performances. A Fuzzy Controller is introduced in this paper in order to improve the system performance. The MATLAB/Sim ower Systems tool has proved that the combined system can simultaneously inject maximum power from a PV unit and compensate the harmonic current drawn by nonlinear loads.

Keywords: *Harmonic Current, Total Harmonic Distortion, PV system, Power Quality.*

I. INTRODUCTION

In the present scenario, power quality and power supply are the main problems in power system. So that, the DG systems has got lot of importance because of the limitation of conventional power generation. The main advantage of DG system, it is more productive, high quality, and provide power to loads to maintain continuous administration. Therefore, the PV system is considered as an infinite, uncontaminated alternative resource. In PV systems, there is a possibility to convert direct sun energy to electrical energy without any interruptions. The efficiency of the solar system can be improved by using general MPPTs. The frequently used MPP techniques are given below:

1. P&O Technique.
2. INC Technique.
3. Fuzzy based MPPT Technique.

The maximum utilization of power electronic systems can produce nonlinearity in network, and its effects on overall system performance. To mitigate problems caused by harmonics, some filter components are used inside the system.

Generally, passive filters is a solution to reduce the harmonics. But these passive filters are responsible for resonance type problems occurred in grid. So that, active power filter is the better solution as compared to general filters for compensating harmonics.

In this paper, PV-APF system is proposed which produces an UPF supply to utility and non-harmonic current to the loads.

a. *Structure of PV-APF System:*

The effective utilization of generated power with more flexible can be achieved by the concept of Grid interconnected PV system. The utilization of

PV system is rapidly increased in distribution network and also power quality problems have been detected that may affect the operation of the network. Generally, Harmonics are main responsible for creating distortions in the power system network, due to this the quality of power delivered to the customers reduces. In, order to overcome these type of power quality problems the basic compensation technique is filters. The combination of PV-APF has been implemented for several years. This PV-APF system has capable to compensate power factor, unbalances in current, current harmonics, and also to inject power developed by solar system with low THD.

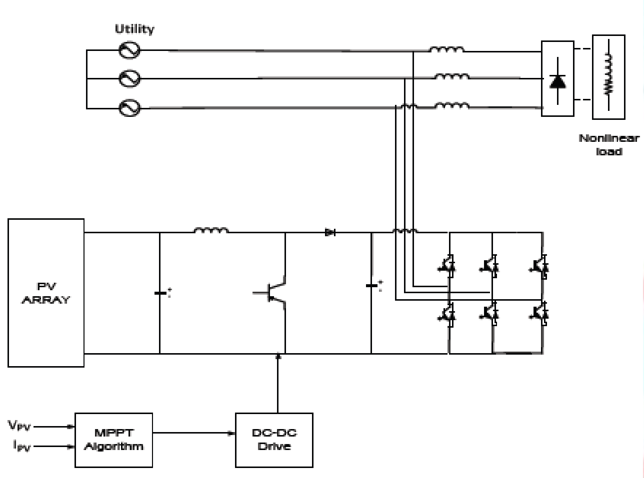

Figure 1. Configuration of Proposed Grid Connected PV-APF System

b. *Photovoltaic Array Modeling:*

In the PV network of electrical phenomenon, cell is the necessary part. For the raise in appropriate current, high power and potential difference, the sunlight dependent cells and their region unit joined in non-current or parallel fashion called as PV exhibit are used. In practical applications, each and every cell is similar to diode with the intersection designed by the semiconductor material. When the light weight is absorbed by the electrical marvel sway at the point of intersection, it gives the streams at once. The (current-voltage) and (Power-Voltage) attributes at absolutely unpredictable star intensities of the PV exhibit are represented in figure 3, whereas the often seen existence of most electrical outlet on each yield is shown in power diagram 2.

