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A PSO MPPT based Fuzzy-SMC Control for Grid tied PV System

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ABSTRACT

Generally, the non-conventional energy sources are being extensively used in case of power electronic converter-based distribution systems. Maximum power point techniques (MPPT) are used in photovoltaic system to make full utilization of PV array output power. The output power of PV array is always changing with weather conditions i.e., solar irradiation and atmospheric temperature. PV cell generates power by converting sunlight into electricity. The electric power generated is proportional to solar radiation. PV cell can generate around 0.5 to 0.8 volts. During cloudy weather due to varying insolation levels the output of PV array varies. The MPPT is a process which tracks the maximum power from array and by increasing the duty cycle of the DC-DC boost converter, the output voltage of the system is increased. This paper presents the pso mppt technique for PV system along with Fuzzy-SMC controller methods in grid connected photovoltaic (PV) systems for optimizing the solar energy efficiency.

INTRODUCTION

At present, most of energy demand in the world relies on fossil fuels such as petroleum, coal, and natural gas that are being exhausted very fast. One of the major severe problems of global warming is one of these fuels combustion products, carbon dioxide; these are resulting in great danger for life on our planet [1].

Among all the available Renewable energy sources, PV array systems are trusted to play a significant role in prospective energy production. PV systems transform photon energy into electrical energy. These energy systems generate low voltage output; thus, high step-up dc/dc converters are employed in many applications, including fuel cells, wind power, and photovoltaic systems, which converts low voltage into high voltage. Due to the increasing demand on electricity, and limited availability and high prices of non-renewable sources, the photovoltaic (PV) energy conversion system has become an alternative as it is freely available, pollution free, and has less operation al and low maintenance cost. Therefore, the utilization of PV energy systems has to be increased for standalone and as well as grid-connected modes of PV systems. Photovoltaic (PV) as a renewable energy resource naturally is not stable by location, time, season and weather and its installation cost is comparatively high. An important consideration in increasing the efficiency of PV systems is to operate the system near maximum power point (MPP) so to obtain the approximately maximum power of PV array. For getting maximum possible energy produced by a solar system.

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Also, maximum power point tracking (MPPT) techniques are used for improving the performance of PV systems, a high efficiency power converter which is designed to extract maximum power from a PV panel is usually considered. Generally, there will be a unique point on the V -I curve, called the Maximum Power Point (MPP), at which the whole PV system serves with maximum efficiency and produces its maximum power output. The position of the MPP is unknown, but can be placed either by search algorithms or through calculation models. Maximum Power Point Tracking Techniques (MPPT) are used to maintain the PV array's operating point at the precise position where maximum power can be delivered. Various MPPT algorithms have been considered in the literature; some of them are the Perturb and Observe (P&O) method, the Incremental Conductance (lC) method the Artificial Neural Network method, the Fuzzy Logic method. The P&O and IC techniques, are the most widely used. In this paper, four MPPT algorithms are considered: P&O, Incremental Conductance (lC) method, Fuzzy Logic method, Particle Swarm Optimization method. These methods are quite easily implemented and have been widely adopted for low cost applications. Other methods such as Sliding Mode, are not considered in this paper, because they are more complex and rarely used.

This paper focuses on developing a simulation model for grid connected PV system with Cuckoo MPPT technique to improve the performance of system. This simulation model is performed using Matlab and SimPower Systems and results are presented to verify the effectiveness of the proposed system. The proposed grid connected PV generation system is shown in figure 1.

