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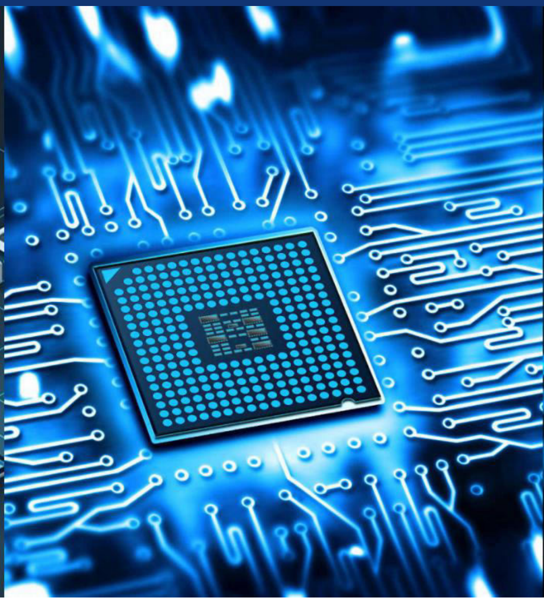


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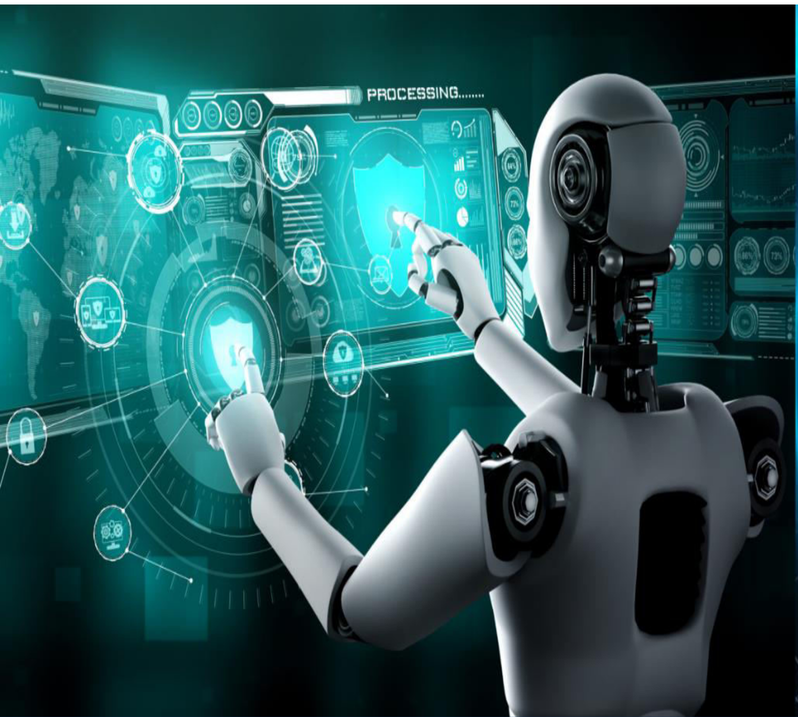

