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International Journal for Modern Trends in Science and Technology, 7(03): 101-106, 2021

ISSN: 2455-3778 online
DOI: https://doi.org/10.46501/IJMTST0703018
Available online at: http://www.ijmtst.com/vol7issue03.html

Power Quality Enhancement of Grid-Connected Solar Photovoltaic System Using ANN based Filter

B Anand Swaroop[1] | K Jagadeesh[2]

[1]Assistant Professor, Dept of EEE, Avanthi Institute of Engineering & Technology, Vijayanagaram.
[2]PG Student, Dept of EEE, Avanthi Institute of Engineering & Technology, Vijayanagaram.

To Cite this Article
B Anand Swaroop and K Jagadeesh, "Power Quality Enhancement of Grid-Connected Solar Photovoltaic System Using ANN based Filter", *International Journal for Modern Trends in Science and Technology*, Vol. 07, Issue 03, March 2021, pp.: 101-106.

Article Info
Received on 06-February-2021, Revised on 02-March-2021, Accepted on 05-March-2021, Published on 12-March-2021.

ABSTRACT

Grid-connected photovoltaic (PV) systems are increasingly attracting the attention of industry and academia as a means of providing an alternative to conventional fossil-fuel generation and pollution-free power. This project aims to improve the power quality level of a grid-tied PV distribution system using shunt active power filter (APF) along with adaptive current control technique.

In this work Fuzzy Logic controller used to destroy the voltage and current harmonics in a grid-tied PV system. A reference current generation strategy is implemented to mitigate the current harmonics by extracting the fundamental constituents (FCs) from the nonlinear load currents. MCCF is employed to separate the FC from the distorted grid voltages and eliminates the voltage harmonics during extremely polluted grid voltage condition. The comparative analysis is analyzed to check the effectiveness of the proposed hybrid control scheme with existing and adaptive control techniques in respect of power quality, better dc offset rejection, better FC and frequency extraction, and grid synchronization.

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 becomes 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.

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 [15-17]. 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 [2-5], the Incremental Conductance (IC) method [2-6], the Artificial Neural Network method [7], the Fuzzy Logic method [8] etc .. The P&O and IC techniques, are the most widely used. In this paper, four MPPT algorithms are considered: P&O, Incremental Conductance (IC) method [2-6], Fuzzy Logic method [8], Particle Swarm Optimization method [10].These methods are quite easily implemented and have been widely adopted for low cost applications. Other methods such as Sliding Mode [9], are not considered in this paper, because they are more complex and rarely used.

This paper focuses on developing a simulation model to design and size the hybrid system for a variety of loading and meteorological conditions. 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 hybrid energy generation system is shown in figure 1.

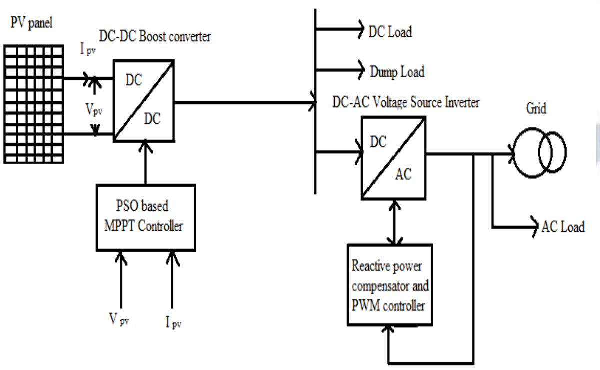

Figure 1: Configuration of proposed grid connected hybrid system

Literature Survey:

Ciobotaru et al. [15] discussed the issue of control strategies for single-stage photovoltaic (PV) inverter is addressed. Two different current controllers have been implemented and an experimental comparison between them has been made. A complete control structure for the single-phase PV system is also presented. Mahmud et al. [16] presented a robust nonlinear distributed controller design for islanded operation of microgrids in order to maintain active and reactive power balance. In this paper, microgrids are considered as inverter-dominated networks integrated with renewable energy sources (RESs) and battery energy storage systems (BESSs), where solar photovoltaic generators act as RESs and plug-in hybrid electric vehicles as BESSs to supply power into the grid. Power electronics converters play an important role in realization and performance improvement of electrical power system. With the demand for new power resource and better power supply quality, more and more distributed energy resources (DERs) come into practice. A model predictive controller is designed to decrease common mode voltages and errors between the capacitor voltages and their reference values. Finally, simulation diagram, parameters and results using software PLECS are provided to demonstrate the merits of multilevel inverters and the validity of proposed control method by Bo and Yang [17].