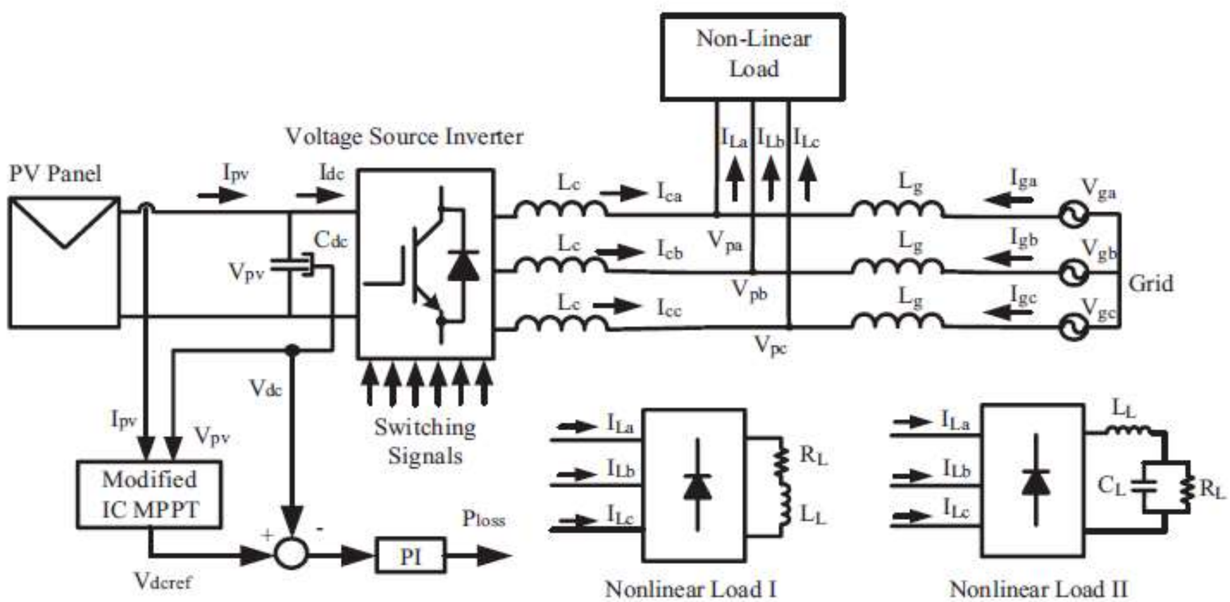

Figure 1: Diagram for Proposed System

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.

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

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

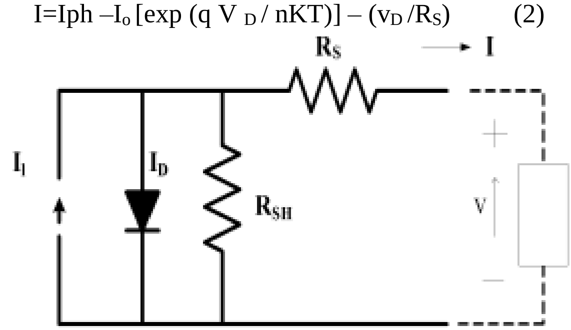

Figure 2: PV Electrical Equivalent circuit

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

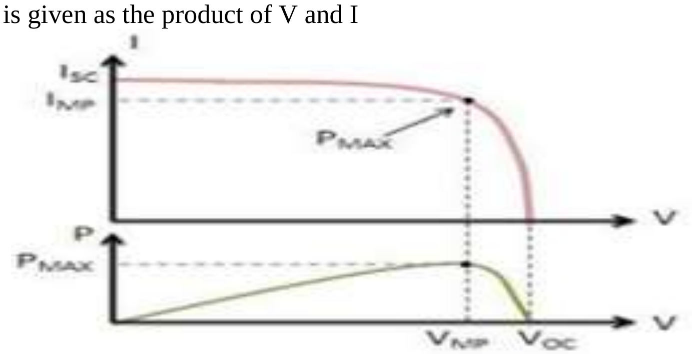

Figure 3: Response of output characteristics of PV Array

Control Technique for VSI:

Figure 4 shows the structure of the proposed ASMC employed with the instantaneous power theory for the GCPVS. The reference active power and reactive power for VSI are calculated using the instantaneous power theory. Then the reference inverter current is calculated using the following equations. After implementation of ASMC, the required gate signal is generated using equation, which is applied to the VSI.

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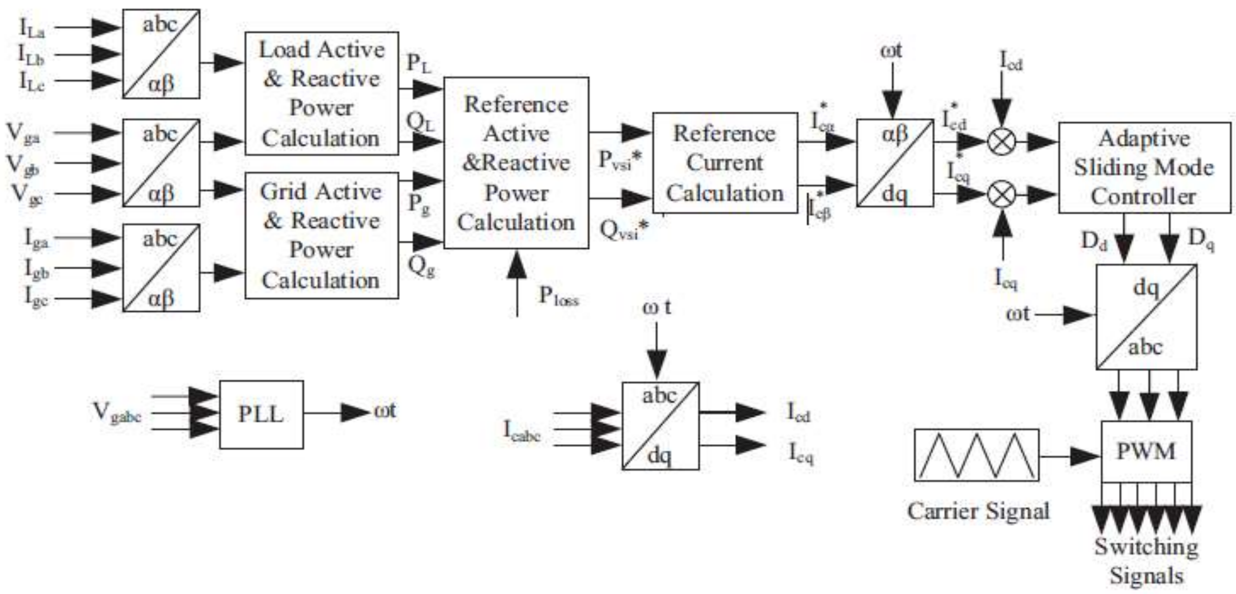