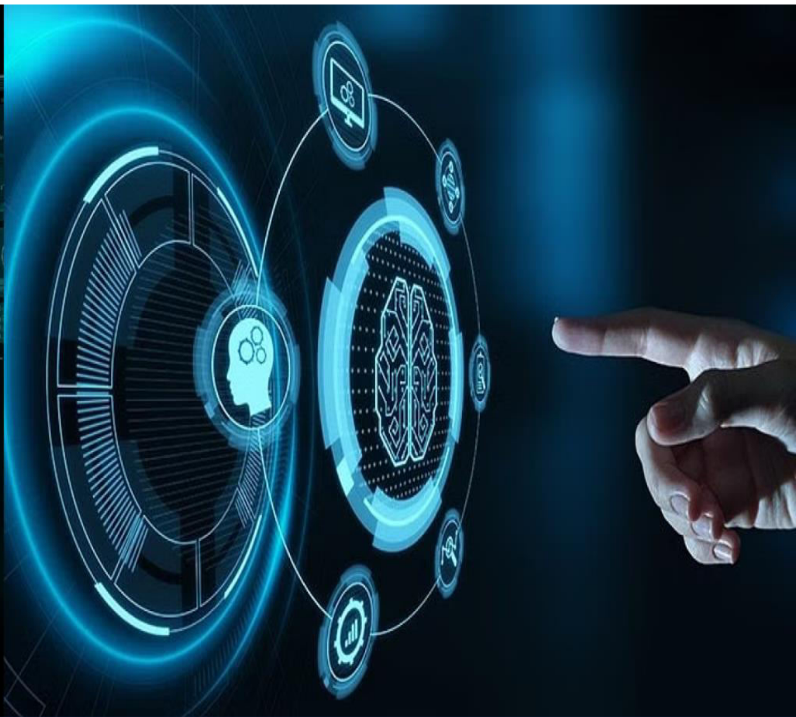

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An Innovative Integrated Control Technique for Micro grid Systems Using UAPF and Pi Controller

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ABSTRACT: Integrating solar energy systems into microgrids has various advantages, including sustainability and energy independence. However, power quality concerns such as harmonic distortion, voltage fluctuations, and reactive power imbalance may affect solar microgrid performance, reducing energy distribution efficiency and dependability. This study suggests an enhanced hybrid control technique for a microgrid system based on a universal active power filter (UAPF) for active power line conditioning. Conventional UAPF only improves power quality (PQ) and uses more power to do so. As a consequence, the converter's utilisation factor and power handling capabilities in the system diminish. To enhance the foregoing, the microgrid system is implemented by integrating external sources into the UAPF's DC connection.

KEYWORDS: Micro grid, PV, Solar, MPPT Controller

I. INTRODUCTION

Electrical energy is the most convenient type of energy, and in today's society, it is inconceivable to imagine a future in which people do not have access to electricity. The demand for electrical energy surges in unison with the rise in the number of requirements that are required on a daily basis. In recent years, there has been a growing worry about the environment and the detrimental impact that burning conventional fossil fuels has. This concern has led to the utilisation of renewable resources, in combination with the systems that are already in place, in order to fulfil the need for energy. Hydrogen energy, solar energy, wind energy, geothermal energy, and geothermal energy are all examples of renewable energy sources (RES) that may be used to create power [1-3]. Microgrids that are based on stand-alone solar photovoltaics are not connected to the utility grid and are instead able to operate independently as self-sufficient units. Power that is provided to the load in a photovoltaic (PV) system that is stand-alone is dictated by the amount of solar energy that is available. By its very nature, the generation of SPV is sporadic and changes depending on the conditions of the surrounding environment. 4–6. [4]–9. In addition to installing a photovoltaic system, it is necessary to establish an energy storage system in order to guarantee that the load is supplied around the clock. A battery is the storage device that is used the most often because it is able to provide the load with power in a continuous manner.

The transition to renewable energy sources, most notably solar power, has emerged as a fundamental component in the endeavour to construct energy systems that are both sustainable and robust. Solar microgrids, which provide energy independence and reliability, have acquired appeal that may be attributed to their capacity to offer clean power in areas that are not connected to the grid or that are isolated. Despite the many advantages they provide, solar microgrids are not without their share of power quality problems. Harmonic distortion, voltage fluctuations, and reactive power imbalances are some of the problems that might arise. Each of these issues has the potential to have a significant influence on the efficiency, performance, and lifetime of the solar power system as well as sensitive electrical equipment. These issues may be resolved with the use of a Universal Active Power Filter (UAPF) in solar microgrids, which is one potential solution. By actively adjusting for harmonic currents, rectifying voltage imbalances, and providing reactive power support, the UAPF is able to ensure that the power that is provided to the grid or load is of the highest possible quality. This not only enhances the performance of the solar system, but it also optimises the production and consumption of energy, so reducing waste and boosting the overall efficiency of the system. Additionally, since solar power is intermittent and variable, the flexibility of the UAPF ensures that power quality remains consistent even when load conditions are changing. This is a crucial problem to consider given the unpredictability of renewable energy sources. Through the enhancement of power quality and the reduction of disturbances, the UAPF assists solar microgrids in reaching their full potential. This results in the microgrids being more reliable, efficient, and environmentally friendly. As a result, it improves the overall resilience of solar-powered

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systems and makes them more economically feasible. It also extends the operational life of electrical components and reduces energy losses. It is because of its ability to ease power quality concerns, enhance system efficiency, and expedite broader adoption of solar energy that UAPFs are being included into solar microgrids. This opens the way for cleaner and more reliable energy solutions on a worldwide scale than ever before.