SOLAR SYSTEM

In photovoltaic (PV) system, solar cell is the basic component. PV array is nothing but solar cells are connected in series or parallel for gaining required current, voltage and high power. Each Solar cell is similar to a diode with a p-n junction formed by semiconductor material [5]. It produces the currents when light absorbed at the junction, by the photovoltaic effect. Figure 3 shows at an insulation output power characteristic curves for the PV array. It can be seen that a maximum power point exists on each output power characteristic curve. The Figure 3 shows the (I-V) and (P-V) characteristics of the PV array at different solar intensities. The equivalent circuit of a solar cell is the current source in parallel with a diode of a forward bias. Load is connected at the output terminals. The current equation of the solar cell is given by:

$$I = I_{ph} - I_D - I_{sh}$$

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

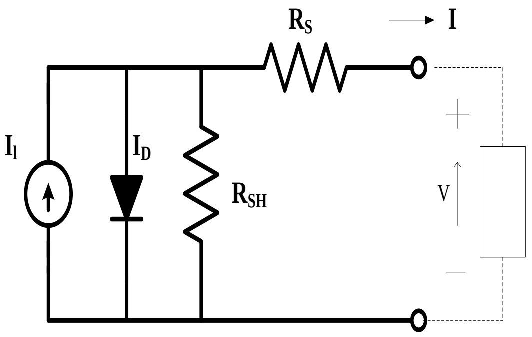

Figure 2: Equivalent circuit of PV Module

Power output of solar cell is P = V * I

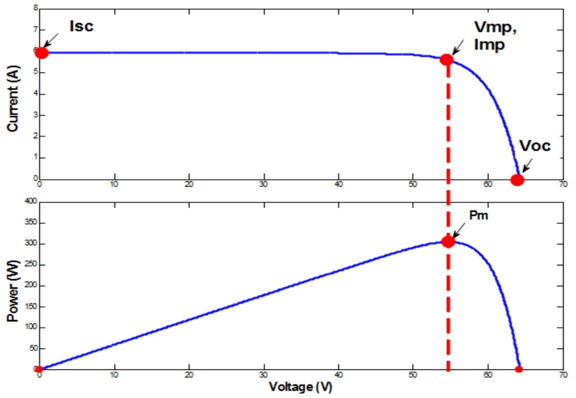

Figure 3: Output characteristics of PV Array

MAXIMUM POWER POINT TRACKING METHOD:

The irradiance and temperature curves are the two most vital factors which influence the output power characteristics of the PV system. And these two are momentarily maintained by solar irradiation and temperature. As discussed, there will be blunt changes in the values of solar radiation during the day as shown in Figure 1. A typical solar panel converts only 30 to 40 percent of the incident solar irradiation into electrical energy. According to Maximum Power Transfer theorem, the power output of a circuit is maximum when the thevenin impedance of the circuit (source impedance) matches with the load impedance. In this way, Maximum power point tracking technique is necessarily used to improve the efficiency of the solar panel.

As the solar panel voltage /current increases, the PWM generator increases its repetition rate thus resulting in increased output current. At the same time, additional voltage is applied to the inductor thus increasing its charge current. Where the initialization is based on voltage and power calculations that are based on current and voltage values acquired from sensors [9]. Once the actual power is calculated, then the next cycle of the measurement is compared to previous value to change the reference voltage V_{ref}.

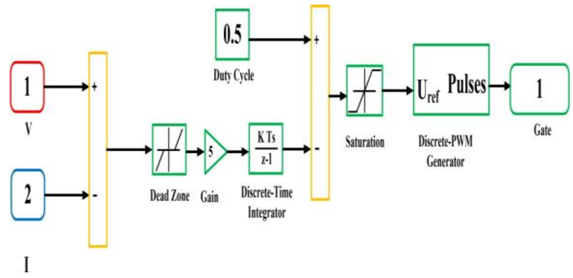

Figure 4: DC-DC converter MPPT Controller

PROPOSED SYSTEM

The active power pumped by grid tied solar inverter into the grid is a function of solar insolation. This means that the amount of active power pumped into the grid will be lower than the designed rated capacity of solar inverter if the solar irradiance is less (which actually happens as the solar irradiance is not uniformly maximum throughout the day). This leads to underutilization of the inverter resource. If the inverter is programmed to provide reactive power also in addition to active power (based on solar irradiance availability) then the inverter can be operated at its rated capacity even when the solar resource is not fully available. Reactive power compensation through solar inverter is an interesting method to manage network voltages through reactive power injection and absorption.

