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GRID POWER QUALITY ENHANCEMENT USING FUZZY CONTROL-BASED SHUNT ACTIVE FILTERING

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ABSTRACT
Industry and academia are becoming more interested in grid-connected photovoltaic (PV) systems as a way to offer pollution-free power and a substitute for traditional fossil fuel generating. In this work, a grid-tied photovoltaic system's voltage and current harmonics are eliminated using a fuzzy controller. In order to reduce the current harmonics, a reference current generation approach is used to separate the FCs (fundamental constituents) from the nonlinear load currents. When the grid voltage is significantly contaminated, MCCF is used to remove voltage harmonics and separate the FC from the distorted grid voltages. In distribution grids, active filtering has shown to be an effective method of reducing harmonics. This research focuses on designing fuzzy control techniques for a three-phase shunt active filter in order to improve power quality by controlling the distribution network's DC bus voltage. A simulation analysis is conducted using Simulink/Matlab to assess the resilience and performance of the suggested control strategy.

Keywords: Photovoltaic System, fuzzy controller , P & O ,MPPT, Boost Converter, LCL Filter, and Grid Connection,SAPF.

INTRODUCTION:

A method for maximum power point tracking (MPPT) in a photovoltaic (PV) system using fractional-order fuzzy logic control (FOFLC) is provided. Shunt active power filters (SAPF) represent a feasible solution to the problems caused by the non- linear loads. These loads draw non-sinusoidal currents from the 3-phase sinusoidal, balanced voltages which are classified as identified and unidentified loads. The SAPF can compensate for the harmonics, correct the power factor and work as a reactive power compensator, thus providing enhancement of power quality in the system [1, 2]. The control scheme of a SAPF must calculate the current reference waveform for each phase of the inverter, maintain the dc voltage constant, and generate inverter gating signals. The current reference circuit generates the reference currents required to compensate the load current harmonics and reactive power, and also try to maintain constant the dc voltage across the capacitor [3]. First, the fuzzy controller's dynamic range is carefully considered while choosing the fractional order factor. Expanding the fuzzy domain and finding the MPP faster requires a larger alpha factor in the first place. It limits the fuzzy domain and removes oscillations at the maximum power point (MPP) by using a decreasing alpha factor as it approaches the MPP. As a result, the FOFLC in a PV system responds quickly to changes in the environment and tracks the maximum power point with great accuracy. Second, a PV power system is simulated using MATLAB/Simulink software, and multiple simulations are used to validate the suggested algorithm. A field programmable gate array (FPGA) board has been used to develop the improved MPPT algorithm. The majority of the world's energy needs currently come from fossil fuels, which are running out quickly and include natural gas, coal, and petroleum. Carbon dioxide, a byproduct of burning fuel, is one of the main, serious issues with global warming; it puts life on Earth in grave danger [4]. PV array systems are considered to be one of the most reliable forms of renewable energy in terms of potential energy generation. Photon energy is converted into electrical energy by PV systems. High step-up dc/dc converters are used in various energy systems, such as fuel cells, wind power, and solar systems, to convert low voltage into high voltage because these systems produce low voltage output. Owing to the growing need for power, restricted supply, and expensive nonrenewable resource costs, photovoltaic (PV) energy conversion systems have emerged as a viable alternative because of their abundance, lack of pollution, low operating and maintenance costs, and ease of use[5].

PROPOSED DESIGN:

It is therefore necessary to enhance the use of PV energy systems, both standalone and grid-connected. As a renewable energy source, photovoltaics (PV) is inherently unstable due to changes in location, time, season, and weather. Additionally, the cost of installation is rather expensive. Operating the system close to the maximum power point (MPP) in order to achieve the estimated maximum power of the PV array is a crucial factor in improving the efficiency of PV systems for obtaining the solar system's greatest energy output. Due to the increasing use of nonlinear loads such power electronic converters, variable-speed motor drives, and consumer electronics, power quality issues have grown significantly in importance in recent years[6]. In the power network, nonlinear loads introduce harmonics that lead to various disruptions such electromagnetic interference, distortion of the voltage and current waveforms, and overheating of the power distribution components, which shortens their lifespan and results in losses [7], [8]. Known also as Active Power Line Conditioners (APLCs), Active Power Filters (APFs) are a relatively new technology that offers a more flexible alternative to conventional passive filters, which are made of specially designed LC filters that are tuned to provide fixed frequency compensation. Additionally, APFs provide superior filtering performance characteristics and faster transient response [9]. A control circuit and a power electronic inverter make up the majority of AFPs. These filter systems' performance is mostly determined by the converter topology used, the reference current generation approach chosen for harmonic compensation, and the controller in charge of controlling the DC bus voltage. By keeping the voltage across the capacitor linked to the inverter at the appropriate level, the DC bus voltage is regulated.