In recent time, SPV based microgrid has received widespread acceptance as, it is a green source with less harmful effect on environment. Further, the price of PV module is reducing day by day making the energy production more economical. As per the operating conditions, SPV based microgrid can be used either in stand-alone or in grid tied manner. All these advantages of PV based microgrid motivated and led to the following research objectives:

1. Development of reliability and sensitivity model of the PV based microgrid.
2. Development of control algorithms for tracking of Global Maximum Power Point (GMPP) under partial shading condition.
3. DC link voltage control of stand-alone PV system with battery energy storage system for improved performance.
4. Design and development of inverter control algorithms for enhanced performance of the system

This research suggests using a Universal Active Power Filter (UAPF) to overcome these difficulties in solar microgrids. The UAPF is intended to dynamically correct for harmonic currents, reactive power, and voltage sags, resulting in a reliable and high-quality power supply. The UAPF can successfully alleviate power quality disturbances by using sophisticated control algorithms, optimising energy gathered from solar panels, and increasing overall microgrid performance. Furthermore, the UAPF's adaptive nature enables it to adjust to changing load circumstances, making it an appropriate solution for the volatile nature of solar power. Implementing a UAPF in solar microgrids not only improves power quality, but it also increases the lifetime of sensitive equipment, decreases energy losses, and improves grid stability, all of which contribute to the creation of more robust and efficient renewable energy systems.

II. LITERATURE SURVEY

It is becoming more important to include renewable energy sources, particularly solar power, into microgrids in order to increase the likelihood of achieving energy sustainability. On the other hand, problems with power quality, such as harmonics, voltage sags, and reactive power, have the potential to put solar microgrids' reliability and efficiency at risk. An technique based on artificial bee colonies was proposed by Diego Oliva and colleagues [7] in order to estimate the unknown parameters of PV cells for the purpose of sensitivity analysis. A current source inverter-based grid-tied SPV system was the subject of a sensitivity analysis that was carried out by P. P. Dash and colleagues [8]. The sensitivity and voltage stability of a photovoltaic (PV) system that is linked to the grid were explored by Yaosuo Xue and colleagues [9]. An technique known as cat swarm optimisation was introduced by Lei Guo and colleagues [10] for the purpose of parameter discovery and sensitivity analysis of the solar cell single and double diode models' parameters. Track sensitivity analysis is a technique that was presented by L. Shu and colleagues [11] for the purpose of assessing the parameters of the inverter and filter that have an effect on the PV system itself. The authors H. Andrei et al. [12] investigated how the properties of PV cells change depending on the irradiance and temperature. MPPT for incremental conductance was shown by M. A. Elgendy and colleagues [13] for a photovoltaic array that was linked to a resistive load. It was proved by S. Singh and colleagues [14] that solar panels may be controlled by an intelligent MPPT. Comparisons were made between the perturbation and observation, as well as fuzzy logic control, with regards to a number of different situations. For solar systems, Chun-Liang Liu and colleagues [15] proposed an asymmetrical fuzzy logic control-based maximum power point tracking (MPPT) system. Using a PV system that has fluctuating irradiance and load resistance, T.K. Soon et al. [16] present a quick converging maximum power point tracking (MPPT) algorithm. A hybrid maximum power point tracker (MPPT) was developed by K. Sundareswaran and colleagues [17] for a photovoltaic (PV) system that was subjected to non-uniform irradiation. P. Mohanty and colleagues [18] examined the performance of a number of different MPPT algorithms together. The performance of the MPPT was evaluated using a MATLAB/Simulink model in order to assess how well it dealt with shifting environmental circumstances. A dual search strategy is presented by J. Shi et al. [19], in which a dormant particle swarm optimisation first searches for the global peak point of the P-V curve, and then use the INC algorithm to track the maximum power from that peak. This combination of search methods is referred to as a tandem search. An investigation of the behaviour of photovoltaic panels was carried out by S.E. Boukebbous and colleagues [20] in circumstances of uniform and non-uniform irradiation.

