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Harmonic Mitigation for Enhancing Grid-Integrated Photo voltaic System Power Quality: A Review

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Abstract: *With the growing integration of renewable energy sources, such solar energy systems into electrical grids, power quality issues emerge from possible harmonic distortions. This study analyzes the effectiveness of grid-integrated photovoltaic systems and discusses harmonic mitigation to improve electricity quality. Power quality can be negatively impacted by harmonic distortion due to voltage swings, higher losses, and interference with delicate equipment. As a result, efficient and dependable PV system functioning inside the grid depends on the implementation of effective mitigation techniques. We examine a range of mitigation strategies, such as hybrid solutions, active filters, and passive filters, each with unique benefits and drawbacks in terms of expense, intricacy, and efficiency. The effects of integrating PV systems on grid stability, voltage regulation, and frequency management are also covered in the article, emphasizing the significance of thorough performance analysis. The effectiveness of various harmonic mitigation techniques is assessed by modeling studies and experimental validation, taking into account variables including system efficiency, dependability, and compliance with international power quality standards. The study also looks at how grid circumstances, PV system layout, and size affect harmonic generation and mitigation needs. The research yields valuable insights that aid in the formulation of strategies aimed at improving power quality and maximizing grid-integrated photovoltaic systems' performance under various operating situations.*

Keywords: *Renewable Energy sources, Shunt Active Power Filter, harmonics, fuzzy logic controller, PID controller.*

I.INTRODUCTION

A variety of Renewable Energy Resource options are available, because it is so readily available in nature, solar energy is one of them and is used the most. It also offers many benefits, including cheap maintenance requirements, no noise pollution, no fuel costs, and no air pollution. The grid's power quality suffers when solar electricity is integrated into it. The inverter is a component in PV-based systems that control the flow of power transfer between loads and the DC source. It is necessary to assess different ways to express the challenges and problems with power quality caused by the addition of solar electricity into the grid. Grid An electrical inverter that changes a photovoltaic module's DC current into alternating current is known as a connected solar PV system. As PV scheme is connected to the grid, it can send any excess energy back to the grid once the partial order has been met. However, excess energy is taken from the system when demand exceeds generation. As a result, PV energy functions as a backup electrical supply. The PV system in this work refers to the electrical power that is fed into the grid from the PV panels. In order to raise PV voltage above the maximum grid voltage, a DC-DC converter is first used. The RES is connected to the power system using power converters. Harmonics are introduced into the system when power converters are used. Improvement of power quality is therefore one of the major issues facing the electrical manufacturing. Harmonics lead to the source voltage being distorted, additional defeat from undesired current flows in the source, and the malfunction of relays, mains, and other control devices. Therefore, reducing the harmonics is necessary. There are numerous ways to lessen the impact of harmonics. One of these techniques involves the use of SAPF, which generates harmonic current that is equivalent in the harmonic current's polarity and magnitude generated in the system, cancelling it. Due to the presence of the power electrical equipment, it responds quickly and operates with flexibility. Along with the study of power quality, its causes and its effects, many new optimization techniques have been used by many researchers such as Fuzzy logic, Artificial intelligence, artificial bee colony, Bacteria foraging optimization (BFO),Ant colony. Optimization (ACO), civilized swarm optimization (CSO), Ant predatory PSO (APSO), Particle swarm optimization (PSO) Tabu search (TS), meta heuristic algorithm and Gray Wolf optimization (GWO), which make the reliability and quality of electricity An important step to keep.