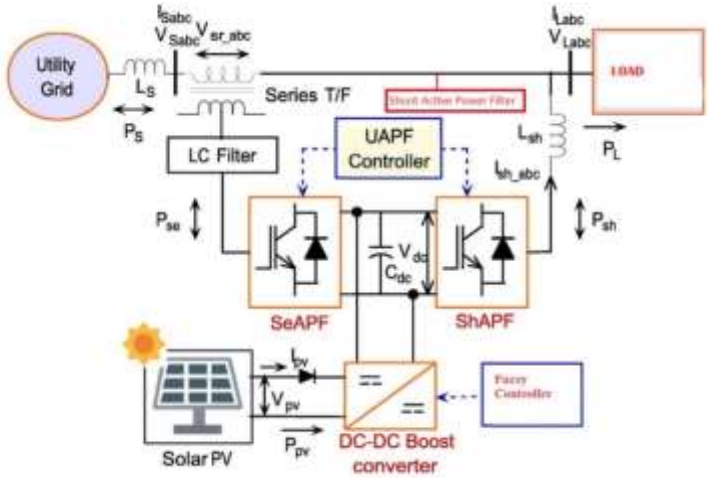

Fig-1 Structure of Grid Connected PV system for Reactive Power Control

The capacitor voltage serves as a means of offsetting inverter losses as well as any brief variations in real power between the AC and DC sides in response to changes in load. The literature has presented a number of different DC bus voltage management techniques [4, 5]. Over the course of more than 40 years, fuzzy systems have developed into a potent tool for handling uncertainty, parameter fluctuation, and situations in which the system model is complicated or not precisely stated for the intended control action. Numerous real-world applications, mostly in the areas of quantitative modeling and control, have effectively adopted them [10]. Configuration of Shunt AFP The idea behind APF is to cancel out the harmonic components that the load generates by using an inverter to provide certain currents or voltages. The Shunt APF (SAPF), which introduces current harmonics into the point of common coupling (PCC), is the most widely utilized AFP design. The basic SAPF principle is shown in Fig. 2.

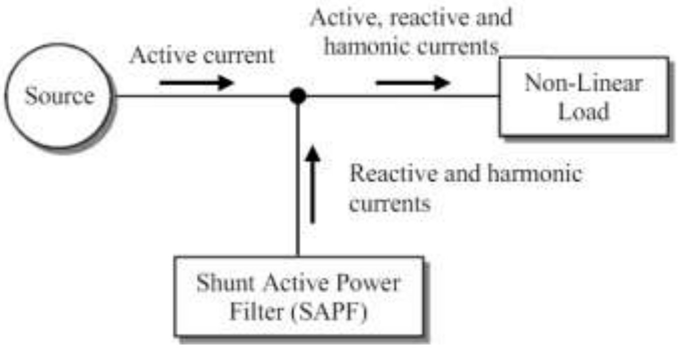

Fig. 2 Basic principle of a SAPF.

CONTROL SCHEME OF SAPF:
A shunt active power filter's control scheme has to produce the inverter gating signals, keep the dc voltage constant, and compute the current reference waveform for each inverter phase. Fig. 2 displays the block diagram of a shunt active power filter's control scheme. The reference currents needed to offset reactive power and load current harmonics are produced by the current reference circuit. It also attempts to keep the dc voltage across the electrolytic capacitors steady. Additionally, the capacity of an active power filter to follow the reference signal designed to correct for the distorted load current with the least amount of error and delay determines how effective the filter is in compensating for it. Ultimately, the overall DC bus voltage must remain constant and equal to a specified reference value thanks to the DC voltage control unit. The tiny amount of real power that the inverter absorbs is adjusted to manage the dc voltage. By altering the amplitude of the reference current's basic component, the tiny real power can be changed. In recent years, many SAPF control topologies have been well documented [11– 14].