III. METHODOLOGY

There is a possibility that a Universal Active Power Filter (UAPF) might assist in enhancing the efficiency and reliability of a solar microgrid. As a result of the fact that solar energy systems are often affected by power quality issues, such as harmonics, voltage sags, and flickers brought on by nonlinear loads, the UAPF may be employed to lessen the impact of these disturbances. It is the purpose of the UAPF to introduce compensating currents into the system in order to eliminate undesirable harmonics and achieve a balance in the flow of power. This will ensure that the microgrid operates in a straightforward and consistent manner. In addition to ensuring that sensitive equipment in the microgrid receives a clean and constant power supply, the UAPF helps to enhance power quality, which in turn helps to maximise the amount of energy that is generated by solar panels, limit energy losses, and maximise efficiency. Additionally, the UAPF provides improved flexibility, which makes it suitable for the variable nature of solar power. This is because of its ability to dynamically adapt to ever-changing load situations. Because of this, the overall performance of the system is improved, the lifespan of the electrical components is extended, and the microgrid develops more resilience

The block diagram of a standalone photovoltaic (PV) system that makes use of BESS is seen in Figure 1. An array of photovoltaic cells, a battery energy storage system that includes a charge controller, a DC-DC converter, an inverter, and a load are the components that make up the system.

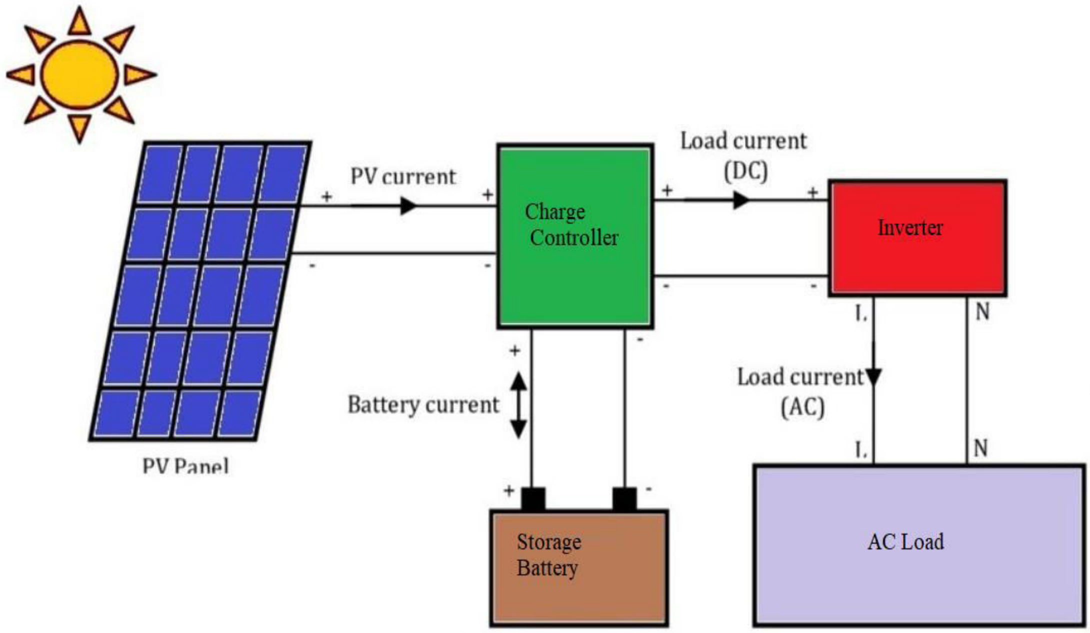

Fig: 1 General Block Diagram

PV System Modelling:

A single diode model may stand in for a whole PV module. I is the current that would flow out of a single diode model.

$$I = I_{pv} - I_0\left[\exp\left(\frac{V+R_sI}{V_t a}\right) - 1\right] \qquad [1]$$

The amount of current I_{pv} produced by a PV panel may be expressed as a function of the available light, or irradiance, $\mathcal{G}$.

