Implementation of ANN Controller to enhance the performance of Solar PV and battery integrated Unified Power Quality Conditioner for Micro Grid Systems.

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▶ ***Abstract***— **T**he purpose of the research is to evaluate and optimize the performance of a Solar PV and battery-integrated Unified Power Quality Conditioner (PV-B-UPQC) for micro grid systems with ANN controller. The growing demand for sustainable and reliable energy sources has led to an increased focus on micro grid systems, which integrate solar photovoltaic (PV) arrays, energy storage and power quality enhancement technologies. The goal of this research is to find a solution for the UPQC system's power quality problem. When UPQC is managed using synchronous reference frame theory (SRF) and instantaneous reactive power theory (PQ) control, the overall harmonic distortion of the grid current is greater than 5% in conditions such as excessive voltage sag and swell. The artificial neural network modifies the UPQC's shunt active filter in order to address this specific problem. The performance of the proposed model is assessed using a variety of case situations, such as voltage sag and swell situations, imbalanced load conditions, and non-linear load conditions. MATLAB Simulink was used to execute the simulations. The results shown substantial improvements in energy efficiency, power quality, and grid reliability, making this technology a promising solution for enhancing micro grid system performance in the era of renewable energy. The recommended artificial neural network controller efficiently reduces power quality problems and optimizes control complexity.

Index Terms— Power quality, solar photovoltaic array, unified power quality conditioner (UPQC), ANN controller, battery, uninterrupted power generation, automated transition.

INTRODUCTION

The usage of composite equipments in data base centers and semiconductor businesses has grown quickly. These systems require high quality, stable and uninterrupted electricity. Additionally, there is a greater emphasis on using renewable energy sources rather than fossil fuels, which are running out and contribute to both pollution and global warming [1], [2]. Renewable energy systems are required and they must also enhance power quality and be able to function when the grid is unavailable. The freestanding mode of operation is made possible by the inclusion of a battery energy storage system. Additionally, the energy from the batteries may be utilized to mitigate power oscillations brought on by sporadic solar PV generation [3]. Multi-objective systems, which can enhance power quality and generate clean energy and further it has been the subject of current research.

In addition to injecting power from the PV array, the shunt-compensation based topologies compensate for nonlinear load current. Although these systems are effective at correcting for problems with load current quality but they are unable to control load voltage to prevent variations in PCC voltage. To overcome these issues especially when Grid is connected, series compensation topologies improve the power quality. It does this by controlling the load voltage to prevent variations in PCC voltages and compensating for problems with load current quality. [7]–[9]. The ability of a unified power quality conditioner (UPQC) to improve power quality in the distribution network has been thoroughly studied.

In recent times research has focused on integration of solar energy and storage with specialized power devices in order to fulfill the needs of enhanced quality and reliable power, solar energy, and continuous stable power for key loads [15]. For solar energy systems to function in independent mode, battery backup energy storage is necessary. The additional cost of incurred for the battery is acceptable if the continuous power supply extension is a major for significant loads, such as semiconductor plants or hospitals, where a consistent source of high-quality power is essential. Utility systems can also increase grid stability overall by using battery energy storage to control the amount of electricity added to the grid.

For smooth functioning of essential equipments an automated switch among islanded and grid connected mode is required. Numerous combinations of multifunctional, integrated renewable-battery systems have been investigated for use in micro grid operations. A PV array and battery integrated shunt compensation system is provided with a method to easily transition between grid linked and independent operation. It has been proposed to control the power of the system by means of a self-normalized estimator control. Systems that combine PV and batteries in a single phase have been developed [10], Integrating renewable energy and storage with UPQC systems solves the problems of clean energy generation, voltage management, and load current quality adjustment. However, UPQC still has issues that need to be fixed, like the transition's control logic, how to transition with the least amount of disturbance to the critical load, and how to bypass series compensation when operating in standalone mode. PV-B-UPQC solar inverters differ from conventional solar inverters in that they can operate in the presence of voltage swells and sags. Because of this, a seamless transition needs to consider the voltage threshold at which the system can operate without needing to convert to standalone mode. A plan has been proposed to ensure a smooth transfer of the UPQC system. Nevertheless, the system can only correct for voltage sag for a finite number of cycles before entering islanding mode. Furthermore, the results depend on the program utilized in loop simulations.