$i_s(t) = i_L(t) + i_c(t)$ (1)
Source voltage is given by
$V_s(t) = V_m sin\omega t$ (2)
If the nonlinear load is applied, then the load current will have a fundamental component and harmonic components, which can be expressed as:
$i_L(t) = \sum_{n=1}^{\infty} I_n \sin(n\omega t + \varphi_n)$ (3)
Instantaneous power can be given as:
$P_L(t) = v_s(t) * i_L(t)$ (4)
$= V_m I_1 \, sin^2\omega t \cos\varphi_1 + V_m I_1 \, sin\omega t \cos\varphi_1 + V_m \sin\omega t \sum_{n=2}^{Y} \sin(\omega t + \varphi_n)$ (5)
The utility must provide a tiny overhead for capacitor leakage and converter switching losses in addition to the actual power of the load because the PWM converter has some switching losses as well. As a result, the source's (Isp) total peak current is:
$I_{sp} = I_{sm} + I_{sl}$ (6)
If the active filter provides total reactive and harmonic power, then i_s (t) will be in phase with the utility voltage and purely sinusoidal. At this time, the active filter must provide the following compensation current:
$I_c(t) = I_L(t) - I_s(t)$ (7)
With SAPF's control, current harmonics on the ac side are eliminated and the source current is brought into phase with the source voltage by drawing or providing a compensating current to or from the utility. The instantaneous currents from Fig. 3 can be expressed as follows:

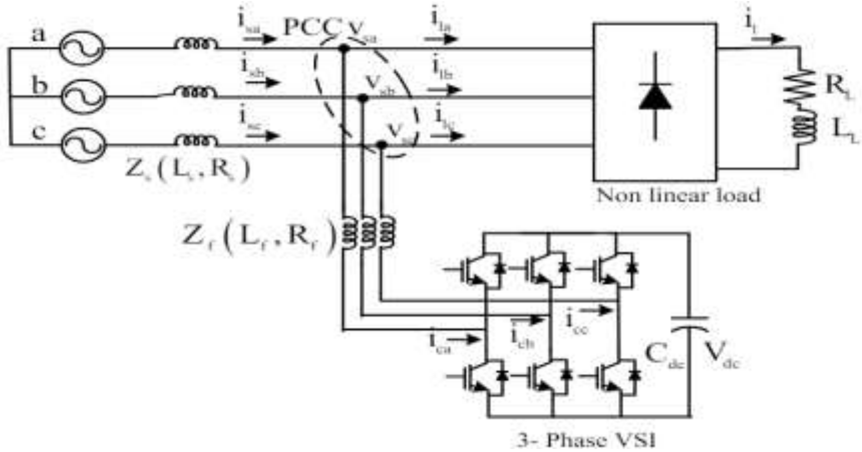

Figure 3: Basic Compensation Principle of Shunt Active Power Filter (SAPF)

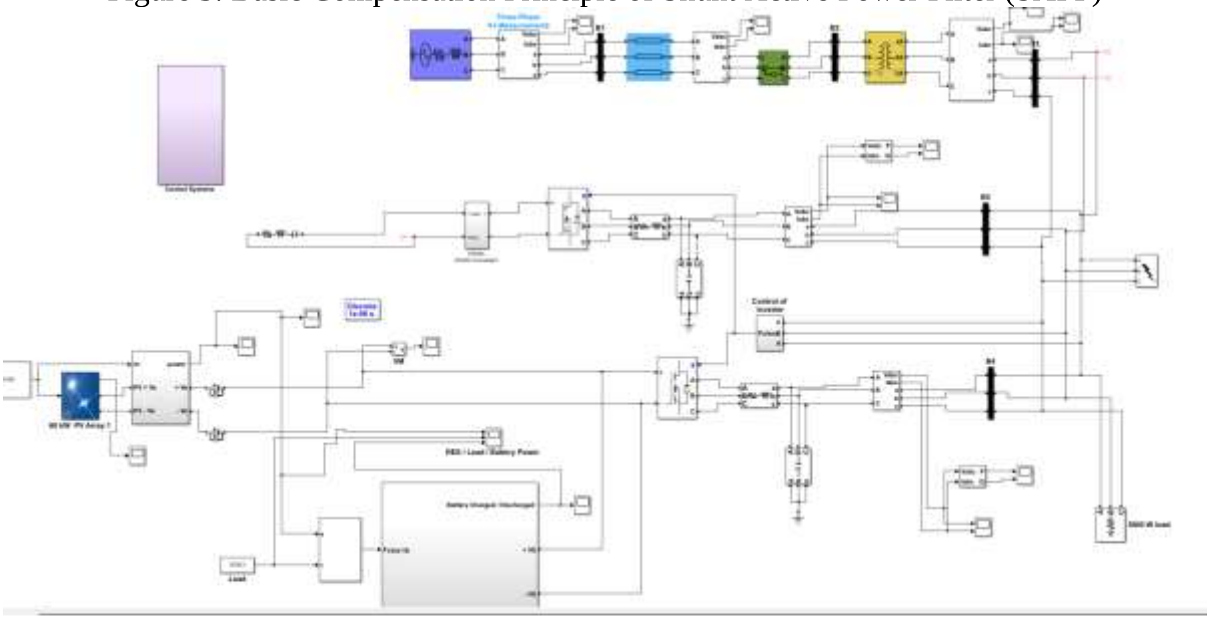
Fig-4 MATLAB simulation of proposed micro grid

