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Improving Grid-Connected PV System Power Quality using Fuzzy Logic Controller

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ABSTRACT

The global transition to renewable energy sources has led to a considerable increase in the integration of photovoltaic (PV) systems into the electrical grid. The fluctuating nature of solar energy and the switching processes in power electronic converters, however, provide power quality issues for this integration. This study proposes a unique use of a fuzzy logic controller (FLC) to improve the power quality in grid-connected photovoltaic systems. The suggested FLC is made to efficiently manage the inverter management strategy, guaranteeing a reliable and superior power supply to the grid in a range of operating circumstances. Under conditions like varying solar irradiation and load variations, the FLC's performance is contrasted with that of conventional control techniques. The MATLAB/Simulink environment is used to build and simulate the control algorithms and system model. The findings show that by lowering Total Harmonic Distortion (THD), keeping the power factor near unity, and guaranteeing voltage and frequency stability of the grid-connected PV system, the FLC considerably enhances power quality. A more seamless transition to sustainable energy systems is made possible by this study's prospective solution for the power quality problems brought on by the grid's integration of renewable energy sources.

KEYWORDS: Photovoltaic System, Power Quality, Fuzzy Logic Controller, Grid Integration, MATLAB/Simulink, Total Harmonic Distortion, Renewable Energy.

1.INTRODUCTION

Currently, burning quickly depleting fossil fuels like coal, natural gas, and petroleum provides the majority of the world's energy demands. Specifically, carbon dioxide, a byproduct of burning fossil fuels, poses a serious danger to all life on Earth and contributes significantly to global warming [1].

Even more so than other renewable energy sources, PV array systems are anticipated to contribute significantly to future energy generation. Solar photovoltaic (PV) systems generate electricity by converting light. Large step-up dc/dc converters are necessary for the low voltage output of solar, wind, and fuel cell systems in order to satisfy their diverse application needs. Due to its abundance, lack of pollution, and low operating and maintenance costs, the photovoltaic (PV) energy conversion system has become a feasible alternative to nonrenewable energy sources, which are becoming less and more expensive. Consequently, PV systems, whether standalone or grid-connected, ought to utilize this energy source more. Photovoltaic (PV) is a sustainable energy source, but its supply and demand can fluctuate depending on weather, latitude, longitude, and time of day. PV systems are also comparatively expensive to install and maintain. A key element in raising the efficiency of PV systems is operating the system at the maximum power point (MPP) in order to obtain about the maximum power of the PV array. in order to maximize a solar array's output.

It is customary to consider installing a high-efficiency power converter made especially for PV systems in order to maximize their output. There is only one location on the V-I curve where the PV system is operating at peak efficiency and generating the most power, known as the Maximum power Point (MPP). Even if the MPP's exact location is unknown, its position can be estimated using computational models or search techniques. The PV array's operational position is kept at the ideal location for power generation through the use of Maximum Power location Tracking (MPPT) techniques. Numerous MPPT algorithms, such as Perturb and Observe (P&O) [2–5], Incremental Conductance (lC) [2–6], Artificial Neural Network (ANN) [7], Fuzzy Logic (FL) [8], and others, have been examined in the literature. The two most common methods are P&O and IC. P&O, the Incremental Conductance (lC) approach [2–6], the Fuzzy Logic method [8], and the Particle Swarm Optimization strategy [l0] are the four MPPT methodologies that are examined in this work. These techniques are widely used since they are inexpensive and easy to use. Because of their complexity and lack of practical application, methods such as Sliding Mode [9] are outside the purview of this article.

In order to figure out how to effectively build and size the hybrid system under a variety of stress and weather conditions, we will be working on a simulation model in this project. A simulation model done in Matlab and SimPower Systems verifies the effectiveness of the proposed system, and the outcomes are provided. The hybrid energy generating system that is meant to be connected to the grid is depicted in Figure 1.