This study suggests controlling and implementing a PV-B-UPQC system with three phases and three wires in a distribution network that has significant nonlinear loads. The system needs a constant power supply to operate. This is novel mainly in the following ways:

The integration of improved power quality on both the supply and load sides with the generation of renewable energy into a unified system. Consequently, this system utilizes resources more effectively than a traditional solar grid-tied inverter system. The automatic transition between grid-tied and islanded operation of this technology allows important electronic loads to have a continuous power supply. This system keeps the power factor at unity, the grid current sinusoidal, and load voltages under control.The technology improves the stability of the distribution network by providing steady electricity to the grid even in the face of variations in voltage and PV power output.

Evaluation will also be given to how the system behaves when it automatically transitions from grid-tied to independent mode during a grid outage. The behavior of the system is assessed under a range of common voltage and current disturbances found in contemporary distribution networks. A typical sort of feedback control system in process control and industrial automation is the proportional-integral (PI) controller.

The output of a system is changed using a kind of control known as proportional control, which is directly proportional to the difference between the intended set point and the actual output. The proportional controller produces an error signal by deducting the planned set point from the actual output. This error signal is then amplified by a proportional gain. The proportional gain shows how much the output needs to be adjusted for a given error signal. Integral control, on the other hand, adjusts the output by accounting for the accumulated error over time. After computing the integral of the error signal over time, the integral controller raises the integral value by an integral gain. The amount of output adjustment required for a given integral error signal is determined by the integral gain.

A PI controller creates a more efficient control system by combining integral and proportional control. While the integral component assures that there is no steady-state error and that the output converges to the set point over time, the proportional component reacts quickly to changes in the error signal.Process control applications, including temperature, pressure, and flow management in the chemical and industrial sectors, are common uses for PI controllers. They are also utilized in motion control systems, which include servo and robot control systems.

PV-B-UPQC SYSTEM CONTROL

Shunt compensator, Series compensator and a bidirectional converter are all under the supervision of the PV-B-UPQC control concept. The subsequent sections provide a more thorough discussion of these subsystems.

Methodology for Shunt Compensator Control The PV-BUPQC SHC operates in two modes: voltage control mode under islanded situations and current control mode during normal conditions. Figure 1 illustrates how the shunt compensator works. Synchronization decision signal (Dsync) governs the shift between various modes.

When operating in grid-connected mode, the SHC's main duties are to input PV electricity into the grid and compensate load current. Under conditions of mild irradiation changes and load imbalance, the SHC control is set up to feed a constant power into the grid. The battery bank provides the additional power. As a result, the distribution network becomes more stable as the flow of electricity entering the grid is smoothed out.

The following formulas are used to obtain the PCC voltage templates from the PCC voltage phase voltages:

$$V_s = \sqrt{\frac{2}{3}(v_{sa}^2 + v_{sb}^2 + v_{sc}^2)} \quad (1)$$

$$u_{sa} = \frac{v_{sa}}{V_s} u_{sb} = \frac{v_{sb}}{V_s} u_{sc} = \frac{v_{sc}}{V_s} \quad (2)$$

The grid power injected P_{grid}^* is predetermined and the current magnitude per phase magnitude per phase (I_s^*) is evaluated as

$$I_s^* = \frac{2}{3}\frac{P_{grid}}{V_s} \quad (3)$$

Then, the equations for instantaneous currents are:

$$i_{sa} = I_s^* \times u_{sa}; i_{sb} = I_s^* \times u_{sb}; i_{sc} = I_s^* \times u_{sc} \quad (4)$$