Figure 4: Control Diagram for VSI

$$\begin{bmatrix} I^*_{c\alpha} \\ I^*_{c\beta} \end{bmatrix} = \begin{bmatrix} V_\alpha & V_\beta \\ -V_\beta & V_\alpha \end{bmatrix}^{-1} \begin{bmatrix} P^*_{vsi} \\ Q^*_{vsi} \end{bmatrix}$$

$$\begin{bmatrix} I^*_{cd} \\ I^*_{cq} \end{bmatrix} = \begin{bmatrix} \cos\varphi & \sin\varphi \\ -\sin\varphi & \cos\varphi \end{bmatrix} \begin{bmatrix} I^*_{c\alpha} \\ I^*_{c\beta} \end{bmatrix}$$

It employed IPT and power balance to generate the reference current for VSI. The α, β components of grid voltage, grid current and load current can be calculated using Clarke transformation as follows. The load active and reactive power is calculated using the equation as follows

$$\begin{bmatrix} P_L \\ Q_L \end{bmatrix} = \begin{bmatrix} V_\alpha & V_\beta \\ -V_\beta & V_\alpha \end{bmatrix} \begin{bmatrix} I_\alpha \\ I_\beta \end{bmatrix}$$

The real power and reactive power of the load comprises of an average component and an oscillating component. The oscillating component of power can be obtained using a low pass filter (LPF). The dc link capacitor voltage of VSI is measured at the time of operation of VSI. A PI-controller is employed to regulate the dc link voltage. The reference dc link voltage is obtained as the output of the modified IC MPPT algorithm. The output from the PI-controller represents as power loss (P_{loss}) which flows to (from) the capacitor C_{dc} to keep the dc link capacitor voltage at a fixed value.

$$P_g = V_{g\alpha} I_{g\alpha} + V_{g\beta} I_{g\beta}$$

If the (P_{loss}) is supplied by the PV panel, then the reference real and reactive power for inverter is calculated as follows

$$P^*_{vsi} = P_L - \overline{P}_g + \overline{P}_{loss}$$

Accordingly the reference d-q component of inverter current can be estimated by following equations

$$\begin{bmatrix} I^*_{c\alpha} \\ I^*_{c\beta} \end{bmatrix} = \begin{bmatrix} V_\alpha & V_\beta \\ -V_\beta & V_\alpha \end{bmatrix}^{-1} \begin{bmatrix} P^*_{vsi} \\ Q^*_{vsi} \end{bmatrix}$$

$$\begin{bmatrix} I^*_{cd} \\ I^*_{cq} \end{bmatrix} = \begin{bmatrix} \cos\varphi \ \sin\varphi \\ -\sin\varphi \ \cos\varphi \end{bmatrix} \begin{bmatrix} I^*_{c\alpha} \\ I^*_{c\beta} \end{bmatrix}$$

Particle Swarm Optimization

The swarm intelligence technique is one of the artificial intelligences, this technique is based on collective behavior of decentralized and self-organized systems. The main advantage to apply this proposed optimization technique to hybrid system is to get less oscillations in system as compared with conventional P&O method. As per literature survey, previously PSO technique as applied to only photovoltaic system for extracting maximum power [14].