- $$I_{pv} = \left(\frac{G}{G_0}\right) I_{go} + J_0(T - T_{ref}) \qquad [2]$$

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Saturation current in a diode, which is determined by temperature, may be expressed as:

$$I_o = I_{o,n}\left(\frac{\mathrm{T}}{T_{ref}}\right)^3 \exp\left[\frac{\mathrm{q}E_g}{\mathrm{ak}}\left(\frac{\mathrm{T}}{T_{ref}} - \frac{1}{\mathrm{T}}\right)\right] \qquad [3]$$

In the previous section, we defined the terms that are used in equations (1), (2), and (3).
As an optimisation problem, the proposed maximum power extraction is as follows:

$$\text{Maximize } (\mathcal{P}(d))$$

$$\text{Subjected to } d_{\min} \le d \le d_{\max}$$

$\mathcal{P}(d)$ represents the power produced by the PV array, d is the duty ratio of the dc-dc converter, and $d_{\min}$ and $d_{\max}$ represent the minimum and maximum values of the duty ratio, 10% and 90%, respectively.

IV. EXPERIMENTAL RESULTS

The mathematical modelling and design of stand-alone PV system is presented below. SimPower/Simulink software is used for the simulation studies.

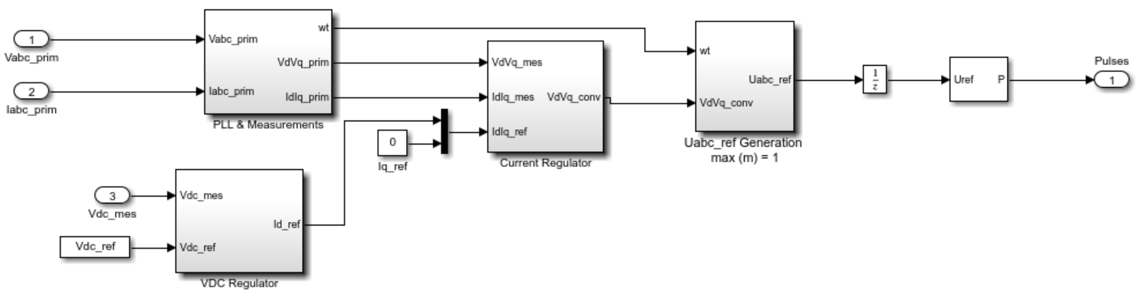

Fig.2. Schematic Diagram of Control Technique

In experiments assessing the performance of a Photovoltaic (PV) system connected to a grid, the voltage and current characteristics are key indicators of the system's efficiency, stability, and integration with the grid. The grid voltage waveform is typically sinusoidal under ideal conditions, but when a PV system is integrated, certain disturbances may occur due to the nature of power conversion and the variability of solar generation. In the experiment, the grid voltage is measured at the point of common coupling (PCC) where the PV system is connected to the utility grid.

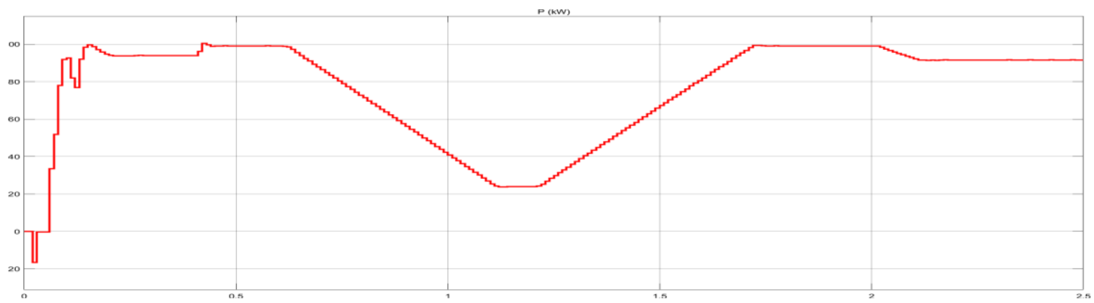

Fig 3: Generated Power

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The output power of a photovoltaic (PV) system is directly influenced by solar irradiance, which is the amount of sunlight incident on the PV panels. As irradiance increases, the photogenerated current in the PV cells rises, leading to a corresponding increase in PV output power. Conversely, when irradiance drops—due to passing clouds, shading, or time-of-day variation—the power output decreases significantly. This dynamic behavior affects the voltage-current (V-I) and power-voltage (P-V) characteristics of the PV system. This power fluctuation is shown in fig 3.