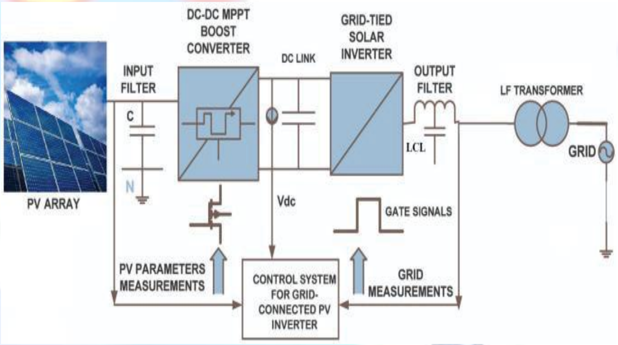

Figure 5: Structure of Grid Connected PV system for Reactive Power Control

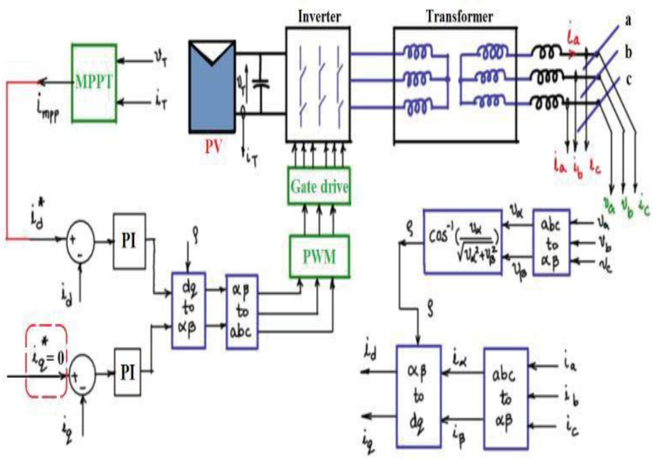

Figure 6: Control of VSI

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 7. 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.

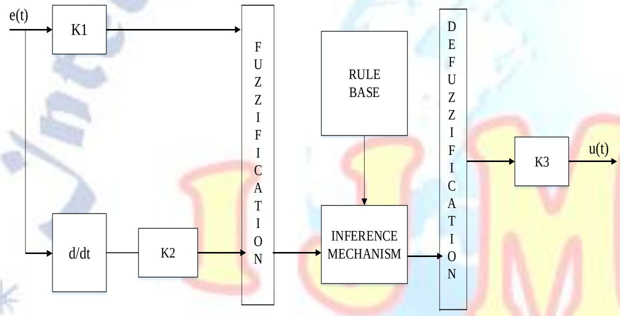

Figure 7: basic structure of fuzzy logic controller

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.

RESULTS AND DISCUSSION:

The model of the proposed control scenario is developed on MATLAB/Simulink platform. The proposed system is implemented on several conditions, such as steady state, dynamic load, load removed, grid voltage unbalanced, variable solar irradiation level, and distorted grid voltage condition

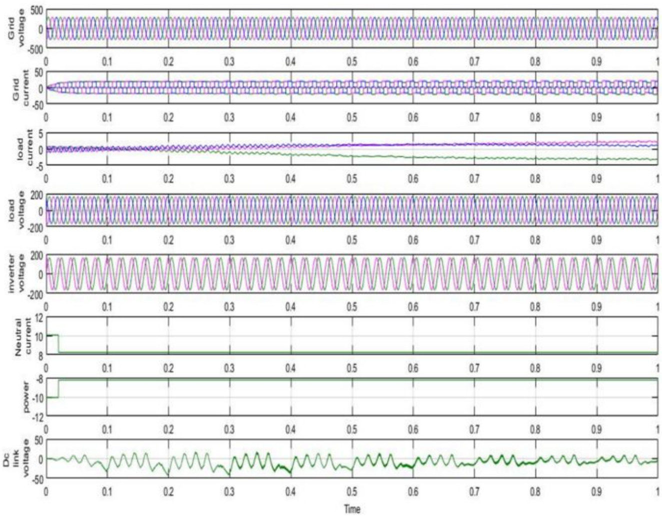

Figure 8: Simulation characteristics under polluted grid voltage condition

Figure 8 shows that the system is running under balanced supply voltage, load removed, and dynamic load conditions. From 0 to 0.08 s shows the grid balanced supply voltage condition. To examining the controller dynamic performance, phase "a" load is removed, which is shown in Figure 5.6 from 0.08 to 0.15 s. During 0.15–0.2 s, the proposed system is working under dynamic load condition.