II. LITERATURE REVIEW

When non-linear loads are present in single and three phase AC electrical power network were studied, reactive power adjustment and harmonic suppression capabilities of the Active Power Filters were demonstrated. Ant Colony Algorithm has been used to tune PI and lower total harmonic distortion. [1]. Suggested model includes a battery energy storage system that is managed by a cascaded F and PI controller. Shunt active power filters are linked across the grid and non-linear load to control the grid current because an electrical load current fluctuates suitable to the non-linear load. MATLAB 2021a is use to simulate the model, while an OP-4510 simulator is used to examine grid synchronization. [2], Prove that in the present, grid management measures are necessary to deal with the problems caused by means of the extensive integration of SECS. The increase of power quality, stability, and dependability through the use of static compensators is another technological development of the solar system. [3], According to this study, SAPF should include two control loops: The inner current loop controls the source current profile, while the outer control loop sets the DC link voltage. [4], with the increasing the future smart grid's complexity and data-generating potential, data-intensive technologies and artificial intelligence solutions are being implemented. [5], Evaluated most application including solar systems need a power dc-dc converter and micro grids. For these applications, a consistent output voltage with a range of load values is necessary. To adjust output voltage and current, dc-dc power converters are required, which increases the resilience of the controller. PID controllers are created for buck boost converter load current. [6], making use of an R-L nonlinear load rectifier feed, a photovoltaic scheme, and the perturbed and observed MPPT method, provide a single phase supply scheme. [7], Studied a PWM inverter is suggested to enhance power quality by lowering total harmonic distortion (THD). Equipment performance and lifetime are affected by power quality issues. The THD produced by the nonlinear loads is decreased by the suggested system. Because the existence of harmonics causes issues likes overheating, insulation failure, etc. Here, MATLAB is used to analyze the simulation results of the optional system. Lower THD is attained with the device, demonstrating its usefulness. [8], Studied to decrease the harmonics in nonlinear load applications, employs a supervised PID controlled (SAPF) with an efficient adaptive neural fuzzy interface system [9], suggested using an active power filter using a fuzzy logic-based control strategy to reduce the system's harmonics. With the help of the MATLAB Power System Toolbox, a dynamic simulation is used to validate the suggested topology.. The proposed method uses harmonic mitigation to pump power from a hybrid system into the grid [10],. Display in the proportional integral controller, fuzzy logic controller, conventional synchronous reference frame and modified SRF reference current generation techniques, and basic hysteresis band current controller to generate switching pulses for the inverter and SAPF for inductive and capacitive loads techniques under the MATLAB setting. [11] Currently, a synchronous DC-DC buck converter is used to regulate the power that is provided to the subsystems from the PV panels and keep them operating at full power. The tracking problem is solved using artificial intelligence approaches like as neural networks and adaptive neural fuzzy inference systems. The outcomes of experiments and simulations show their reliability, effectiveness, and tracking quality. [12] A swarm intelligent enhanced dual extended Kalman filter control technique is given to increase the performance of the shunt active power filter. The technique aims to reduce harmonics, achieve unity power factor operation, and achieve at the shared utility point, the ideal sinusoidal voltage wave shape. The suggested control method's performance is assessed using MATLAB/Simulink. [13]

III. POWER QUALITY

1. Good electrical power quality is defined as the elimination of problems with voltage fluctuations, harmonic distortion, voltage imbalance, flickering, interruption of current, voltage drop, overvoltage, and transients, among other things.
2. From the viewpoint of the end user, any power issue brought on by voltage, current, or frequency abnormalities is said to have poor electrical power quality.
3. The foundation of electrical power quality is stability and reliability, which must deliver the consumer with high-quality electricity free from interference.
4. The performance that is offered for adequate performance by all devices is what is meant by excellent electrical power quality.
5. Customer satisfaction is referred to as having good electrical power quality Reliability is a byproduct of high-quality electricity

IV. OBJECTIVES OF THE PRESENT STUDY

1. Enhancing Grid-Integrated Solar (PV) System Performance Analysis and Power Quality Improvement.
2. Study of related literature to understand the operation of SAPF device and its related work.
3. Mainly reduce the effect of harmonics to enhance Grid-Integrated Solar (PV) System Power Quality
4. By MATLAB/SIMULINK software
5. Any suitable control strategy, optimization, and algorithm are used whenever a necessary.
6. Study of the power quality problem, causes, and its effects on the power system network