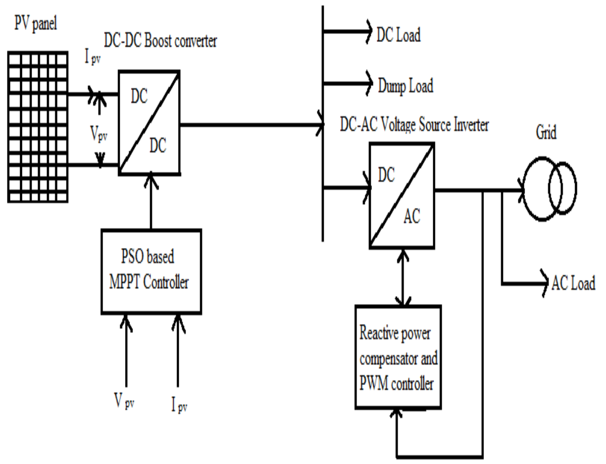

Figure 1: Configuration of proposed grid connected hybrid system

2. LITERATURE SURVEY:

Ciobotaru et al. [15] investigated control strategies for a single-stage photovoltaic (PV) inverter. We built two different current controllers and conducted an experimental comparison of their performance. Additionally, the whole control architecture of the single-phase PV system is described. Mahmud et al. [16] proposed a robust nonlinear distributed controller architecture to maintain the balance between active and reactive power during isolated microgrid operation. In this study, microgrids are characterized as inverter-dominated networks that comprise battery energy storage systems (BESSs) and renewable energy sources (RESs). The BESSs are plug-in hybrid electric vehicles, and the RESs are solar photovoltaic generators. Power electronics converters are essential to the electrical power system's deployment and performance improvement. The demand for new power sources and higher-quality power supplies is correlated with the growing usage of distributed energy resources (DERs). Reducing common mode voltages and voltage differences between capacitors and their nominal values is the aim of a model predictive controller. Bo and Yang [17] demonstrate the effectiveness of their proposed control mechanism and the worth of multilevel inverters by presenting a simulation flowchart, settings, 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:

$$I = I_{ph} – I_D - I_{sh}$$

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

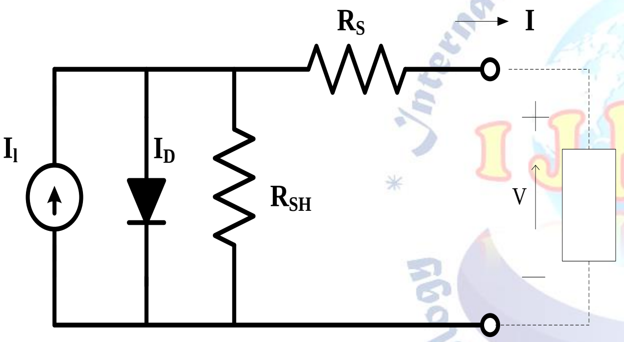

Figure 2: Equivalent circuit of PV Module

Power output of solar cell is P = V * I

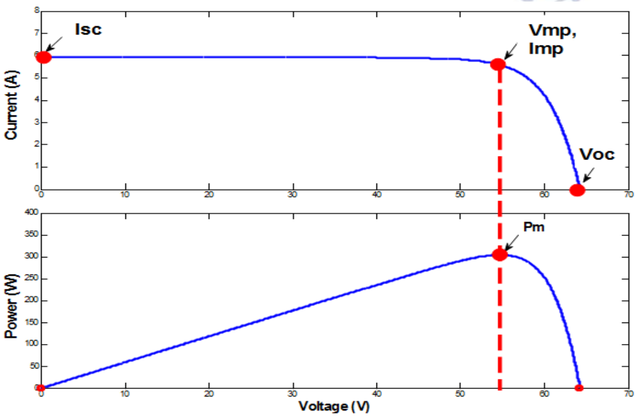

Figure 3: Output characteristics of PV Array

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.