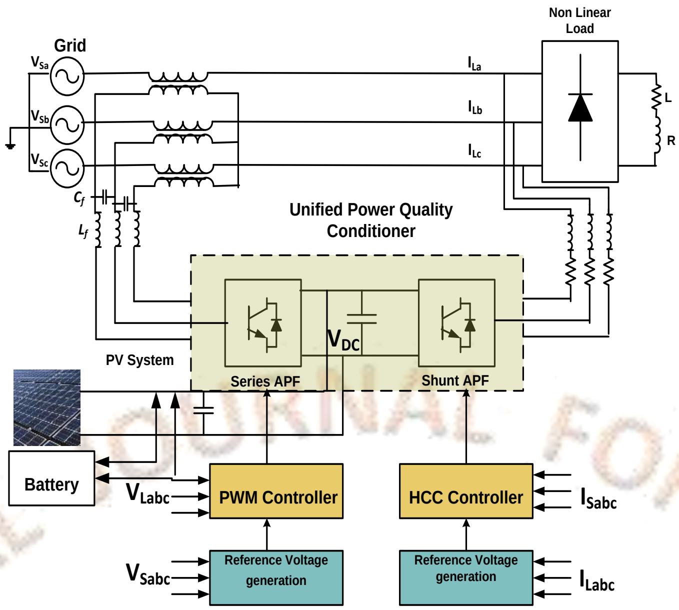

Fig. 1. Solar PV – Battery Fed UPQC System

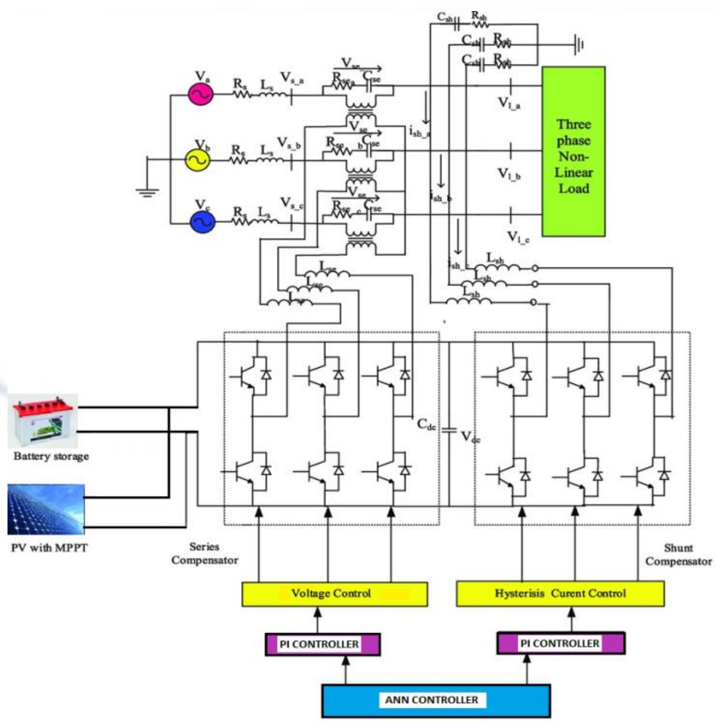

Fig. 2. Solar PV – Battery Fed UPQC System with ANN Controller

A hysteresis current controller receives the reference currents and uses them to produce control pulses for the Shunt controller. Maintaining a steady load voltage in an island mode is the responsibility of the shunt controller, regardless of variations in solar radiation and load current. To create the phase for the load voltage references, the DSP microcontroller does it internally. By multiplying the load voltage reference by the sine of the three phases, the instantaneous load voltage reference is produced. The load current reference is then obtained by comparing this to the load voltages that were detected. After comparing the reference and measured load currents with the hysteresis current controller in standalone mode, the shunt controller generates a gating signal.

Later, the gating signals for both the grid-connected and islanded modes are sent through a decision logic that determines whether to send the signals to the DSP controller's digital I/O based on the mode. As soon as the system is grid-synchronized, To limit the rate at which change of current delivered to the grid, the control approach uses a rate limiter block.