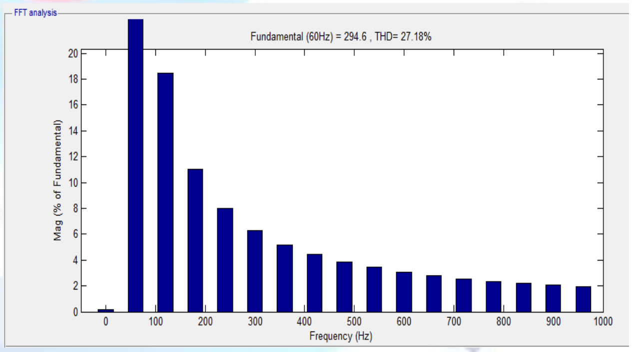

Figure 9: THD Source Voltage

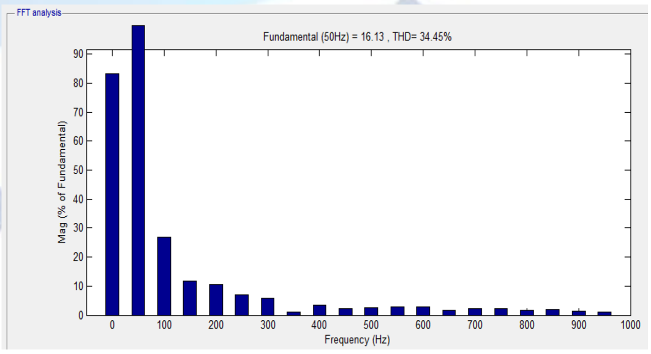

Figure 10: THD for Compensated voltage

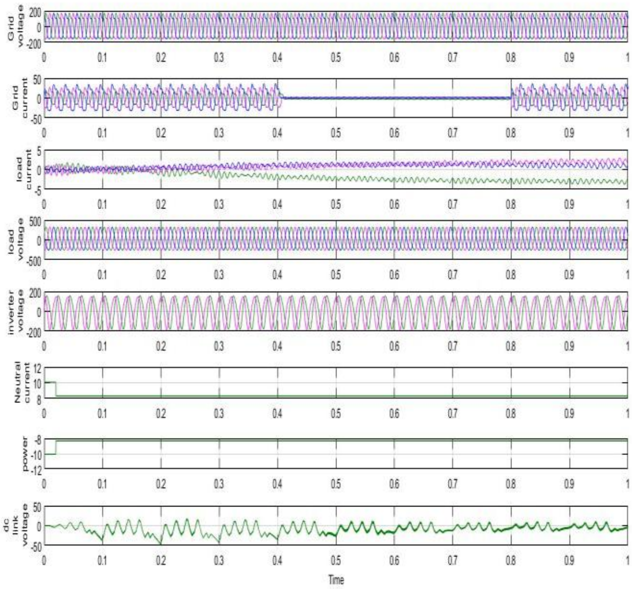

Figure 11: Simulation Results under Steady State, Load Removed, And Dynamic Load Conditions with ANN

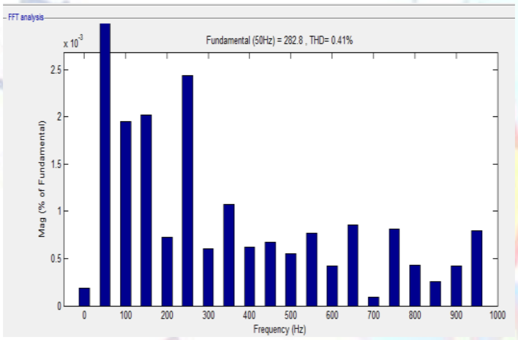

Figure 12: THD for Source voltage

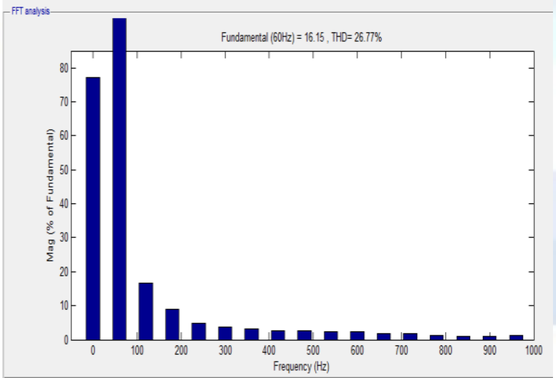

Figure 13: THD for Compensated voltage

CONCLUSION

This paper proposed an ANN based seamless transfer controller between grid and islanding operations, with a stage secured circle controller a three-stage grid-associated Photovoltaic inverter. Both the present control for grid-associated operation and the voltage control for islanding operation were steady with positive stage edges. The synchronization point of the PLL expanded easily without sudden hops even under voltage hangs and operation mode transfer. At the point when both the stage and extent of the heap voltage were at the same time changed in accordance with the grid voltage before transferring to the grid-associated operation, the output voltage and current had a few contortions toward the start of the synchronization process. At the point when the mode transitioned to the islanding operation mode, the heap voltage immediately drew closer its craved voltage without voltage spikes and surge streams by utilizing the proposed working succession for consistent transfer.

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