"A thorough understanding" of the process to be regulated is more important for the creation of the rules than a mathematical model of the system.

PROPOSED FUZZY CONTROLLER:

A fuzzy logic controller's design requires the choice of membership functions[14-16]. Choosing membership functions that cover the full range of discussion is crucial. It's crucial to make sure the membership features work well together. This is done to ensure that the little input changes are not accompanied by any form of discontinuity. Finer control will come from reducing the membership functions in the zero area. Having wider membership functions that go outside the zero area speeds up system response. As a result, the membership functions must be changed accordingly. After the appropriate membership functions have been chosen, a rule base should be created. It consists of a number of hazy if-then rules that define every facet of the behavior of the system. These ideas provide artificial intelligence to the system since they closely resemble human thought processes [17].The reasoning for the creation of this rule base table is that whereas modest errors in a steady state require fine control, which calls for fine input/output variables, major errors in a transitory state require coarse control, which calls for coarse input/output variables for that purpose. Table 1 presents the components of the rule table based on this.

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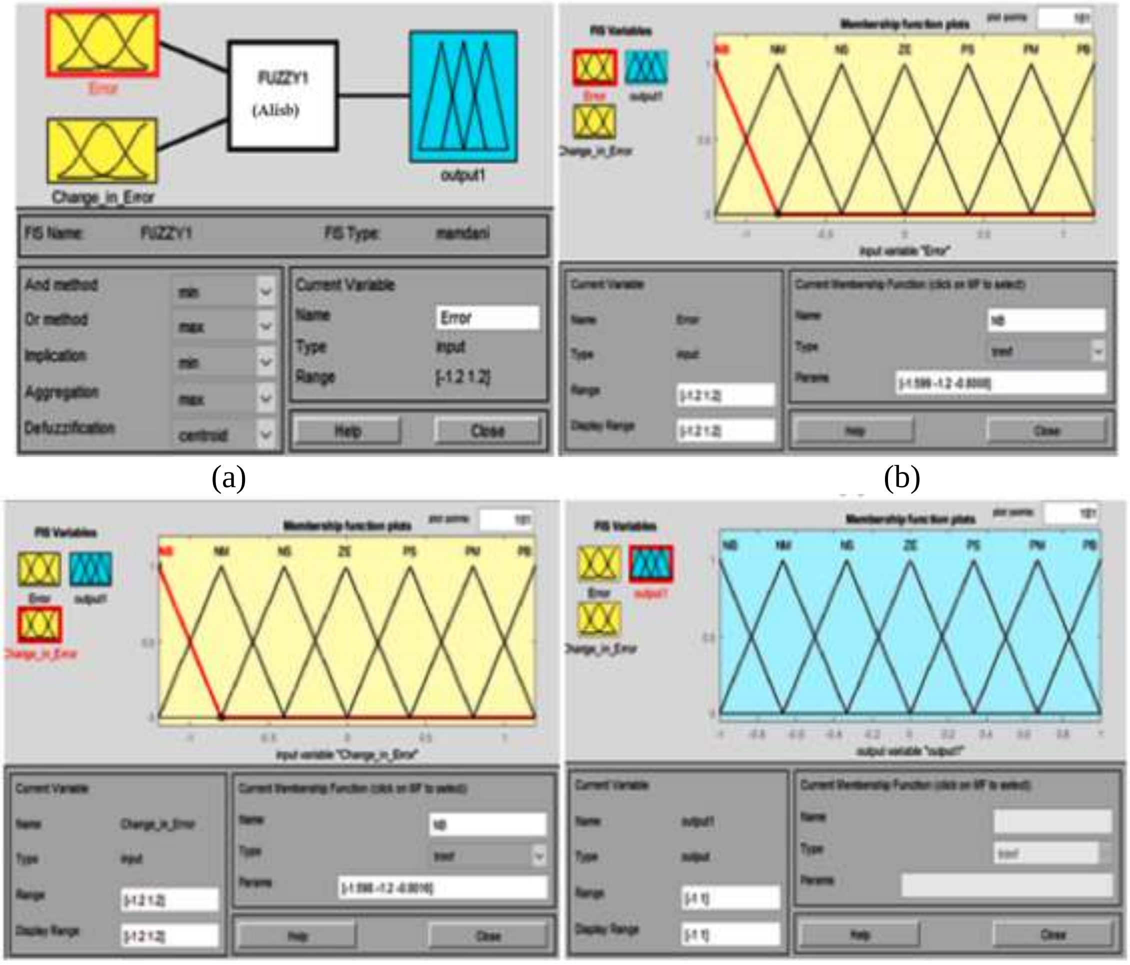
Table-1 Fuzzy rules

