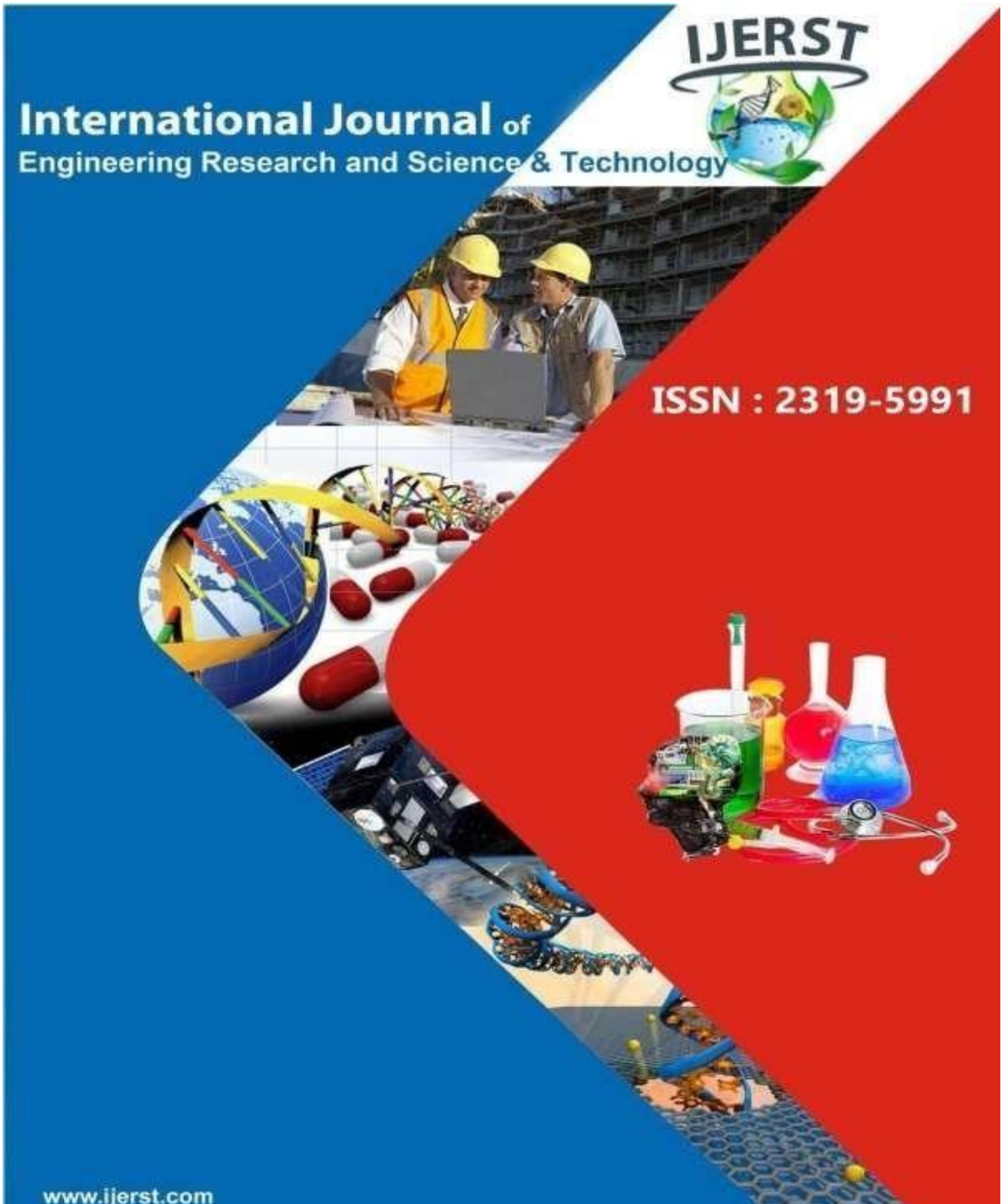

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International Journal of Engineering Research and Science & Technology

ISSN 2319-5991 www.ijerst.com

Vol. 17, Issue 2, 2024

Managing Active Power in Photovoltaic Systems to Aid Grid Frequency Stabilization