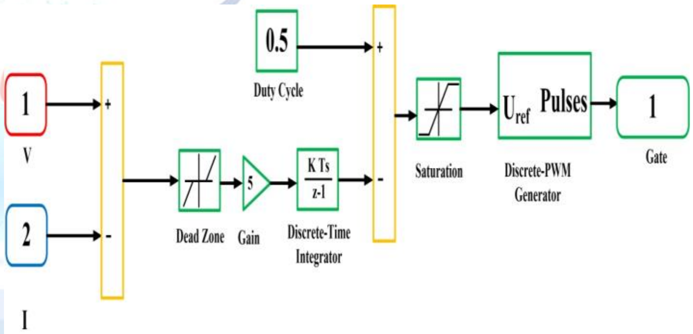

Figure 4: DC-DC converter MPPT Controller

5. PROPOSED SYSTEM

The amount of solar insolation affects the amount of active power that can be pumped into the grid by a solar inverter that is connected to the grid. The amount of active power pumped into the grid will be less than the solar inverter's rated capacity if the sun's rays are less intense than expected. A consequence of this is that the inverter is underutilised. When the solar resource is not at full capacity, the inverter can still function at its rated capacity if it is programmed to provide reactive power in addition to active power (based on the availability of solar irradiance). Controlling network voltages by injecting and absorbing reactive power is an intriguing method, and reactive power compensation using a solar inverter is one promising approach.

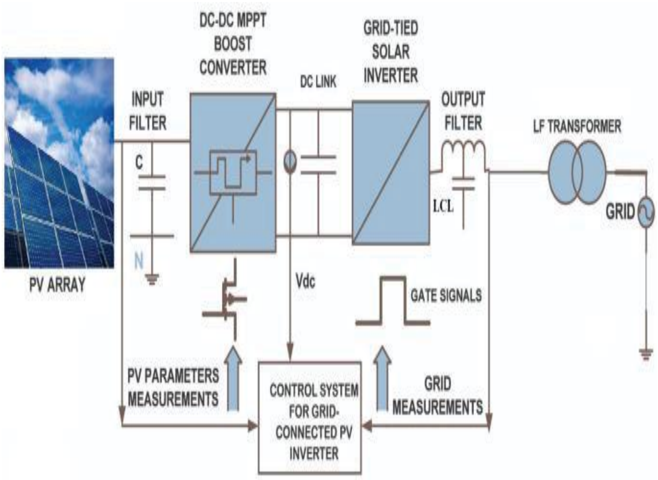

Figure 5: Structure of Grid Connected PV system for Reactive Power Control

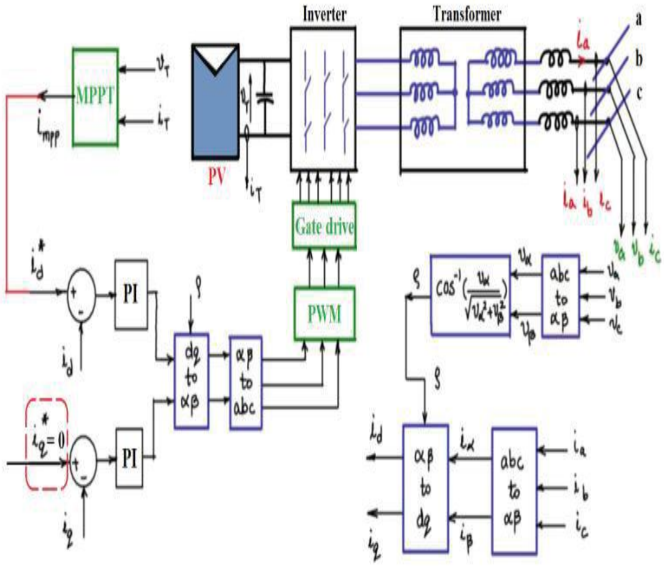

Figure 6: Control of VSI

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.

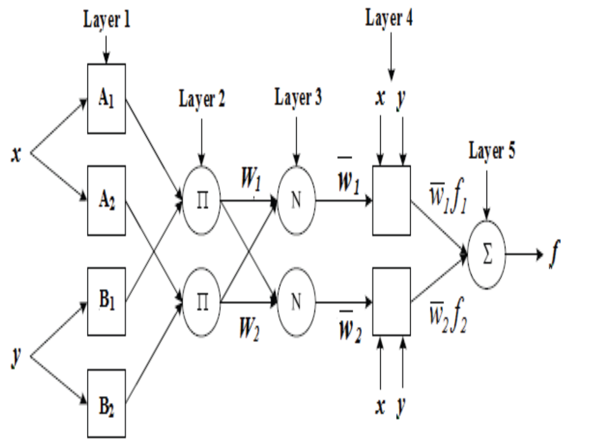

Figure 7: A two-input multi-layer ANN structure

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.

