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ANN-based filters to improve the power quality of Grid Connected solar photovoltaic system

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ABSTRACT

Grid-connected photovoltaic (PV) systems are gaining popularity in both the business and academic sectors as a clean energy alternative to fossil fuels. Using a shunt active power filter (APF) and an adaptive current management approach, this study intends to improve the power quality of a grid-connected PV distribution system.

In this research, an artificial neural network-based controller is used to remove voltage and current harmonics from a photovoltaic (PV) system that is connected into the electrical grid. An strategy for producing a reference current is developed to lessen current harmonics by separating the fundamental components (FCs) of the nonlinear load currents. If the grid voltage is extremely distorted, MCCF may be utilised to protect the FC by isolating it from the distortion and eliminating the voltage harmonics. Power quality, dc offset rejection, FC and frequency extraction, and grid synchronisation are some of the metrics against which the proposed hybrid control technique is measured, as are comparisons to conventional and adaptive control methods.

1. INTRODUCTION

Most of the world's energy needs are now met by burning rapidly depleting fossil fuels including petroleum, coal, and natural gas. In particular, carbon dioxide, a byproduct of burning fossil fuels, is a significant contributor to global warming and a grave threat to all forms of life on Earth [1].

PV array systems are expected to play a substantial part in future energy generation, even more so than other forms of renewable energy. Solar photovoltaic (PV) systems convert light into electricity. Fuel cells, wind generation, and solar systems all provide low voltage output and need large step-up dc/dc converters to meet their various application requirements. With the rising demand for power and the decreasing availability and rising costs of nonrenewable sources, the photovoltaic (PV) energy conversion system has emerged as a viable option since it is abundant, produces no pollution, and is cheap to operate and maintain. Therefore, both independent and grid-connected PV systems should make more use of this energy source. As a renewable energy source, photovoltaic (PV) is subject to fluctuations in supply and demand based on factors such as latitude, longitude, time of day, and weather. Additionally, PV systems have a relatively high upfront cost and maintenance costs. Operating the system close to the maximum power point (MPP) so as to acquire roughly the maximum power of PV array is a crucial factor in improving the efficiency of PV systems. in order to get the most power from a solar array.

In the process of boosting the output of photovoltaic (PV) systems, it is standard practise to investigate the possibility of installing a high-efficiency power converter that was designed specifically for this objective. The Maximum Power Point, also known as the MPP, is the sole point on the V-I curve at which the PV system is producing the most amount of energy while also functioning at its highest level of efficiency. If the precise position of the MPP is unknown, then maybe we can make an educated guess as to where it will be found by using various search strategies or various computer models. It is possible to maintain the operating location of the PV array at the point where power production is maximised by using methods known as Maximum Power Location Tracking (MPPT). Numerous MPPT algorithms, such as "Perturb and Observe" (P&O) [2–5], "Incremental Conductance" (lC) [2–6], "Artificial Neural Network" (ANN) [7], and "Fuzzy Logic" (FL) [8, etc.], have been the focus of study. P&O and IC are the two ways that are used the most often. The Particle and Object method (P&O), the Incremental Conductance (lC) methodology [2-6], the Fuzzy Logic method [8], and the Particle Swarm Optimization strategy [l0] are the four different MPPT methodologies that are studied and contrasted in this article. These methods are gaining popularity since they are not very expensive and are simple to use. Approaches that are difficult to implement and not very practical, such as Sliding Mode [9], are beyond the focus of this study.In this study, we will work on a simulation model to determine how to best design and dimension the hybrid system across a wide range of stress and weather circumstances. The efficiency of the suggested system is confirmed by a simulation model run in Matlab and SimPower Systems, with the results reported. In Figure 1 we can see the hybrid energy generating system that is intended to be linked to the grid.

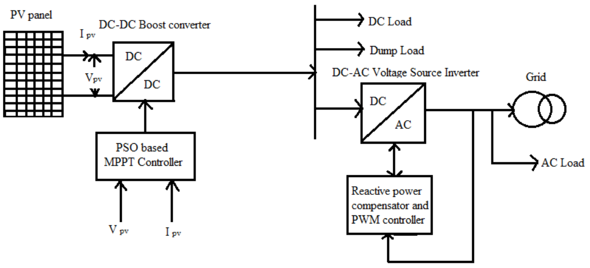

Figure 1: The configuration of the proposed hybrid system that is grid linked

2. Literature Survey:

Ciobotaru et al. [15] looked at several ways to regulate a single-stage PV inverter. Two separate current controllers were built, and their respective performances were compared experimentally. Additionally, the whole control architecture of the single-phase PV system is described. Mahmud et al. [16] recommended a robust nonlinear distributed controller design for maintaining active and reactive power balance in isolated microgrid operation. Specifically, solar photovoltaic generators play the role of RESs and plug-in hybrid electric vehicles play the function of BESSs in this study's definition of microgrids as inverter-dominated networks with RESs and BESSs. Power electronics converters are essential to the development and improvement of the electrical power system. The rising popularity of DERs is driving the need for both more power sources and better quality power distribution. The purpose of a model predictive controller is to lessen deviations in capacitor voltage from their nominal values and common mode voltages. Bo and Yang [17] demonstrate the effectiveness of their proposed control mechanism and the usefulness of multilevel inverters by giving a simulation flowchart, parameters, and results using the PLECS software.