Each particle tries to modify its current position and velocity according to the distance between its current position and P_{best}, and the distance between its current position and g_{best}.

$$v_{n+1} = v_n + c_1 rand1() * (P_{best,n} - CurrentPosition_n) + c_2 rand2() * (g_{best,n} - CurrentPosition_n)$$

Analysis of PSO Technique:

The convergence criteria in the standard PSO algorithm aim to find the optimal solution or the success of the maximum number of iterations. However, in a PV system, the optimum point is not constant, as it depends on both weather conditions and load impedance. Therefore, the proposed PSO algorithm will reinitialize and search for the new MPP whenever the following conditions are satisfied:

$$\left| v(i+1) < \Delta v \right|$$
$$(pi(k+1) - pi(k) / pi(k) > \Delta p)$$

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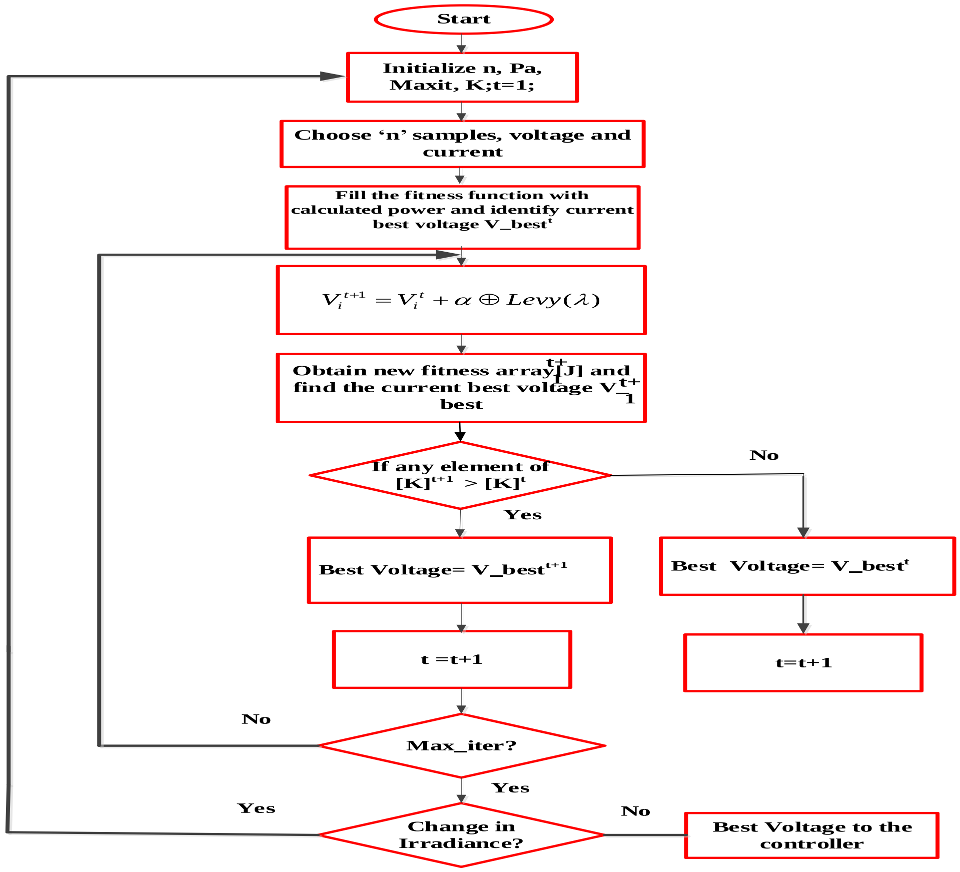

Figure 5: Algoritham for PSO Technique

Where pi (k+1) is the new PV power, pi (k) is the previous PV power at maximum point. From above equations, stand for the agent's convergence detection and abrupt alteration of insolation, correspondingly. There are two matters associated with ΔV choice: 1) lesser values lead to better MPPT firmness but a poor tracking reaction, and 2) superior values result in a faster tracking reaction at the cost of greater oscillations. Therefore, a balanced rate must be selected. Nevertheless, when the ΔP is great, the subsequent constraint might not be fulfilled due to lesser variations in real power; therefore, the agents' rate of initialization is minor.

The complete flowchart for the proposed method is shown in Figure 7 and the proposed algorithm uses the following basic principles:

Step 1: Parameter selection: For the proposed MPPT algorithm, the calculated duty cycle of the converter is defined as the particle position, and PV module output power is chosen as the fitness value evaluation function.

Step 2: PSO initialization: In a standard initialization, PSO particles are usually randomly initialized. For the proposed MPPT algorithm, the particles are initialized at fixed, equidistant points, positioned around the GP.

Step 3: Fitness evaluation: The fitness evaluation of particle i will be conducted after the digital controller sends the PWM command according to the duty cycle, which also represents the position of particle i.

Step 4: Determination of individual and global best fitness: The new calculated individual best fitness (P_{best}) and the global best fitness (g_{best}) of each particle value are compared with previous ones. They are then replaced according to their positions, where necessary.

Fuzzy Logic:

Fuzzy theory was initiated by Lotfi A. Zadeh in 1965 as an extension of the classical control theory. According to him classical control theory put too much emphasis on precision and therefore could not the complex systems. Later he formalized the ideas into the paper "Fuzzy set." Fuzzy sets are sets whose elements have degrees of membership.