$$I = I_{ph} - I_D - I_{sh} \quad (1)$$

$$I = I_{ph} - I_o [\exp (q V_D / nKT)] - (v_D / R_S) \quad (2)$$

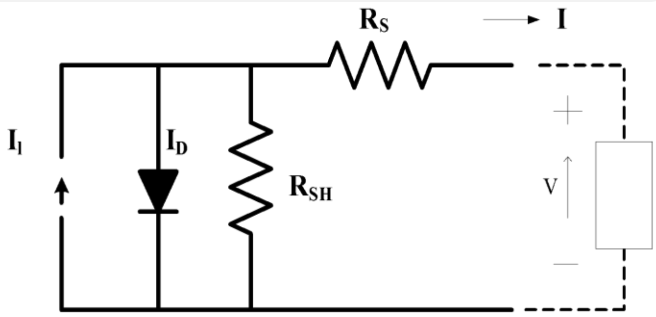

Fig 2: PV Electrical Equivalent circuit

Solar cell output power is given as the product of V and I

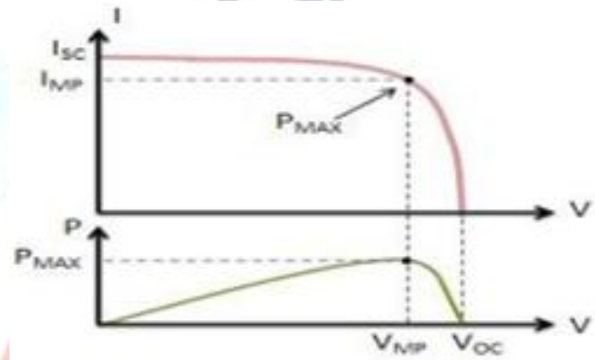

Figure 3: Response of output characteristics of PV Array

c. *INC MPPT Technique:*

In this technique the change of PV voltage can be obtained with respect to MPP voltage peak power. Figure 4 shows the PV power curve for incremental conductance method.

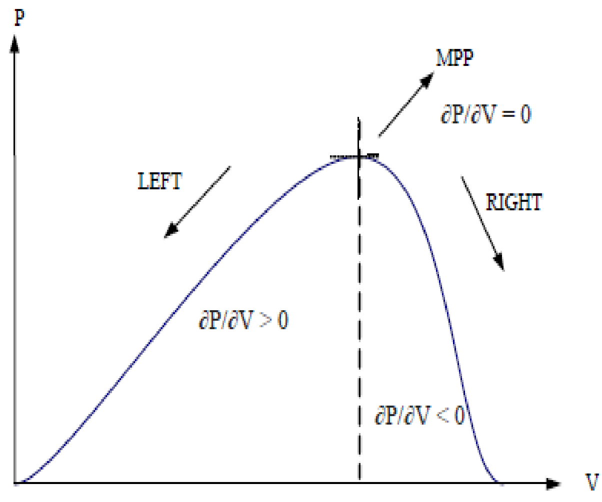

Figure 4: Characterestics of PV Power Vs Voltage under INC method

The relation for conductance in incremental and instantaneous can be expressed in three cases:

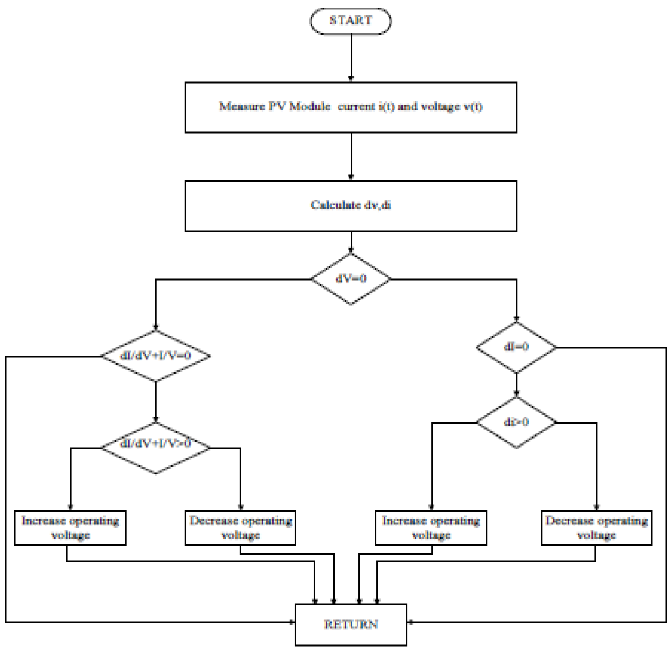

Figure 5: INC MPPT flow chart

The power expression,

$$P = V * I$$

Differentiate the power equation with PV terminal voltage,

$$\frac{\partial p}{\partial v} = \frac{\partial (VI)}{\partial v}$$

At MPP,

$$\frac{\partial p}{\partial v} = 0$$

The modified equation expressed as:

$$\frac{\partial I}{\partial V} = -\frac{I}{V}$$

This MPPT technique controls PWM signal for boost converter until (dI/dV) + (I/V) = 0 is obtained. Figure 5 shows the INC MPPT flow chart.