3. SOLAR SYSTEM

To put it simply, solar cells are the workhorse of any photovoltaic (PV) system. A PV array is simply a group of solar cells wired in series or parallel to produce the desired current, voltage, and high power. Each solar cell can be thought of as an individual diode with a semiconductor p-n junction [5]. When light is shone onto the junction, the photovoltaic effect causes currents to flow. The power output characteristics of the PV array at an insulation level are shown in Figure 3. Each output power characteristic curve displays a maximum power point. In Figure 3, we can see the (I-V) and (P-V) characteristics of the PV array at varying solar intensities. Solar cells have an equivalent circuit made up of a forward-biased diode connected in series with the current source. The terminals at the end of the output are used to link up the load. The solar cell's current equation is as follows:

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

$$I = Iph - I_o \left[\exp\left(q V_D / nKT\right)\right] - \left(v_D / R_S \right)$$

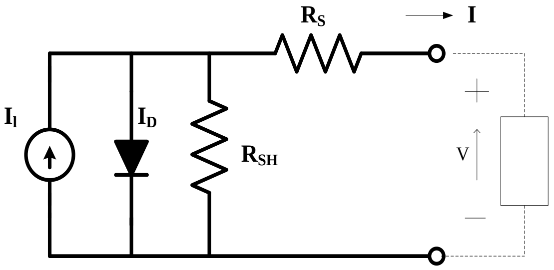

Figure 2: Equivalent circuit of PV Module

Power output of solar cell is P = V * I

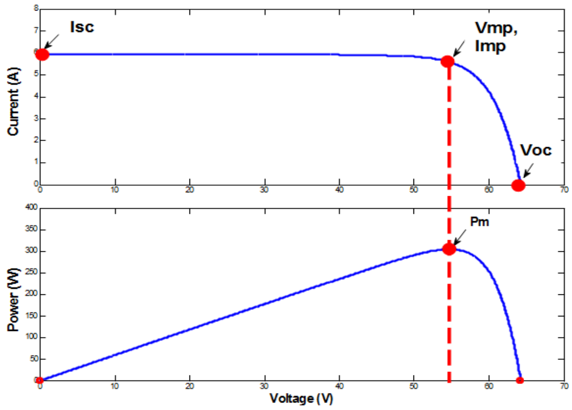

Figure 3: Output characteristics of PV Array

4. MAXIMUM POWER POINT TRACKING METHOD:

When it comes to the output power characteristics of a PV system, the irradiance and temperature curves play the most important roles. For the time being, solar radiation and temperature keep these two constant. Figure 1 depicts the dramatic fluctuations in solar radiation levels that have been described. Only around 30% to 40% of the solar irradiance that hits a typical solar panel is converted into usable electricity. The thevenin impedance (source impedance) of a circuit must coincide with the thevenin impedance (load impedance) of the circuit for maximum power transfer to occur. Therefore, it is essential to employ the Maximum power point tracking approach to maximise solar panel performance.

In response to rising input voltage or current, a PWM generator can increase the frequency of its switching to boost the solar array's output current. While doing this, more voltage is given to the inductor, which increases the charge current. Where sensor readings of current and voltage are used to determine a starting voltage and power output [9]. After determining the true power output, the Vref reference voltage is adjusted by comparing the current measurement to the previous one.

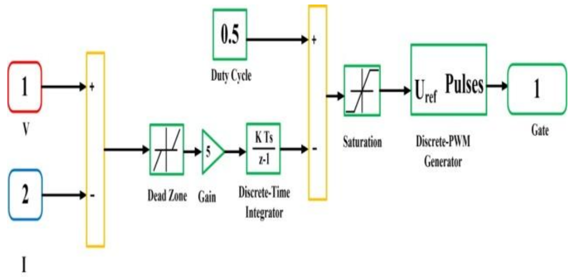

Figure 4: DC-DC converter MPPT Controller

5. PROPOSED SYSTEM

The amount of active electricity a solar inverter can put into the grid is dependent on the quantity of solar insolation. If the sun's rays are weaker than predicted, the solar inverter's output will be lower than its rated capability. The inverter ends up being underutilised as a result of this. If the inverter is set up to produce reactive power in addition to the active power, it may continue to operate at full capacity even when the solar resource is not producing as much energy as it might (based on the availability of solar irradiance). Network voltage regulation using reactive power injection and absorption is an attractive concept, and one possible option is reactive power compensation with a solar inverter.