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Abstract:

system operators are becoming more interested in using inverter-coupled generation to help reduce frequency problems by quickly injecting active power into the system. Increasing the active power during an emergency improves the likelihood of successfully halting it. We provide a predictive methodology for efficiently and accurately controlling the active power output of PV inverters. Efficient active power management can facilitate the implementation of advanced control strategies such as rapid power-frequency droop, inertia modeling, and fast frequency response, which can help mitigate grid frequency issues. A prototype photovoltaic (PV) inverter employs maximum power point prediction and rapid active power control. The prototype inverter has a speedy response, taking 2 line cycles for a mild test event and 4.5 line cycles for a severe test event. It also demonstrates high accuracy, with a steady-state inaccuracy of only 2%, when subjected to a wide range of frequency events.

Introduction:

In recent years, there has been an increase in the level of worry over both the dependability of the power grid and the uniformity of its production. The grid-connected photovoltaic (PV) generator is becoming more popular as a result of its consistent performance as well as its capability to generate power from renewable energy sources. Maximum power point tracking controllers, also known as MPPT controllers, are used to connect the direct current (dc) output voltage of photovoltaic (PV) arrays to a dc/dc boost converter in order to collect the maximum amount of power feasible from a PV system. Connecting the converter to a dc/ac voltage source converter allows the PV system to then potentially contribute to the utility grid by supplying power (VSC). Non-linear loads, including computers, CFLs, and many other household appliances, may make up a significant portion of the local PV system load. Harmonics in the distribution system need the development of a method to compensate for them. So that the utility's injected and absorbed currents are sinusoidal, PV producers must provide distorted correction. As a result, dc/ac VSC may be controlled flexibly to achieve the harmonic compensation function. Active power filter (APF) design based on the notion of instantaneous power is complete and has shown promising results. Although the PV-APF combo has been in development for years, it has only just begun to show signs of rapid growth. Power factor, current imbalance, and current harmonics can all be balanced out using this setup, and the PV-generated power may be injected into the grid with little THD (THD). This setup may continue to improve the utility's power quality even when solar electricity is not being produced. As far as we are aware, this concept was first proposed by Kim et al. in 1996. The cost of the PV system as a whole increases because of the inclusion of energy storage components. In addition, the mathematical proof was inadequate. Afterwards, in some subsequent attempts to create PV inverters with genuine power injection and APF characteristics, the control approaches were enhanced. Their studies did not provide consistent results from applying their presented ideas, and their theories only apply to single-phase PV. In

International Journal of Engineering Research and Science & Technology

ISSN 2319-5991 www.ijerst.com

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line with the fundamental concepts presented here, the most recent comprehensively available article was written in 2013 and makes use of modern references as the primary means by which the dc/ac controller achieves its primary goals. The power reference-based PV-APF controller described in this study demonstrates theoretical advancements and an easy-to-implement control architecture. As the oscillating and imaginary components are generated by the PV-APF system, the utility is better able to offer a unity power factor and pure sinusoidal currents to the local nonlinear loads. Even if there is an abundance of electricity, this PV system will only feed in "normal" amounts to the grid. Therefore, the system may be seen as a distributed APF, which is preferable than using passive filters or centralised APFs.

PROPOSED SYSTEM:

FIGURE 1 shows the design for a three-phase grid-connected inverter in both grid-connected and islanding modes of operation. an LCL filter, grid-on/grid-off control, a static transfer switch, and a three-phase PWM inverter are all part of this setup. To reduce the impact of higher-frequency harmonics with the same inductance value, an LCL filter is preferred over a L filter. If an LCL filter were added to the system, the existing control system would be unstable because of the high-resonant peak at the LCL filter's resonant frequency. We provide several active dampening options, such as raising the amount of feedback or shifting the control frequency with respect to the resonance frequency of the filter, for PI-based current management of a grid-connected inverter using an LCL filter to address this stability issue. The many applications of active damping in LCL filters are addressed. In order to implement a passive damping method, as shown in Fig. 1, we utilise a damping resistor. No matter whether the system is linked to the grid or running in island mode, the grid current controller and the load voltage controller are employed to guarantee safe and dependable operation. The outputs of the dq grid current controllers and the dq load voltage controllers are linked to smooth out any spikes that could occur at the moment of mode changeover. A single-phase grid-connected inverter is wired to the controller's current and voltage outputs in [2]. Since both controllers' outputs generate alternating current voltages, it is crucial that their phases match.