d. *P-Q Theory for Reference Current Generation:*

The VSC integrated by APF should give better solution for harmonic elimination along with reactive power compensation and simultaneously inject the maximum power generated by the solar system. In order to control this system an instantaneous power theory is proposed in this paper. The reference signals for this controller is generated by using grid voltages, non-linear load currents, output currents of VSC, injected currents by APF and dc-link voltages. The instantaneous active and reactive powers of load current and voltages can be obtained by using Clark's transformation technique.

$$\begin{bmatrix} v_{á} \\ v_{â} \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & -1/2 & -1/2 \\ 0 & \sqrt{3}/2 & -\sqrt{3}/2 \end{bmatrix} \begin{bmatrix} v_a \\ v_b \\ v_c \end{bmatrix}$$

$$\begin{bmatrix} i_{á} \\ i_{â} \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & -1/2 & -1/2 \\ 0 & \sqrt{3}/2 & -\sqrt{3}/2 \end{bmatrix} \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix}$$

$$\begin{bmatrix} i_a^* \\ i_b^* \\ i_c^* \end{bmatrix} = \sqrt{2/3} \begin{bmatrix} 1 & 0 \\ -\frac{1}{2} & \frac{\sqrt{3}}{2} \\ -\frac{1}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} i_{á} \\ i_{â} \end{bmatrix}$$

II. FUZZY LOGIC CONTROLLER

In the previous section, control strategy based on PI controller is discussed. But in case of PI controller, it has high settling time and has large steady state error. In order to rectify this problem, this paper proposes the application of a fuzzy controller shown in Figure 6. Generally, the FLC is one of the most important software based technique in adaptive methods.

As compared with previous controllers, the FLC has low settling time, low steady state errors. The operation of fuzzy controller can be explained in four steps.

1. Fuzzification
2. Membership function
3. Rule-base formation
4. Defuzzification.

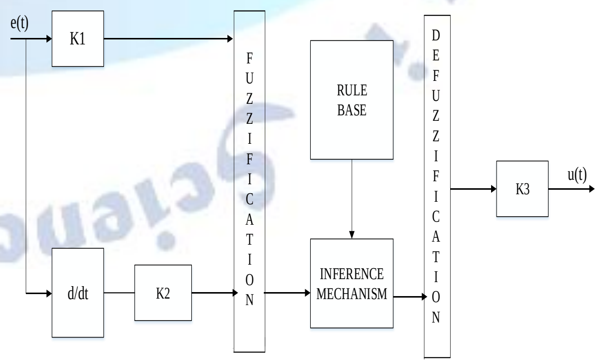

Figure 6: basic structure of fuzzy logic controller

In this paper, the membership function is considered as a type in triangular membership function and method for defuzzification is considered as centroid. The error which is obtained from the comparison of reference and actual values is given to fuzzy inference engine. The input variables such as error and error rate are expressed in terms of fuzzy set with the linguistic terms VN, N, Z, P, and Pin this type of mamdani fuzzy inference system the linguistic terms are expressed using triangular membership functions. In this paper, single input and single output fuzzy inference system is considered. The number of linguistic variables for input and output is assumed as 3.The numbers of rules are formed as 9. The input for the fuzzy system is represented as error of PI controller. The fuzzy rules are obtained with if-then statements. The given fuzzy inference system is a combination of single input and single output. This input is related with the logical operator AND/OR operators. AND logic gives the output as minimum value of the input and OR logic produces the output as maximum value of input

III. SIMULATION DIAGRAM AND RESULTS

The proposed hybrid system shown in figure 1 can be verified using Matlab/Simulink.

The complete system can be simulated for the period of 0.75 sec and this can be divided into following sections. i.e, the period 0.05 to 0.35sec relates to current controlled VSC converter, between the periods 0.35 to 0.5sec relates to MPPT based current controlled VSC converter, between the periods 0.5 to 0.6sec is PV-APF mode and finally, 0.6 to 0.7sec is APF mode.