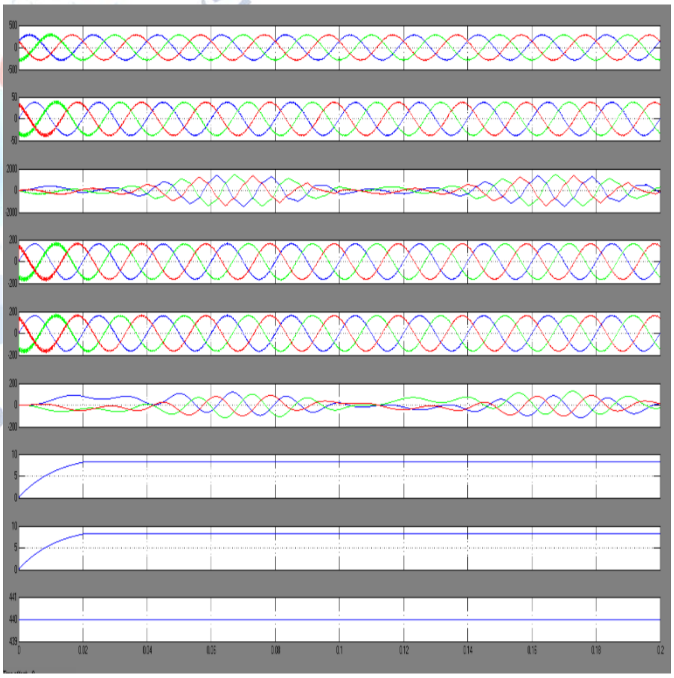

Fig: Without Filter (a) Grid Voltage, (b)Grid Current, (c)Load Current, (d) Voltage at the LCL filter, (e) Voltage at PCC (f) Current at LCL filter (g) DC Voltage