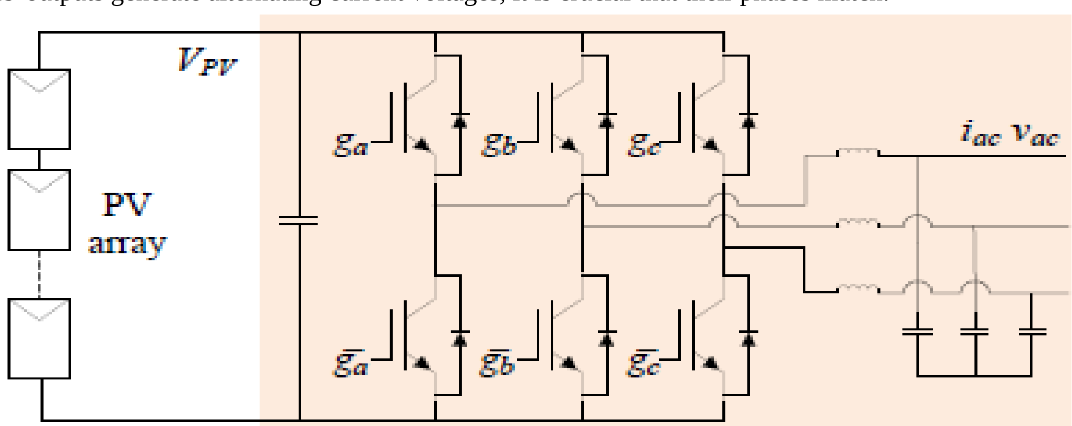

Figure 1: Proposed PV System using APC

The VPV voltage controller, as seen in [4], ensures that the PV voltage follows the d-axis current instruction, id. According to [4], the inverter's output current is controlled by sinusoidal pulse-width modulation (PWM), and the d- and q-axis currents in the rotating synchronous (dq) reference frame are controlled independently using proportional-integral (PI) control. The effect of varying the q-axis current command iq in the voltage regulation block on the generated reactive power is not the focus of this discussion.

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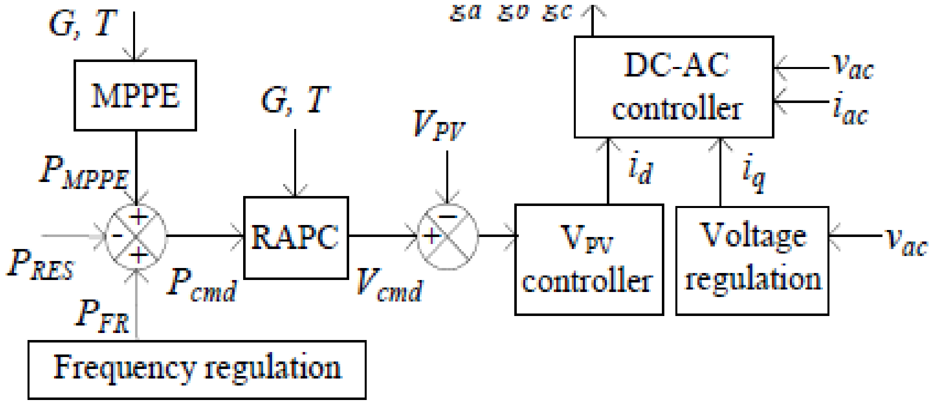

Figure 2: Control Structure for PV Inverter

FUZZY LOGIC CONTROLLER:

Before, we spoke about the PI controller-based control technique. On the other hand, PI controllers need a lot of time to settle and have a lot of steady-state inaccuracy. This research suggests using the FLC seen in figure 7 to fix the issue. The FLC is widely considered to be a crucial software-based tool in adaptive techniques [7]. The FLC is characterised by its short settling time and negligible steady-state errors when compared to other controllers. The workings of a fuzzy controller may be broken down into four stages.