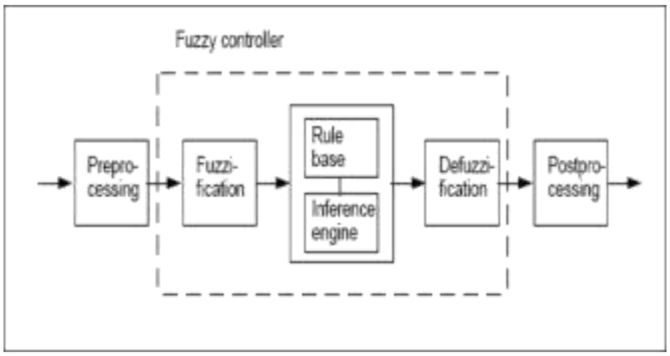

Figure 6: Structure of fuzzy logic controller

Application Area of Fuzzy Logic:

1: Controller application

2: Communication engineering

3: Image processing

4: Production engineering

5: System identification

SIMULATION STUDY

The simulation is performed for GCPVS using both non-linear load I and II with ASMC-IC-IPT scheme shown in Figure 1 in MATLAB/SIMULINK. The performance of ASMC-IC-IPT scheme is compared with that of the SMC-IC-IPT scheme. The parameters used for the PV system are given in table-1.

Case 1: With P&O MPPT Technique

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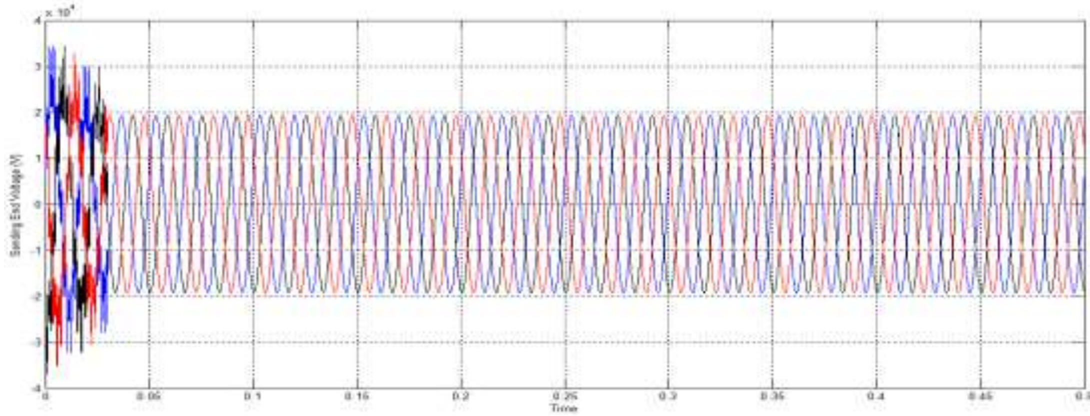