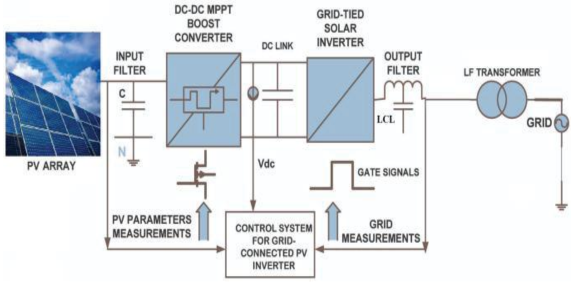

Figure 5: Structure of Grid Connected PV system for Reactive Power Control

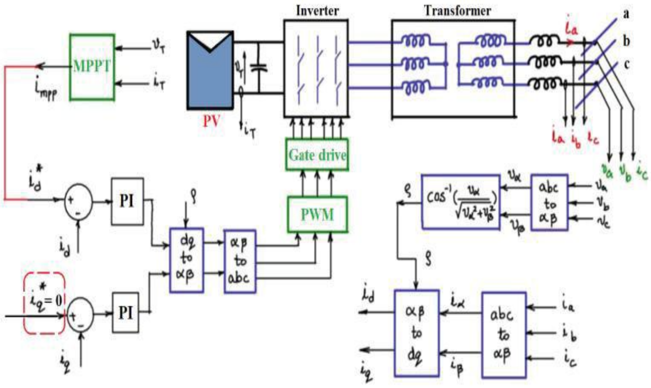

Figure 6: Control of VSI

Artificial Neural Network:

Figure 7 depicts the fundamental structure of an artificial neural network, with a circle representing a hidden layer and a square representing an adaptable node. Nodes serving as membership functions are provided between the input and output levels of this architecture, and the rules established by if-then statements are obliterated. We assume the analysed ANN [14] has two inputs and a single output to keep things simple. Each neuron in this network is linked to each component of the input vector p through a weight matrix W.

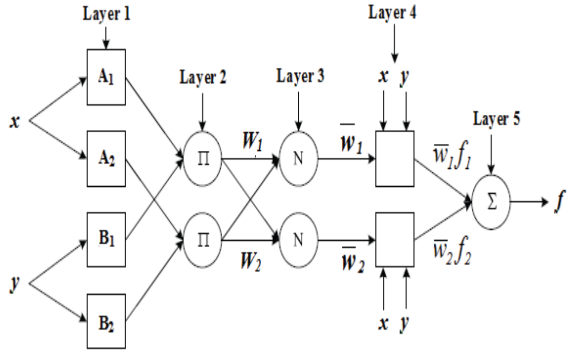

Figure 7: A two-input multi-layer ANN structure

6. RESULTS AND DISCUSSION:

Modeling the intended control situation was done in MATLAB/Simulink. The suggested system is tested under a variety of scenarios, including steady state, dynamic load, load removal, grid voltage imbalance, varying solar irradiance, and distorted grid voltage.

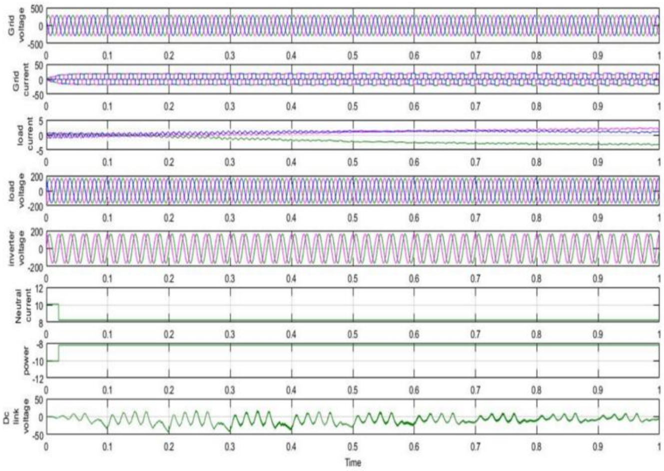

Figure 8: Simulation features under contaminated grid voltage

In Figure 8, we can see that the system is operating with a balanced supply voltage, no load, and a dynamic load. The voltage supply from the grid is balanced from 0 to 0.08 seconds. For the purpose of analysing the controller's dynamic performance, the load on phase "a" is temporarily removed (from 0.08 to 0.15 s in Figure 5.6). In a period of 0.15–0.2 s, the suggested system operates under a dynamic load condition.