1. Fuzzification
2. Membership function
3. Rule-base formation
4. Defuzzification.

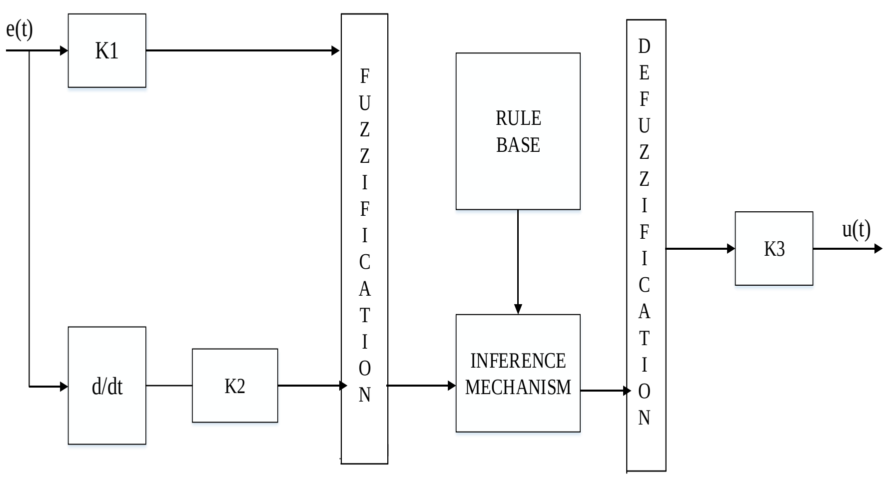

Figure 3: Fuzzy-controller-based on-basic-structure

Here, we model the membership function as a triangular one, and the defuzzification technique as its centroid. Fuzzy inference engine is fed the discrepancy between the reference and real values. Input variables like error and error rate are expressed in the form of a fuzzy set using the linguistic symbols VN, N, Z, P, and and. The mamdani fuzzy inference system uses triangle membership functions to represent language concepts. The study focuses on a fuzzy inference system with a single input and a single output. Assume that there are three linguistic input and output variables. The regulations have been formulated into a total of 9. The PI controller's error serves as the input to the fuzzy system. In order to acquire the fuzzy rules, if-then statements are used. With the input and

ISSN 2319-5991 www.ijerst.com

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output values that have been provided, it is clear that the fuzzy inference system is a single-input system. The logical AND and OR operators are relevant to this input. The result of AND logic is the least possible value of the input, whereas the result of OR logic is the highest possible value.

SIMULATION DIAGRAM & RESULT:

In Figure 4, we see the MPPE method implemented in a simple three-phase bridge power stage and an L-C output filter in a MATLAB/Simulink Environment prototype inverter..

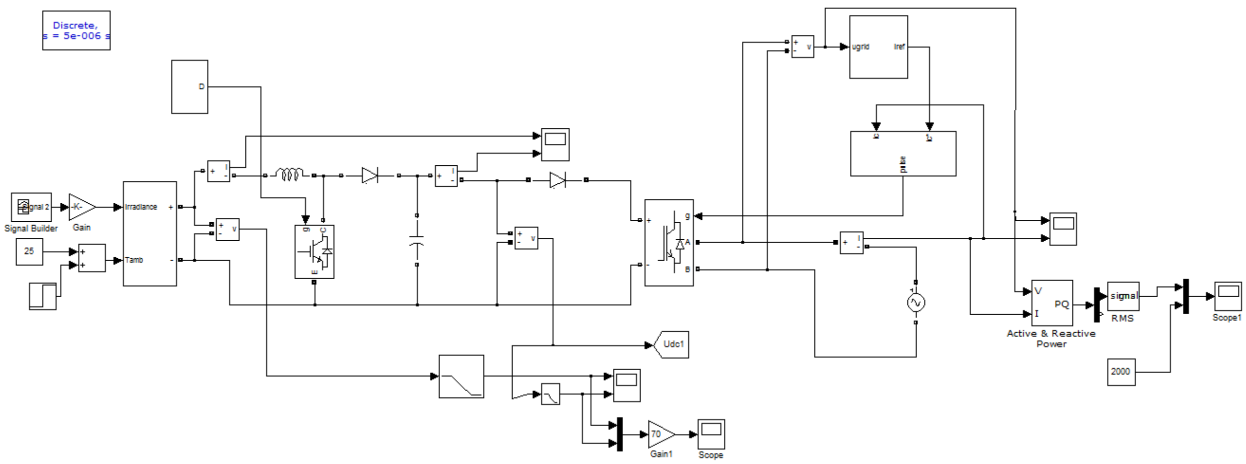

Figure 4: Solar Photovoltaic Grid Simulation Diagram

Case 1: Implementation of Proposed system with Conventional Controller.