V. ISSUES RELATED TO GRID INTEGRATION

Power quality difficulties such as harmonics, power factor, DC injection, and voltage flicker, sag, swell, and transient are the main problems caused by the widespread development of PV systems and their grid integration. Harmonics: More precisely, an integral multiple of the fundamental frequency is a harmonic of a sinusoidal wave. Total harmonic distortion (THD) is the total of all distortions at various harmonic frequencies. Computers, communication devices, and other power systems can malfunction as a result of harmonic effects. The transformer's RMS current may exceed its capacity due to harmonic currents. Heating and conductor losses rise as a result of the higher total rms current. Eddy current losses and core losses are also increased by harmonic currents in transformers. Voltage harmonics cause motor performance to decline. This distortion at the motor terminals results in harmonic fluxes inside the motor, which generate high-frequency currents in the rotor and cause further losses as well as a reduction in efficiency. Electromagnetic interference (EMI) difficulties are brought on by higher order harmonics. Watt-hour and demand meters' accuracy is impacted by harmonic currents from non-linear loads.

VI. PROBLEMS STATEMENTS ON PERVIOUS PAPER

Numerous researchers have shared their thoughts on SAPF, its control technology, and the enhancement in power quality (Reduced Harmonic) that resulted from it. Several of the issues we discovered: In [01] about the sine wave and lowering the THD pace to less than 2.33%. The big overall performance features of the Induction Drive are examined through the compensating vast extended normal performance of the simulation supply to result, which offers a practical approach to the foundation of SAPF. In [04] considering the control complexity constraints, the projected scheme can have dependability issue when compared to a single phase. Comprehensive modeling and many scenario simulations were used to test the system. In the prospect, an new system ought to be made for more verification and application in practical situations. Power quality for nonlinear loads is enhanced via a transformer-less SAPF with supervise PID controllers and an adaptive neural fuzzy interface system. In [05] which could lead to under reporting of poor findings, and a bias risk. In [09] Novel results from an FFT study of THD in the system under nonlinear load conditions are used to validate the proposed model. In comparison to the IEEE 519-permitted 5% THD. As a result, the suggested APF can be used to improve the performance of devices based on high- and low-voltage electrical components. Additionally, the proposed filter helps to guard against the parametric degradation of devices for long-term evolution. In [07] this research study uses a standard PI controller to create SAPF for unit vector generation that is based on a phase detector circuit. In [06] as a result, buck boost converter was created and put into use in Simulink in MATLAB. One PID controller is for load voltage, and the other is for load current. Input voltage and load variations brought on by disruptions are examined. The study found that after PID controllers for load voltage and current were implemented, the system quickly reached steady state. Where the steady state was reached by the load voltage PID controller system in 0.15 S, but by the load current PID controller system at 0.3 S. In addition, the scheme is unaffected by variations in input voltage and load. In [09] it has been noted that in only linear circuits, the line current is sinusoidal, the THD is 0.02%, and the power factor is deterministic at 0.99. While any nonlinearity introduced generates a significant distortion in the flow of current. In [10] this method delivers Active power utilizing a power factor of one to the grid in addition to completing harmonic compensation. It can serve as a SAF and be used to connect actual electricity produced by renewable energy sources to the grid. In [13] this paper only considers harmonic distortion as a power quality issue.

VII. PROBLEMS STATEMENTS ON PRESENT TECHNOLOGY

- Conventional PID controller has not better dynamic performance than Fuzzy Logic controller.
- Harmonic suppression in the power system using PID (Proportional Integral and Derivative) control is limited to non-linear loads.
- The use of SEPIC Converter with PV generators connected to micro grids reduces the total harmonic distortion by 3.44%. When using a SEPIC Converter, the output voltage level is also boosted by 100 V.
- The single power filtering method that has been suggested, known as a "inductively active power filter," reduced harmonics on both the power supply and load sides, but the %THD is only up to 4.71%, which is the only drawback.
- The Adaptive Nuero Fuzzy Systems (ANFS) method seems to be able to solve harmonics only at the PCC.

VIII. PROPOSED METHODOLOGY

It is necessary to build a DC to DC converter with PID controller and a shunt active power filter with fuzzy logic controller in order to enhance power quality in the grid-integrated solar system. An approach for harmonic compensation is the Shunt Active Power Filter. The SAPF is a load-related voltage source inverter. Under a range of load conditions, shunt active power filters can sustain balanced current. The DC to AC power conversion is produced by power switching devices. In a grid-connected solar PV system, an electrical inverter transforms DC electricity from PV modules into alternating current. The fuzzy control-based pulse width modulation technique is applied. The configuration and design of these devices are based on a combination of power electronic and conventional power system components. In order to enhance the grid-integrated solar system's power quality, the proper fuzzy control approach needs to be developed and designed.