Change in error	NB	NM	NS	ZE	PS	PM	PB
NB	ZE	ZE	NB	NB	NM	NS	PB
NM	ZE	ZE	NB	NM	NS	ZE	PS
NS	ZE	ZE	NM	NS	ZE	PS	PM
ZE	NB	NM	NS	ZE	PS	PM	PB
PS	NS	NS	ZE	PS	PM	PB	PB
PM	NS	ZE	PS	PM	PB	PB	PB
PB	ZE	ZE	ZE	NM	NS	NS	NS

The DC-link voltage is maintained constant in order to calculate the peak value of the reference currents. To track a reference current signal, the capacitor voltage Vdc is compared to a predefined reference value. In order to create zero stable error, the data is processed by a fuzzy logic controller (FLC) [18]. By using knowledge bases or expert experience, an expert builds fuzzy rules that transform verbal control tactics into automatic control strategies. To maintain a dc-link voltage, which is necessary to keep the dc-link voltage constant, this amount of active current is needed. These numerical variables can be converted to linguistic variables by selecting fuzzy levels, as shown in Table 1. The hysteresis current controller generates pulses by comparing the source current and reference current. Using a fuzzy controller eliminates the necessity for a quantitative system analysis based on expert knowledge, and there was the transient.



(a) (b)

(c) (d)

Fig. 5. (a) Fuzzy Logic Designer (b) Error Voltage (k) (c) Change in Error Voltage (d) Reference Current Output.

Fuzzy logic controller (FLC) is a nonlinear control method that can be easily applied to nonlinear characteristics of PV systems in order to track maximum power point . The fuzzy logic control principle was developed in 1965. The main benefit of FLC is that it can operate in uncertain conditions, such as weather changes and load variations, and it is not dependent on the precise model of the system; instead, its control strategies are based on measured data bases and expert knowledge of the system. Additionally, FLC based MPPT has superior robustness and good tracking accuracy when compared to hill climbing techniques .

The following parts make up the fuzzy logic controller (FLC) based MPPT method:

• Fuzzification interface: input crisp values are determined by predefined fuzzy subsets.

• The set of "if then" statements that describe the controller behavior are provided by the fuzzy rule base.

• An inference engine that uses a fuzzy rule base to process output from an input collection of fuzzy values.

• The defuzzification interface, which yields the output fuzzy set's crisp values.

The variety and quantity of applications for fuzzy logic have significantly increased recently. Applications include choosing emotionally supportive networks, controlling mechanical procedures, therapeutic instrumentation, portfolio selection, and purchasing things like cameras, camcorders, laundry washers, and microwave cookers. You must first understand what fuzzy reasoning implies in order to understand why the use of fuzzy logic has grown. There are two distinct consequences of fuzzy logic. Fuzzy logic is essentially a cohesive framework that is an extension of multivalve reasoning. Nevertheless, fuzzy logic (FL) is almost synonymous, in a broader sense, with the fluffy sets theory, which associates classes of things with unsharp bounds, often involving degree. According to this perspective, fuzzy logic is a subset of fuzzy logic. In fact, fuzzy logic differs from traditional multivalve consistent frameworks in both concept and content, even in its more constrained formulation. Fuzzy logic, or fuzzy logic in its broadest meaning, should be translated as FL in fluffy Logic Toolbox programming. Foundations of Fuzzy Logic provides a clear and intelligent explanation of the core concepts of fuzzy logic.