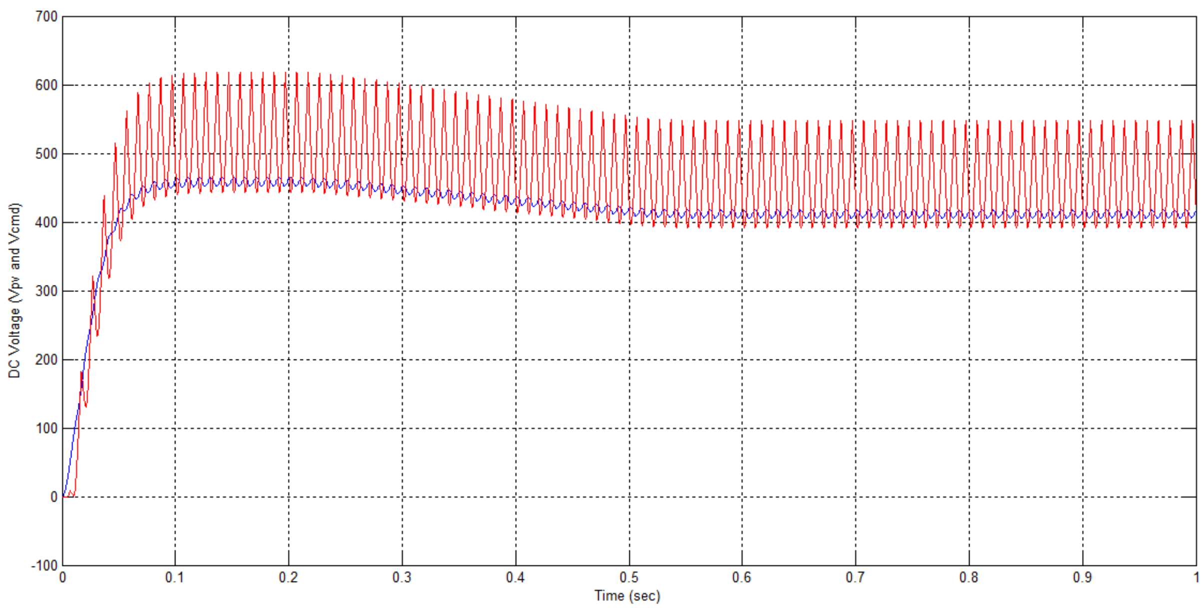

Figure 5: Comparison of PV and CMD DC Voltage Simulation Results

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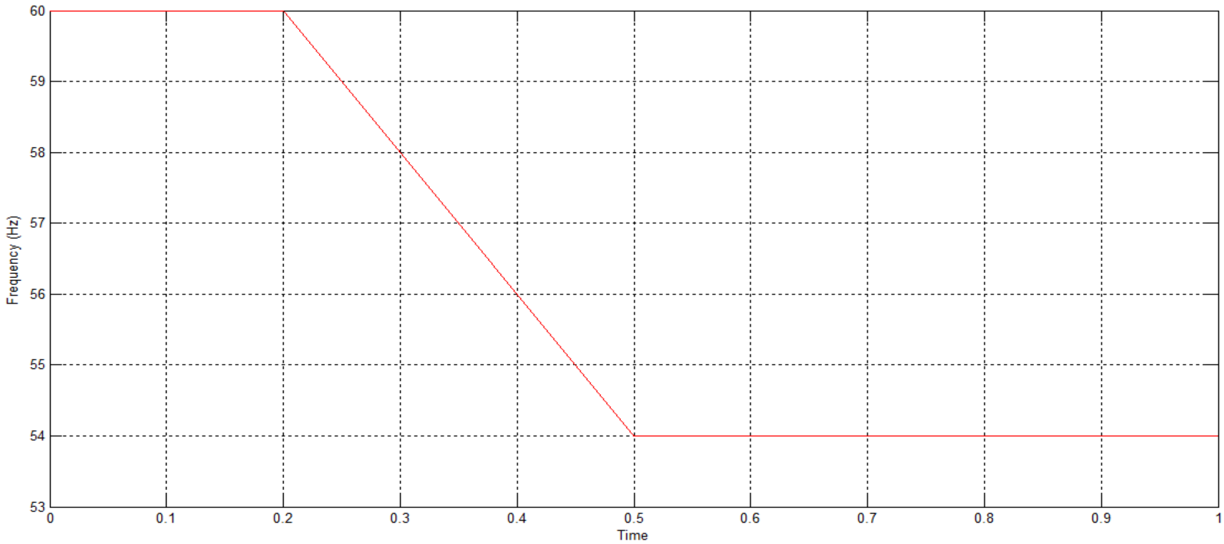