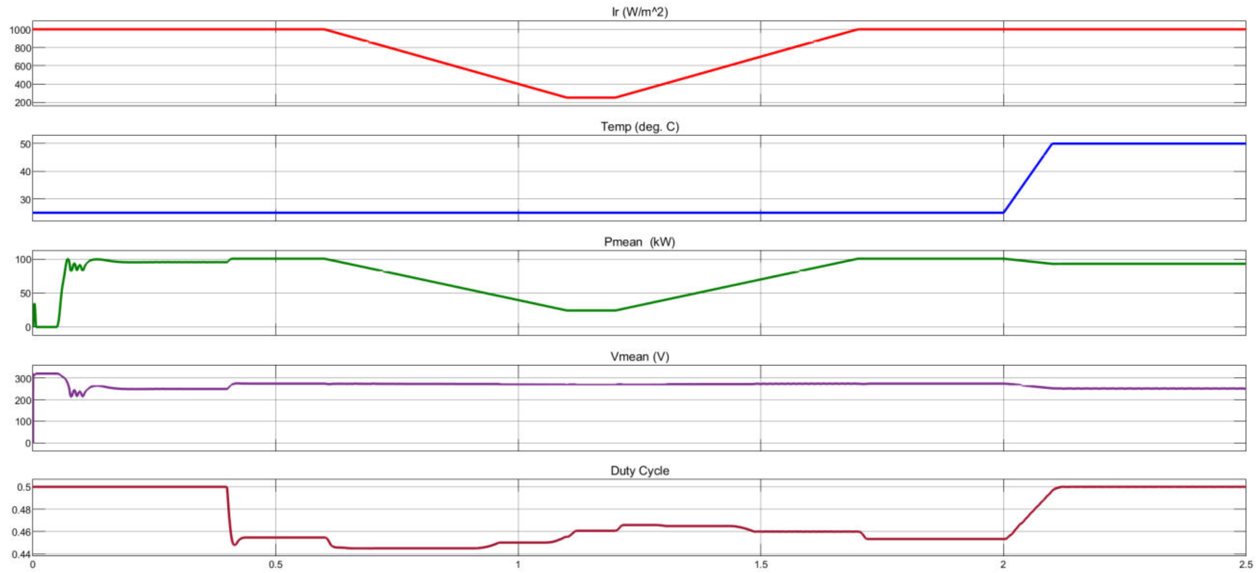

Fig 4: PV Input and output

In fig 4 irradiance changes is happens at duration 0.6 to 1.7. Temperature fluctuation occurs after 2 duration.
These rapid fluctuations in power generation can lead to **instability in microgrids** if not properly managed, especially in systems with a high penetration of solar energy. Therefore, **Maximum Power Point Tracking (MPPT)** algorithms are essential to continuously adjust the operating point and extract the maximum available power under varying irradiance conditions.

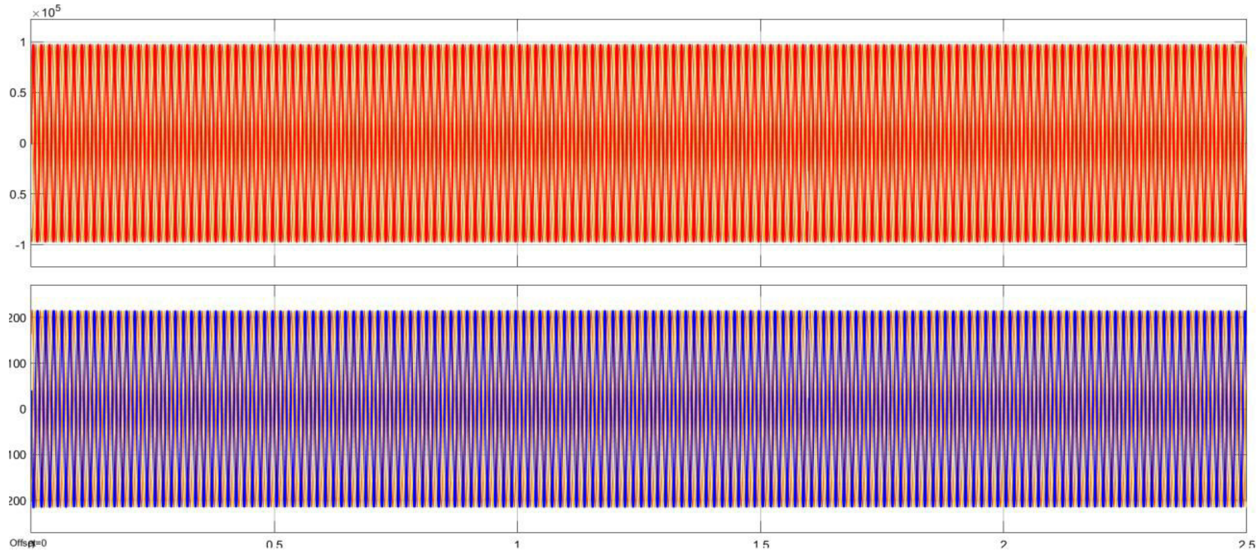

Fig 5: PV Grid Voltage & Current

Fig 5 shows smooth nature of voltage and current.