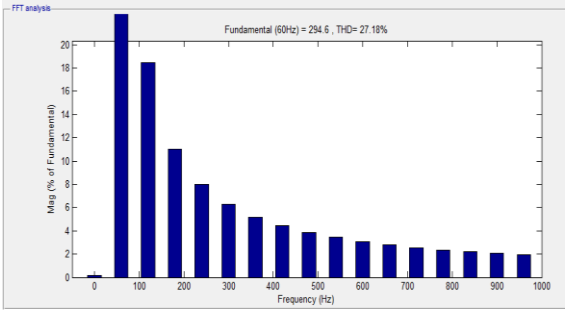

Figure 9: THD Source Voltage

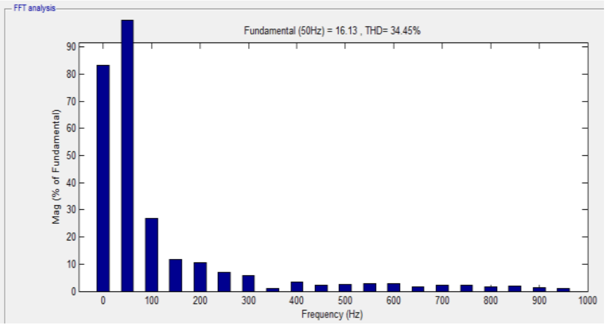

Figure 10: THD for Compensated voltage

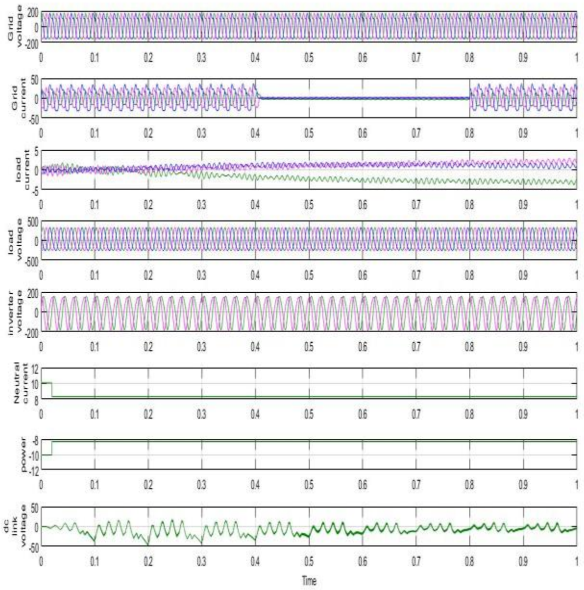

Figure 11: The results of running a simulation using ANN while in Steady State, with the Load Removed, and under Dynamic Load Conditions

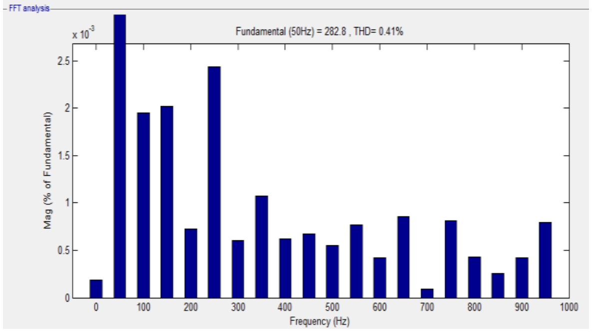

Figure 12: THD for Source voltage

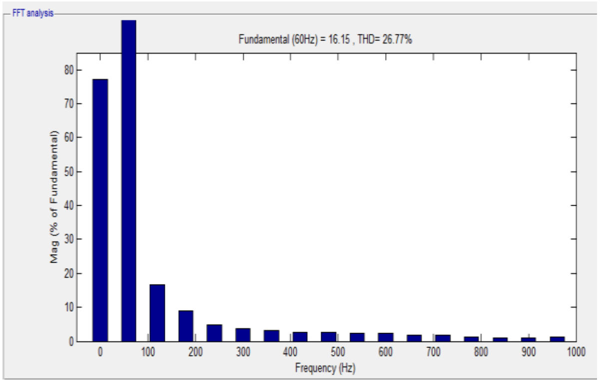

Figure 13: THD for Compensated voltage

7. CONCLUSION

In this research, a three-stage grid-connected Photovoltaic inverter with an ANN-based seamless transfer controller between grid and islanding operations is suggested. For both grid-connected and islanding modes of operation, the stage edges of the corresponding current and voltage controls remained constant. Even when the voltage dropped or the mode of operation switched, the PLL's synchronisation point grew without any jarring jumps. At the beginning of the synchronisation procedure, the output voltage and current exhibited a few bendings in accordance with the stage and amount of the heap voltage being altered simultaneously in accordance with the grid voltage before switching to the grid-associated operation. The suggested working sequence for constant transfer caused the heap voltage to quickly approach its desired voltage upon switching to the islanding operation mode, spikes and surge streams notwithstanding.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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