Figure 6: Result of a Frequency Simulation

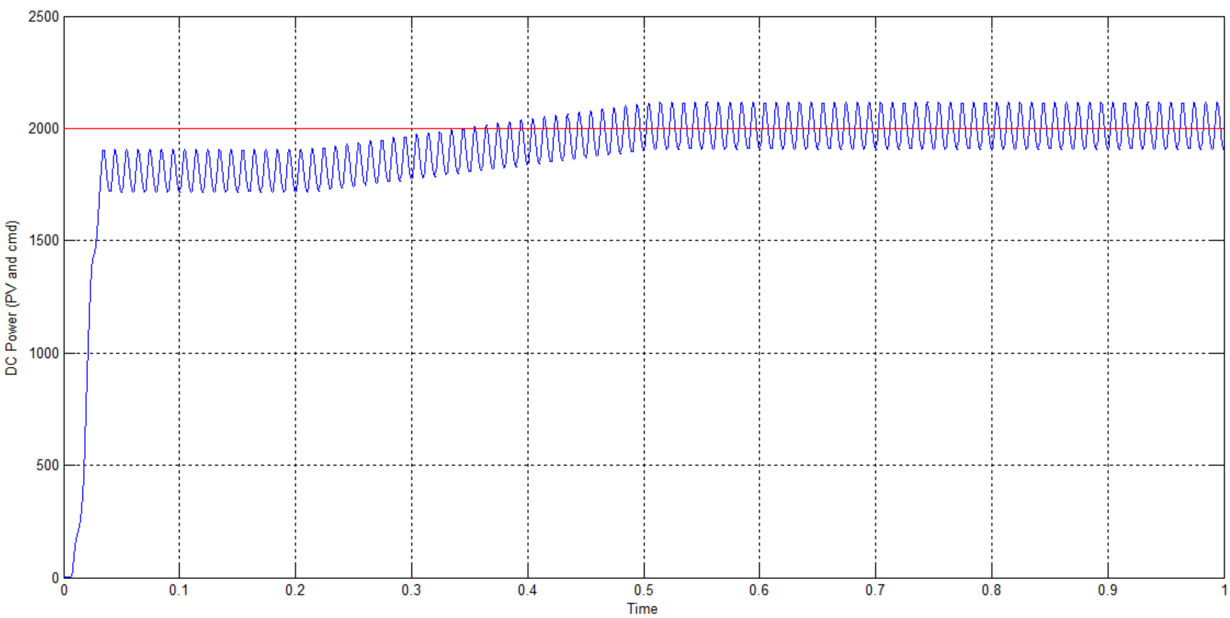

Figure 7: DC Power from PV and CMD Simulation Result

The droop slope for the frequency regulation block is shown to be 5% in Fig. 5. The following formula is used to get the power factor response: Rating factor (PFR) = rated inverter power (P0) (f - f0) / (f0 - 0.05) where f is the measured grid frequency from the PLL and f0 = 60 Hz. The power output will double for every 3 Hz shift in frequency from the normal frequency. Although the droop slope of synchronous machines is generally 5%, the reaction time of the machine is much longer than the inverter responses shown below by many orders of magnitude.

Case 2: Implementation of Proposed system with Fuzzy Logic Controller.