Figure 6: Simulation Result for Three Phase Output Voltage from Sending End

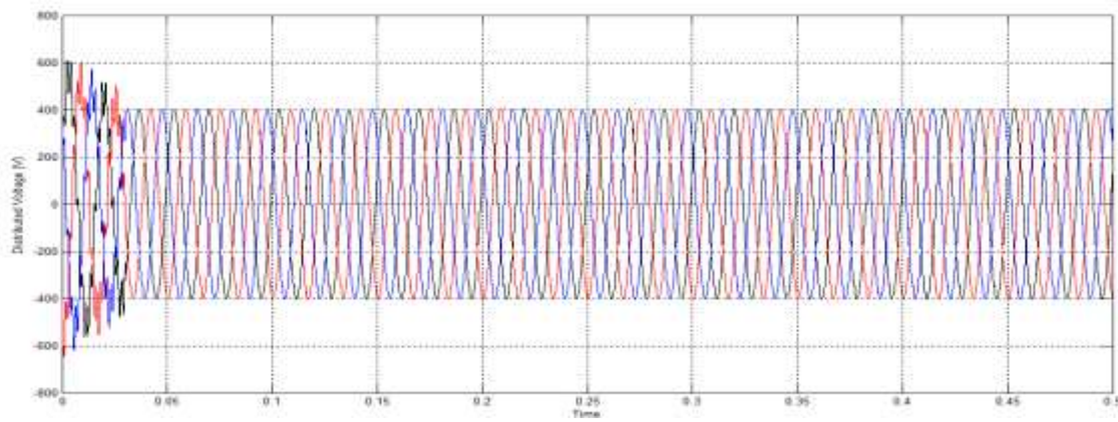

Figure 7: Simulation Result for Three Phase Output Voltage at Distribution Level

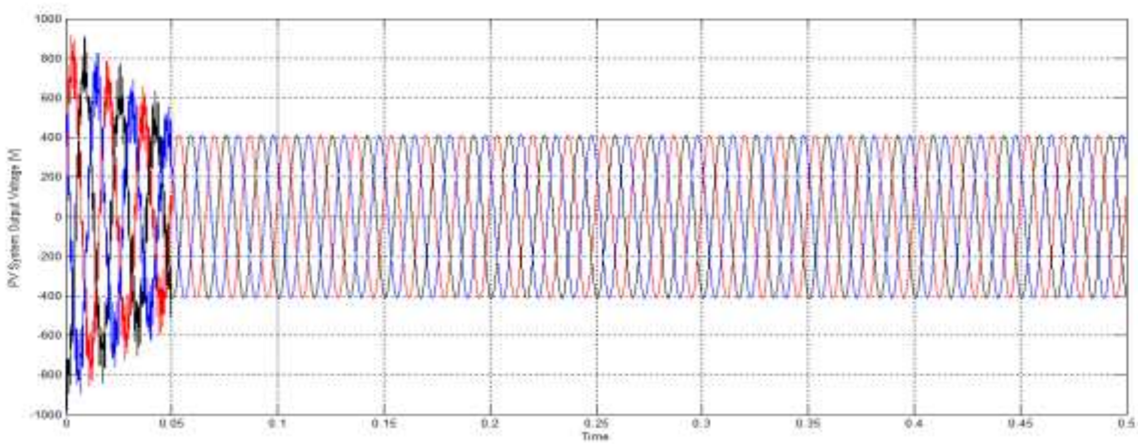

Figure 8: Simulation Result for Three Phase Output Voltage from PV System

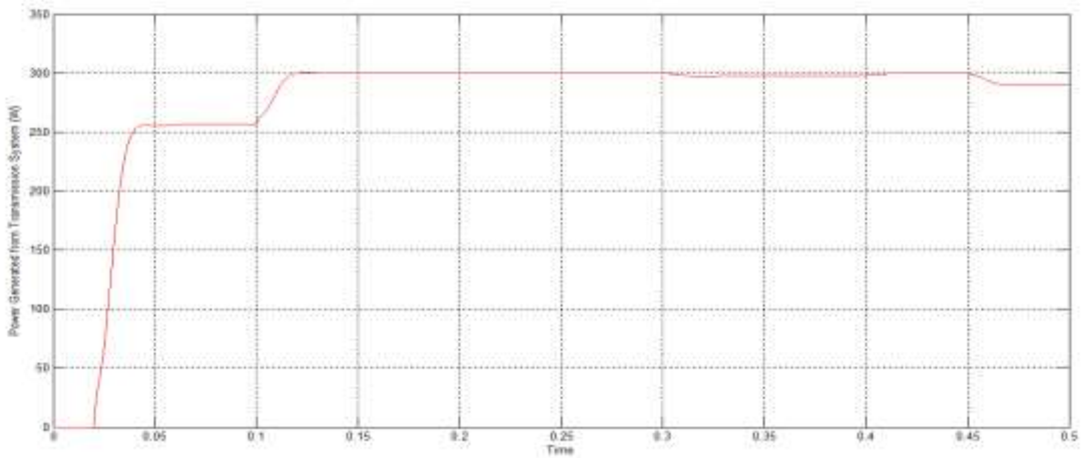

Figure 9: Simulation Result for Power Generated from the Transmission System

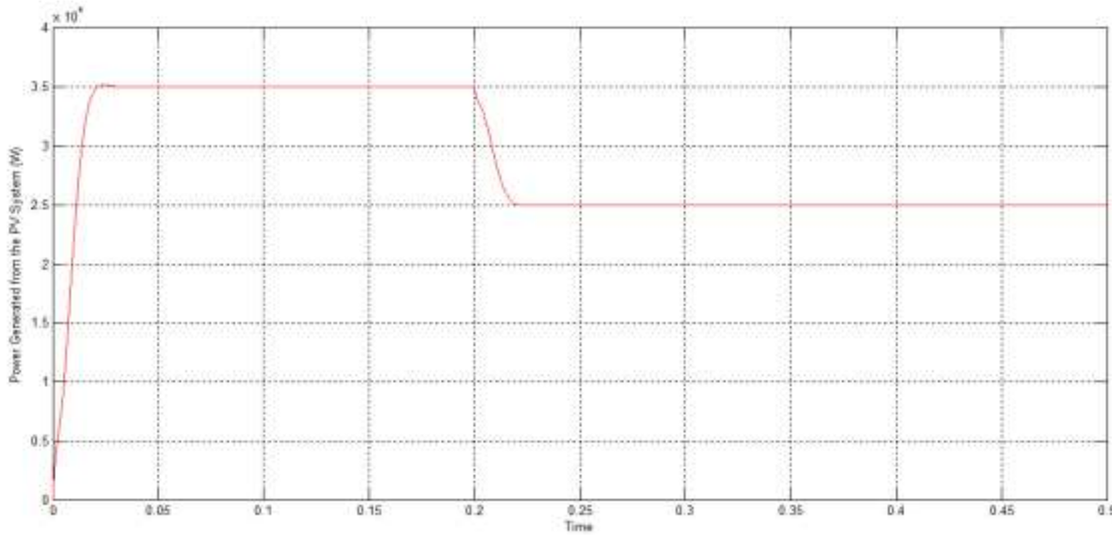

Figure 10: Simulation Result for Power Generated from the PV System

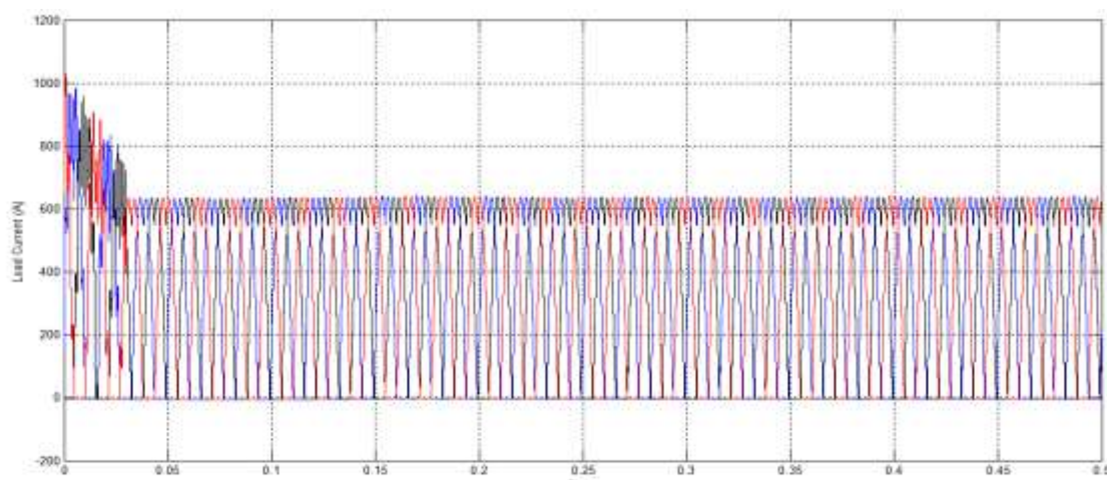