Case 1: With PI Controller.

In this case the proposed system can be simulated using PI controller for compensating the current harmonics. The performance results for this proposed system and its total harmonic distortions are shown below.

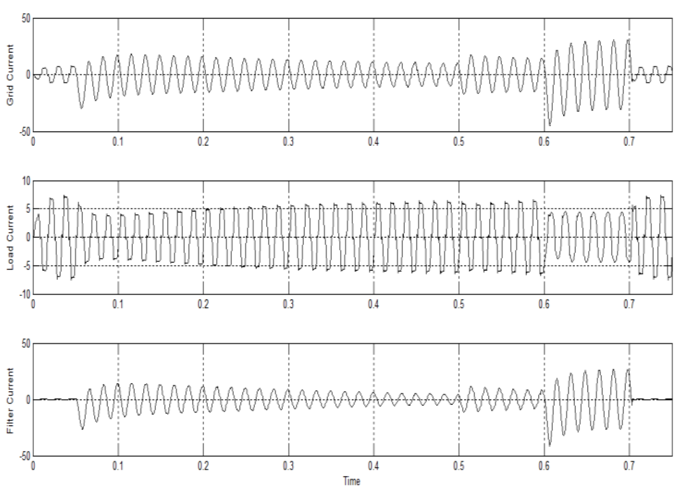

Figure 7. Waveforms for (a) Source Current. (b) Non-Linear Load current. (c) APF current with PI controller

Figure 7 shows the simulation result for (a) grid current, (b) load current and (c) filter current. As we know, because of non-linear load presence in the system the load current is effected by unwanted harmonics. In order to compensate these problem a PV-APF is proposed under three cases as explained above and the filter grid current is also shown.

Case 2: With Fuzzy Controller

In this case the proposed system can be simulated using Fuzzy controller instead of conventional PI controller for compensating the current harmonics. The performance results for this proposed system and its total harmonic distortions are shown below.

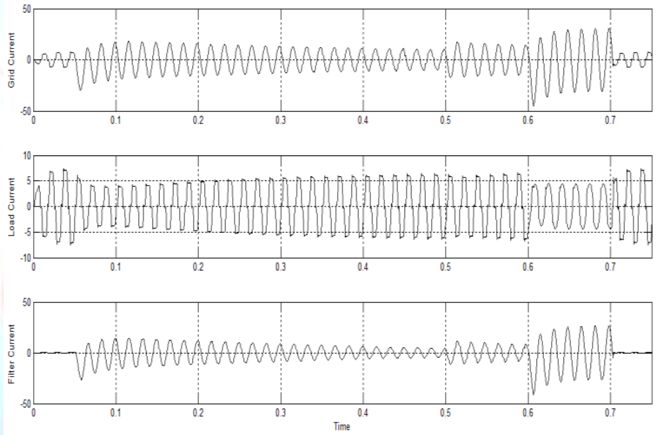

Figure 8: Waveforms for (a) Source Current. (b) Non-Linear Load current. (c) APF current with fuzzy controller

Figure 8 shows the simulation results of (a) grid current, (b) load current and (c) filter current. As we know, because of non-linear load presence in the system the load current is effected by unwanted harmonics. In order to compensate these problem a Fuzzy based PV-APF is proposed under three cases as explained above and the filter grid current is also shown. And the comparison of total harmonic distortion for the two cases such as PI and Fuzzy controller is formulated in table.

Modes→ Type↓	d-q Current (0.07S)	PV-APF (0.5S)	APF (0.68 S)	Utility (0.72 S)
PI Controller	3.73	8.4	2.40	15.6
Fuzzy Controller	1.73	3.04	0.18	7.8

Table. %THDs Evaluation

IV. CONCLUSION

This paper proposed concept of PV based active power filter for power quality improvement using instantaneous power theory controller. This controller can be implemented for two purposes i.e, one for to supply power from PV system and other one is for filtering the harmonics caused by non-linear load. In this paper PI, Fuzzy Controllers are developed for controlling Dc link voltage. The performance of this system can be tested and verified in Matlab/Simulink. From the results we conclude that, Fuzzy Logic Controller shows better performance over conventional controller.

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