International Journal of Engineering Research and Science & Technology
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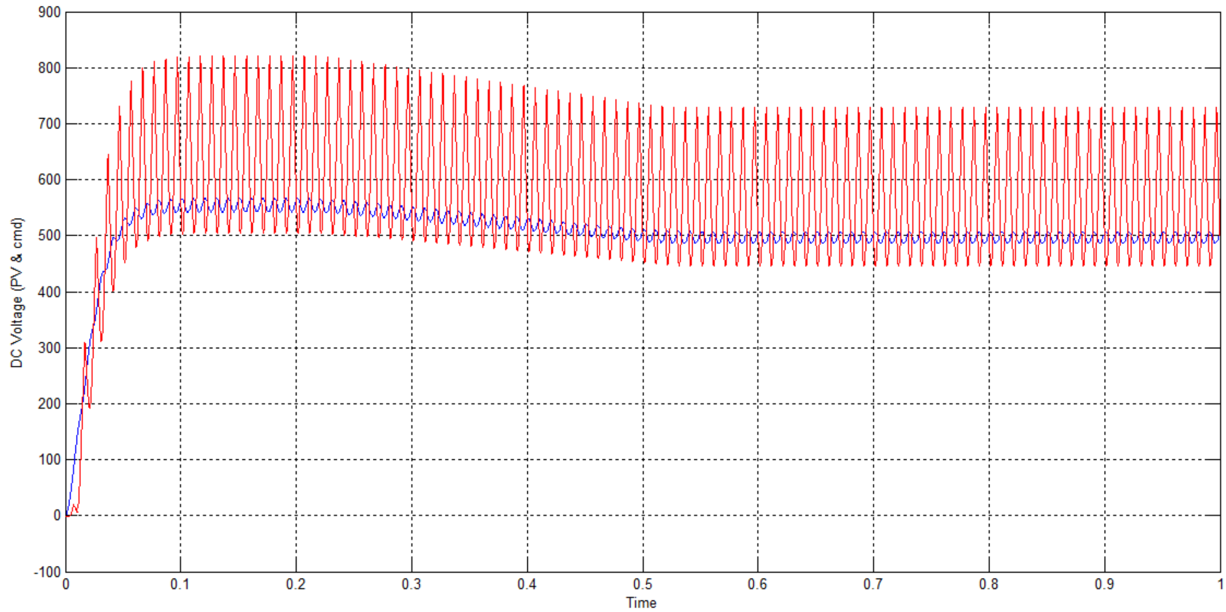