Results:

Figures 6–10 show the performance outcomes of the shunt active power filter with fuzzy controller. Figure 6 displays the THD content of the source and load currents using a fuzzy controller.

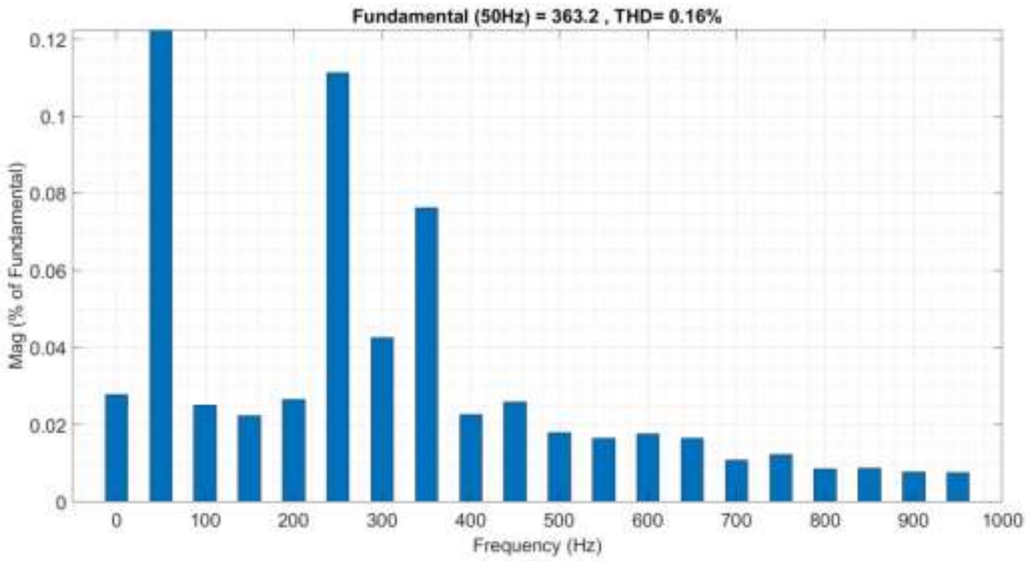


Fig-6 THD in load voltage

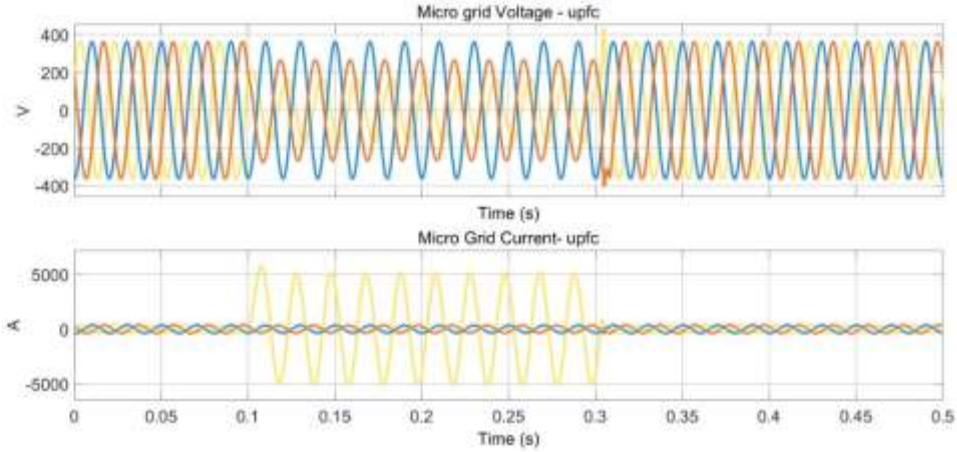


Fig-7 Grid voltage and current

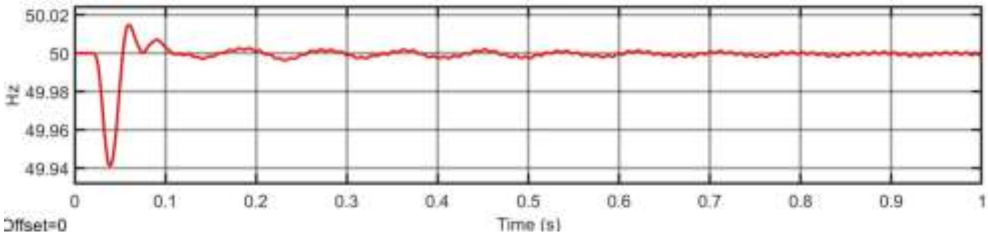


Fig-8 Grid frequency

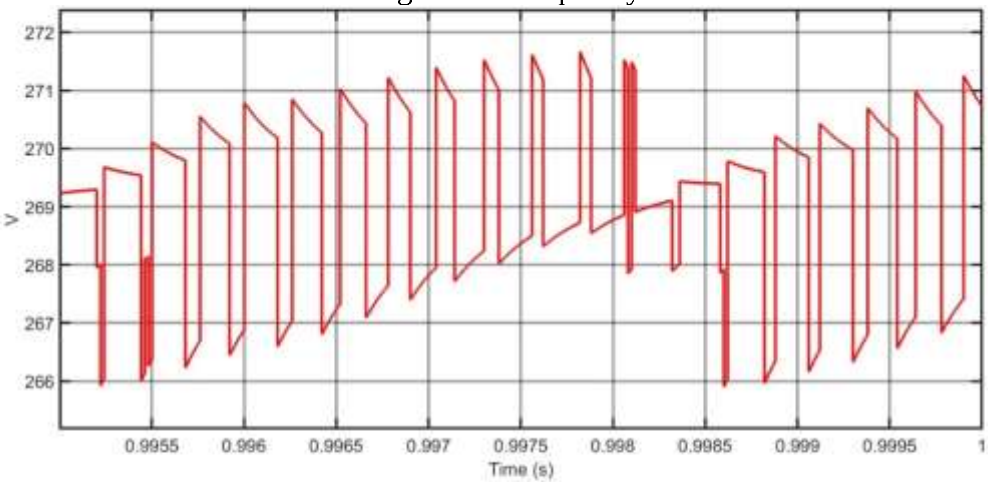


Fig-9 PV voltage

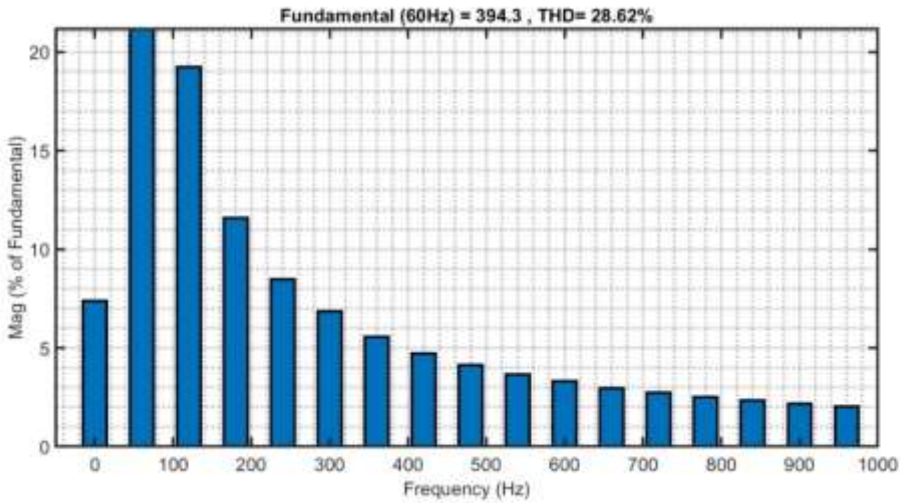


Fig-10 THD in solar inverted voltage

Conclusion:

The fuzzy logic controller and microgrid-based unified power quality conditioner have been built successfully in this work. Generally speaking, the microgrid concept focuses primarily on reducing transmission losses and system-related power quality issues, with the latter being offset by a single power quality controller. The system's total harmonic distortion is decreased by the usage of the fuzzy logic controller, which improves performance. With standard MPPT and a fuzzy logic controller, series and parallel converter systems are used to generate the simulation results for the grid interface. Voltage distortions result from harmonics that are created by the system's nonlinearity. We can lessen these distortions in the system by utilizing a traditional PI controller. Nevertheless, the simulation findings show that fuzzy logic controllers are more effective at mitigating harmonics and enhancing THD.

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