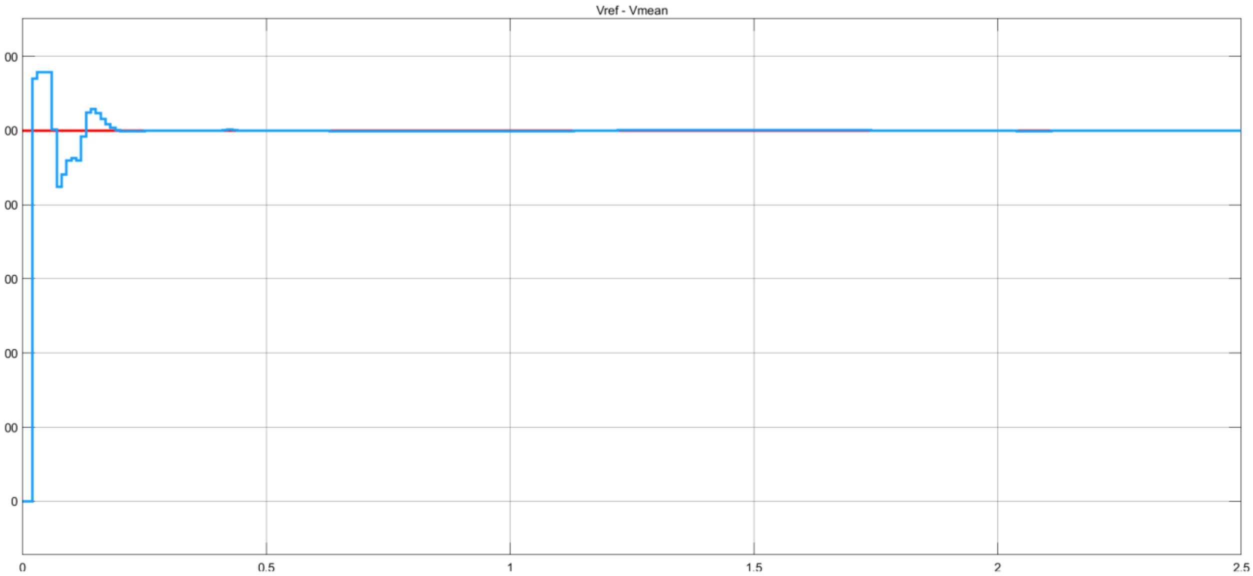

Fig 6: Reference and actual DC Voltage

The PV system should ideally produce a voltage waveform that closely matches the grid voltage. Any deviation from a pure sinusoidal waveform indicates harmonic distortion. Experimental results may show minimal distortion in the grid voltage under steady solar generation, as the inverter synchronizes with the grid.

During dynamic load changes or grid faults, the voltage waveform may show brief dips (voltage sags) or spikes (voltage swells). The PV system's response, especially in systems with active power filters (like UAPF), is to compensate for these disturbances, ensuring that the voltage remains stable and close to its nominal value. In some experiments, the presence of a UAPF helps in significantly reducing these fluctuations, improving the grid voltage quality.

V. CONCLUSION

For the purpose of enhancing power quality and handling capabilities, this study developed a hybrid control approach that could be used in a microgrid system that is based on UAPF. For voltage changes of 0.25 p.u. with R-L and nonlinear loads, the performance of the system is checked and validated. In addition, it is possible to perform harmonic correction (with a degree of total harmonic distortion (%THD) less than 3%) for nonlinear loads and power factor increase (nearly unity) for highly inductive loads. In general, the control strategy that was recommended improves converter utilization and makes it possible for the system to run in a multifunctional mode while simultaneously minimizing the amount of computational burden.

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