PID Controller

PID controllers actually combine three different types of controllers in order to increase control performance. This allows for the coverage of each controller's shortcomings. Each controller has unique qualities. The steady-state error cannot be decreased by the P controller, although the rising time can be. Contrarily, I can lower steady-state error with a controller, but the output response is subpar. D controller can improve transient response and decrease overshoot.

Fuzzy-PID Controller

This controller combines fuzzy logic and PID controllers. This technique allows the fuzzy logic controller to precisely and swiftly adapt the PID parameter changes, guaranteeing that in the case of external interference, the process will continue to follow Kp, Ti, and Td. PV arrays are utilized as input boost converters and to convert solar energy into a DC voltage. The MPPT, which is based on fuzzy-PID control, regulates the boost converter to raise DC voltage and optimize PV array production. The DC Bus receives the output voltage from the DC boost converter. The parameters to be employed for fuzzy design based on PV characteristics include variations in power and PV output voltage. What is intended is fuzzy logic with two inputs and three outputs. The complete rule in fuzzy is the outcome of combining two inputs and is based on observations made during system interruptions to reach the desired value. Next, the rule evaluates the degrees of membership of the fuzzy set's membership functions.. Fuzzy logic has two inputs, PPV and IPV, and three outputs: Kp, Ki, and Kd. The upper and lower bounds of the values are used as a basis for quantizing the input and output values into a membership function. Fuzzy logic can only adjust the PID parameter after a system failure if the PID value is set to the intended value. PWM waves produced by the fuzzy PID controller are used as an IGBT trigger on the boost converter. The centroid method of defuzzification is the last phase of fuzzy logic.

DC TO DC converter with PID controller

When the input voltage (DC) is lower than the output voltage (DC), DC to DC converters are utilized as boost converters. As a result, the boost converter's output exceeds the PV input. Therefore, in order to raise a PV system's voltage using a PID controller, a boost converter is required. Given the necessity to improve the PV output, a boost converter is recommended. Three categories are commonly used to categorize DC-DC converters, boost, buck, and buck-boost. The DC-DC boost converter is composed of a MOSFET, a diode, a capacitor, and an inductor. The switch duty cycle may have an impact on the output voltage.

Design MPPT with Fuzzy-PID controller

To extract as much power as possible from the PV, the primary objective of the fuzzy PID controller is to track the maximum power point. PV will use this technique to output its greatest power in the MPP region. This MPP may vary depending on the radiation intensity and temperature. PV (characteristics P-V or I-V) complies with its characteristics when it employs MPPT to generate its maximum power.

Follow the Designing process;

1. PV capacity calculation,
2. Design of PID controls,
3. Fuzzy control design, and
4. Hybrid control system (fuzzy-PID) design