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Figure 11: Simulation Result for Load current

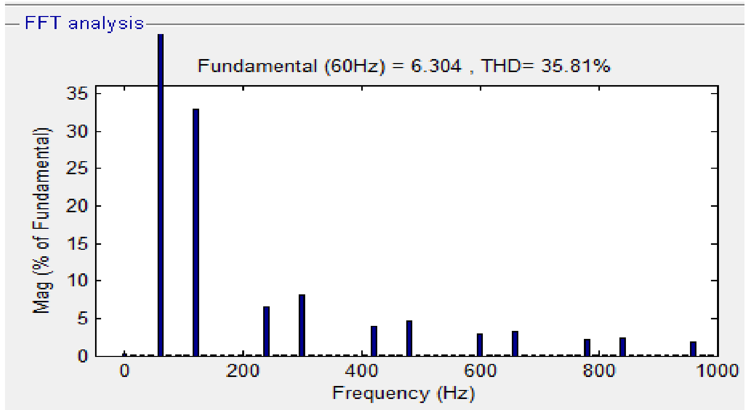

Figure 11: Harmonic Distortion for Source Current

Case 2: With PSO MPPT Technique

Here, the proposed Grid Connected PV system is implemented with Cuckoo Search algorithm. In order to improve the performance of PV system a DC-DC converter is implemented. A Cuckoo-MPPT controller is implemented to generate gate signal for DC-DC Converter. The simulation results for PV system with Cuckoo MPPT technique is shown in figures.