Figure 8: Comparison of PV and CMD DC Voltage Simulation Results

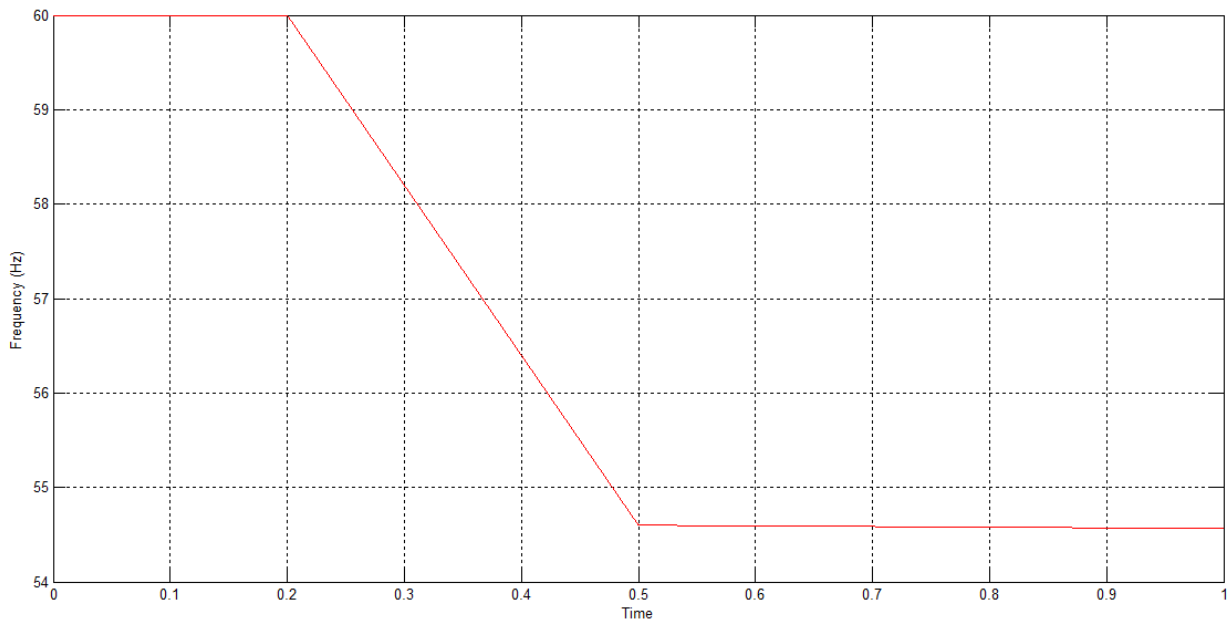

Figure 9: Result of a Frequency Simulation

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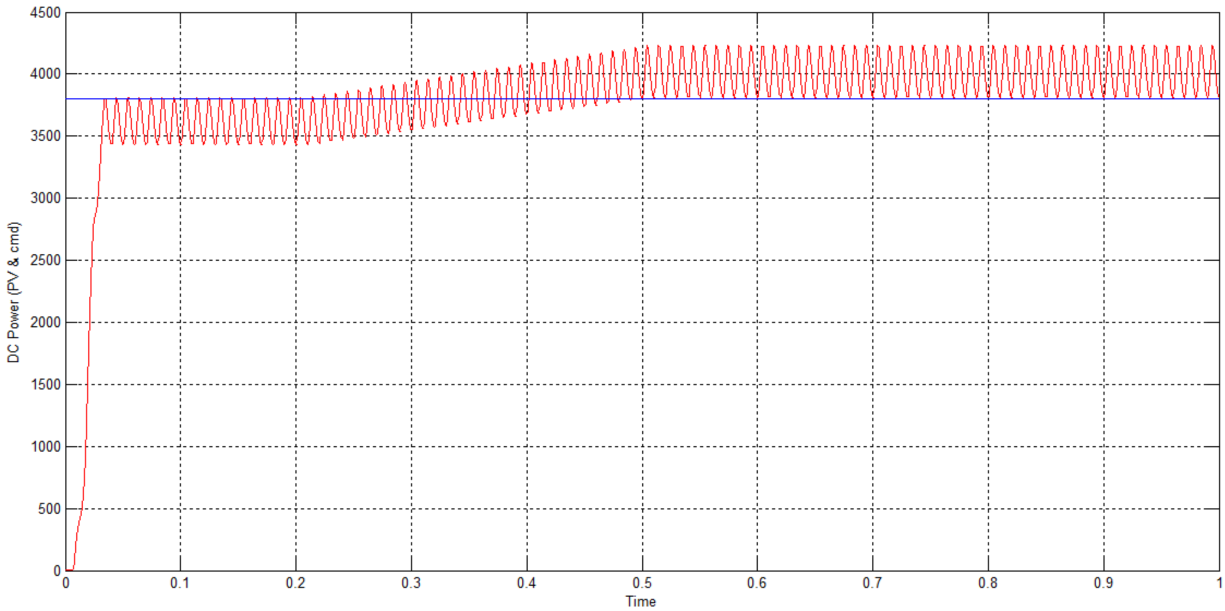

Figure 10: DC Power from PV and CMD Simulation Result

Conclusion:

The conventional and fuzzy logic controllers were used to test the fast active power control system that will be detailed in this paper. Based on the test findings, the system can respond quickly and accurately to a broad range of difficult grid frequency occurrences. To show that the technology is resilient enough to withstand the impacts of diverse weather, the experiment used two actual solar arrays. This is only one example of how the RAPC approach may be used with a PV maximum power point estimate method that has been confirmed experimentally to provide results like the fast power-frequency droop response seen here. In the past, DC voltage controllers and very high-bandwidth phase-locked loops (PLLs) weren't particularly useful in grid-interactive PV inverters. Results from trials using fuzzy logic control given here, on the other hand, imply that it may be useful to construct speedier low-level controllers. For emerging uses, including instantaneous active power regulation, a quicker response time to frequency spikes and other grid interruptions is desirable.

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