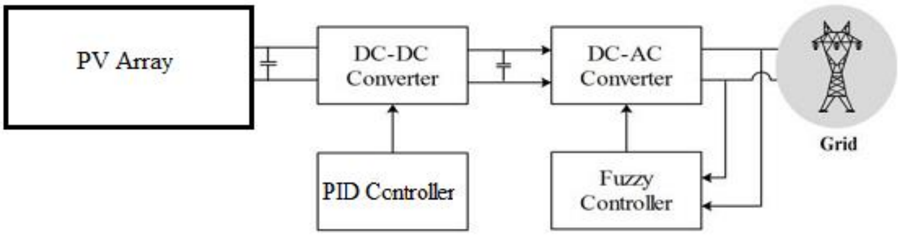

Figure1.Block schematic of the suggested system

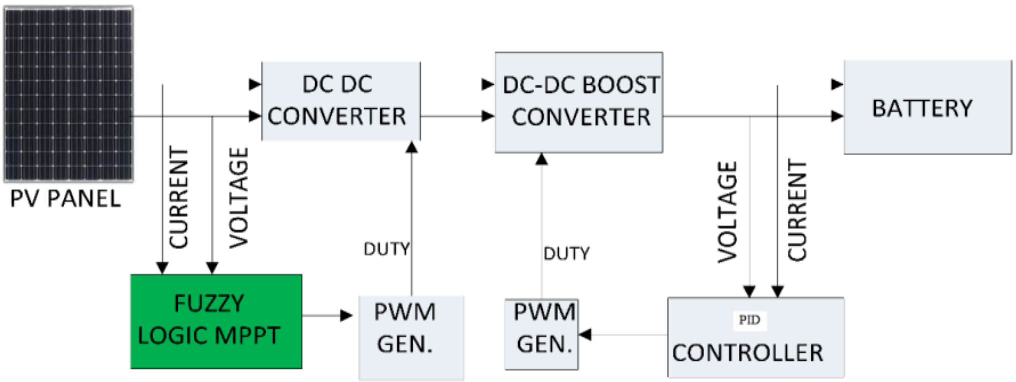

Figure.2. Block schematic for the suggested fuzzy logic MPPT system

IX. CONTROL STRATEGY

SAPF with fuzzy logic controller

Six switches are used in a bidirectional current converter called a Shunt Active Filter (SAPF), which combines filter and switching network components. The VSI control method, which saves DC energy in a capacitor, serves as the foundation for the creation of this power filter. An RL-load diode bridge rectifier attached to the inverter output serves as the nonlinear load. Each switch has back-to-back connections between its diodes and IGBTs to allow current to flow in either way. Apart from supplying actual PV power to compensate for reactive power in a distribution line at PCC, the PV linked shunt APF additionally injects compensatory current to mitigate harmonic load currents resulting from nonlinear loads. The nonlinear load and this filter are connected in parallel, or shunt.

X. EXPECTED OUTCOME

Expected outcome are as follows:

1. The suggested system's harmonics were successfully decreased by the use of SAPF. The THD is constrained when FUZZY managed SAPF is contrasted with other conventional techniques. The collected findings demonstrate that the grid THD is decreased and the inverter is executed by the suggested model.
2. The grid-connected PV system simulation model's final result shows that the inverter's harmonics diminish as it interacts with the grid
3. Using solar energy coupled to the DC side of the SAPF, this prototype generates the active power needed for the unstable grid operation. The findings demonstrate that the recommended model operates the source voltages at the grid and inverter with less THD.
4. The outcome of the networked grid The PV system simulation model shows that as the inverter interacts with the grid, its harmonics diminish. To do this, a SAPF is connected.

5. A full analysis was conducted of the problems and difficulties related to the grid integration of solar PV systems.
6. Fuzzy PID controllers outperformed conventional PID controllers in terms of the boost converter's ability to produce a additional constant voltage of 24 V DC. PID parameter generation can be done accurately thanks to the fuzzy mamdani architecture. The fuzzy PID controller generates a smaller overshoot by means of a shorter rising time.

XI. CONCLUSIONS

In summary, harmonic mitigation is critical to enhancing power quality and guaranteeing grid-integrated photovoltaic (PV) systems operate effectively. This essay has examined a number of mitigation strategies, each with specific benefits and drawbacks, such as hybrid solutions, active filters, and passive filters. The efficiency of these methods has been assessed by simulation studies and experimental validation, taking into account aspects like cost, complexity, and conformity with international standards. Furthermore, the significance of taking grid stability, voltage regulation, and frequency management into account has been underlined by the performance study of grid-integrated PV systems. The knowledge acquired from this study aids in the creation of plans for improving power quality and maximizing PV system performance on the grid. Going forward, it will be essential to conduct more study in this field to handle new issues pertaining to the integration of renewable energy sources into electrical grids. In order to confirm the efficacy of these strategies in practical implementations, future work should concentrate on creating sophisticated mitigation procedures, enhancing simulation models, and carrying out field investigations. Overall, the results in this article highlight how important harmonic mitigation is to PV system integration success on the grid, which will ultimately lead to the development of more dependable and sustainable energy systems

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