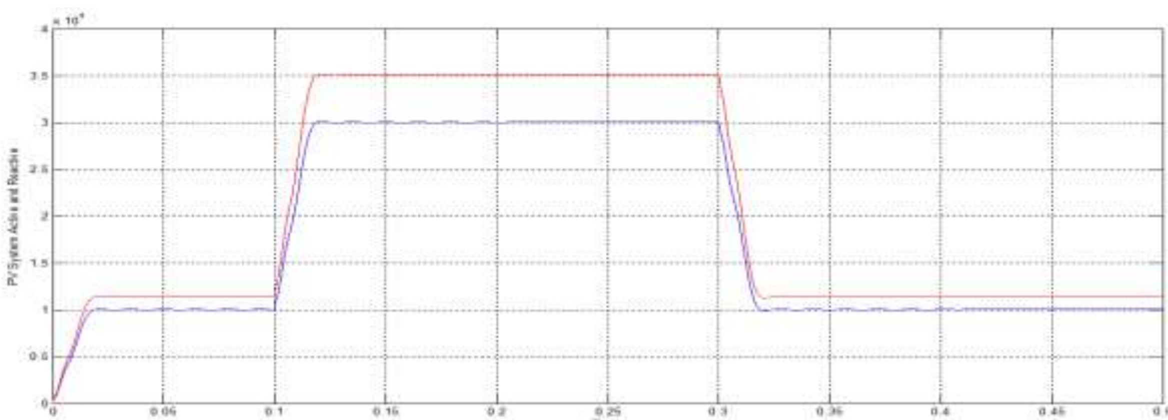

Figure 12: Simulation result for PV Power

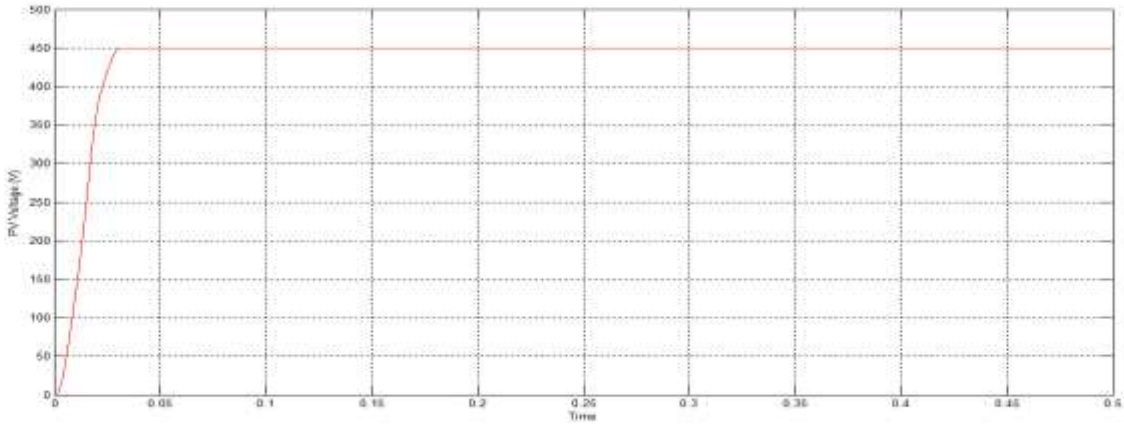

Figure 13: Simulation result for PV Voltage

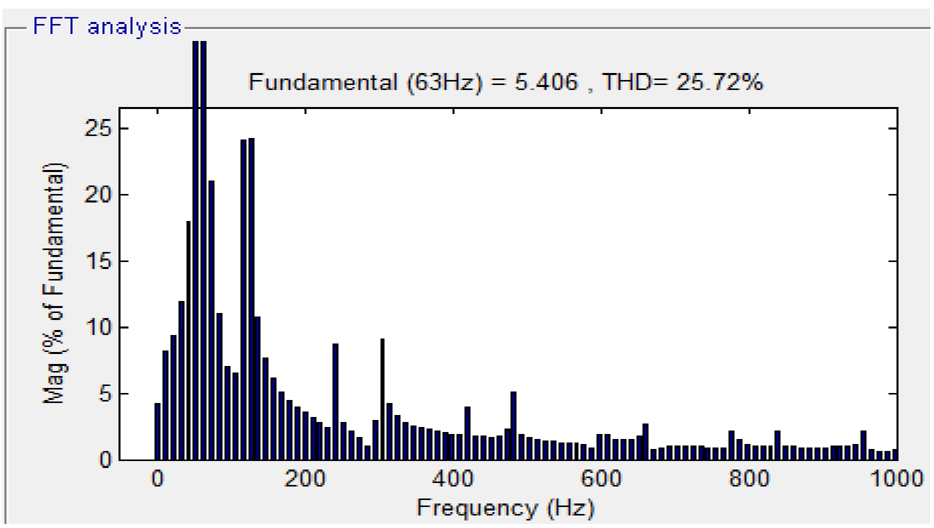

Figure 14: Harmonic Distortion for Source Current

CONCLUSION

The paper presents a novel concept of integration of Cuckoo based PV system with grid interfaced hybrid system to improve the performance. The paper also presents effects of power quality on consumer and power utility systems. The converter proposed for PV system, reduces the distortions in currents, improved the power factor thus reducing the reducing the reactive power demand from the wind generator and the load at point of common coupling. Thus, the integration of PV and Grid devices maintains the desired power quality requirements. The Implementation of PSO MPPT for PV and fuzzy logic control strategies are simulated in MATLAB/SIMULINK.

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