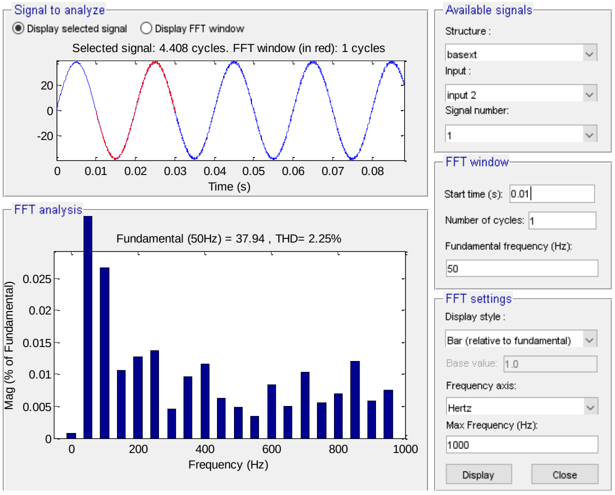

Fig: THD of the grid current without filter

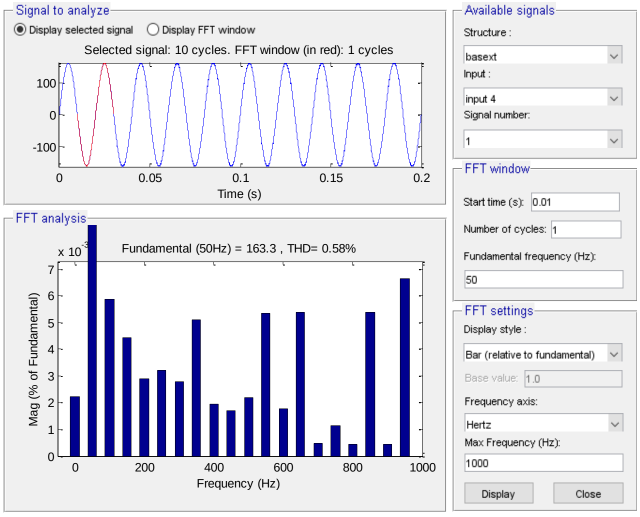

Fig: THD of the grid current when the LCL Filter are connected

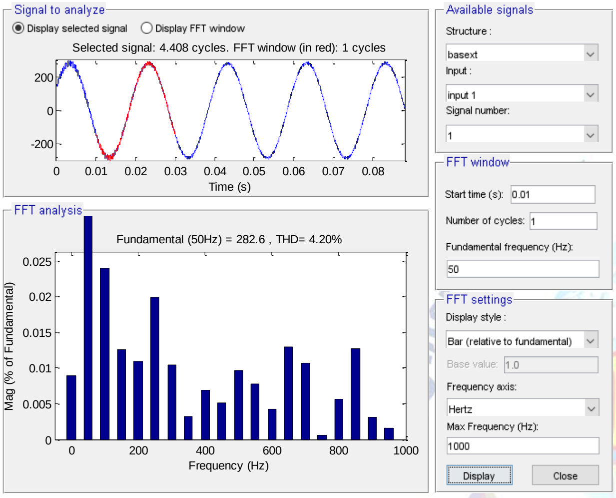

Fig: THD of the grid voltage without filter

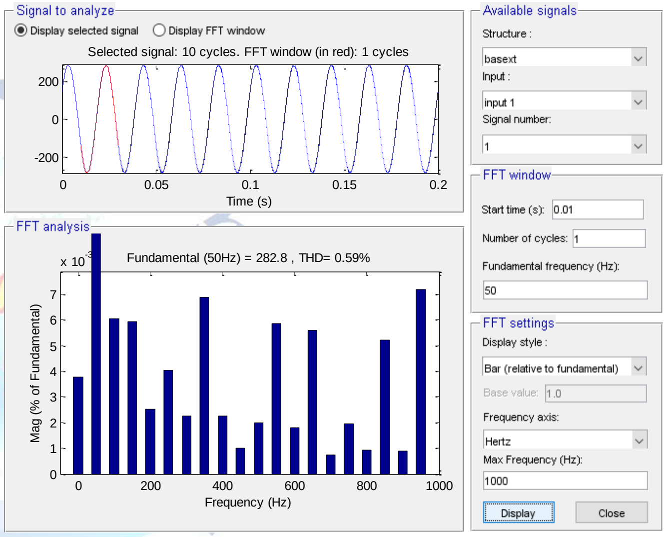

Fig: THD of the grid voltage when the LCL Filter are connected

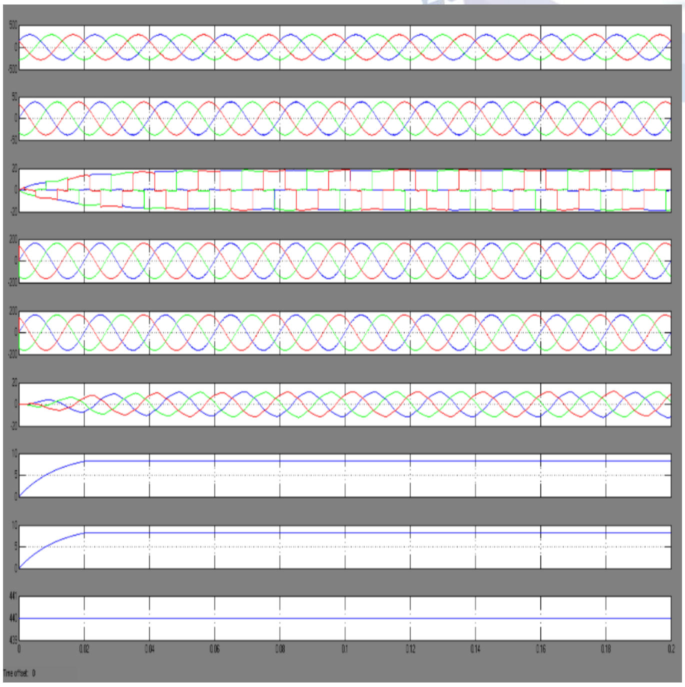

Fig: With Filter (a) Grid Voltage, (b)Grid Current, (c)Load Current, (d) Voltage at the LCL filter, (e) Voltage at PCC (f) Current at LCL filter (g) DC Voltage

Comparision Table

	THD % without LCL filter	THD % with LCL filter
Grid Voltage	4.50	0.59
Grid current	2.25	0.58

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 synchronization point grew without any jarring jumps. At the beginning of the synchronization 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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