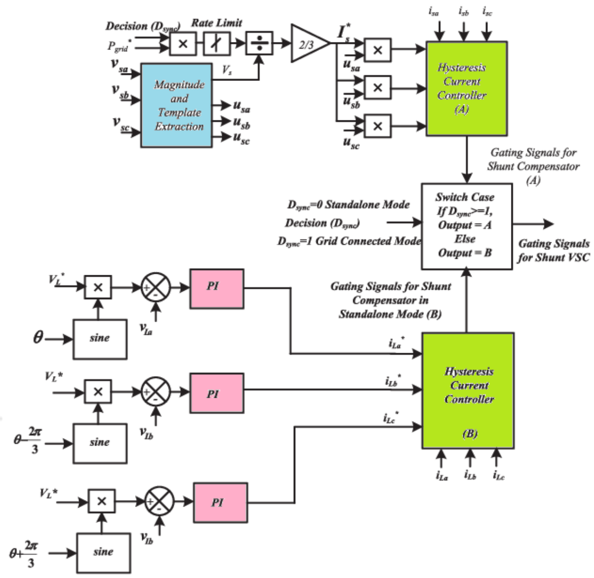

Figure 3: PV-B-UPQC system's Shunt Compensator Control

1) Phase Angle Generation in Islanded Operation: Fig. 3 displays the SHC's phase generation logic. If the grid voltage available and becomes more than 0.7 p.u the phase generation logic aligns the load voltage phases. Two phase-locked loops (PLL), one for the grid voltage and one for the load voltage, are used to achieve this. Any abrupt fluctuations are mellowed out by applying a sine function block to the phase difference between the PCC and load voltages. After that, a proportional-integral controller receives this and produces a frequency component.

$$\Delta\omega_L = \left\{K_{\text{psync}} + \frac{K_{\text{isync}}}{s}\right\}\{\theta_s - \theta_L\} \qquad (5)$$

This frequency component is fed to an integrator, which creates the phases for each of the three shunt VSC phases, after being combined with the load frequency.

$$v_{La}^* = V_L^* \sin(\theta) \qquad (6)$$

$$v_{Lb}^* = V_L^* \sin\left(\theta - \frac{2\pi}{3}\right) \qquad (7)$$

$$v_{Lc}^* = V_L^* \sin\left(\theta + \frac{2\pi}{3}\right) \qquad (8)$$

The load voltages attempt to match the phase of the PCC voltages due to the frequency shift.

2) Synchronization Control: PES can switch between islanded and grid-tied modes and connect and disconnect from the grid using the control signal generated by the synchronization logic. The fig .5 illustrates the synchronization logic diagram. Four procedures are used to assess the synchronization logic output:

1. The phase divergence between the load&PCC voltages.
2. The frequency dissimilarity between the load&PCC voltages.
3. The magnitude of the voltage divergence between the load&PCC 4. Method of act.

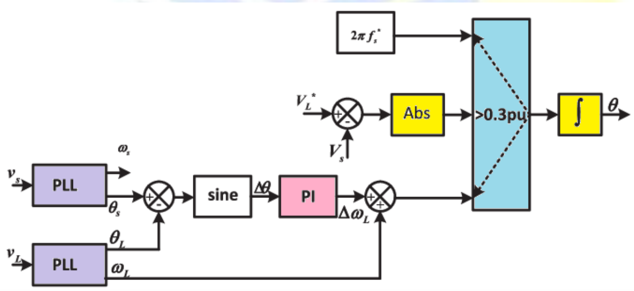

Fig.4. Phase Angle generation during Islanded operation

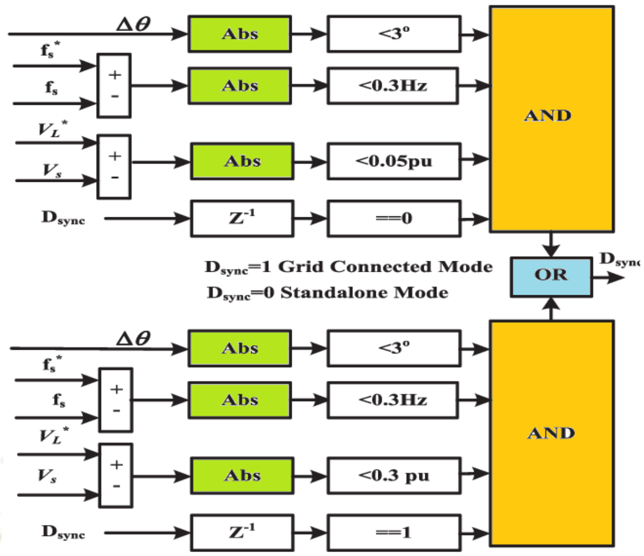

Fig. 5. Switching Between Standalone and Islanded Modes-Control logic

Fig.4 illustrates how the system checks to see if the phase difference between the PCC voltages and load voltages is less than 3 during islanded mode operation. In addition, it determines if the frequency difference is less than 0.3 Hz and the magnitude difference is less than 0.05 pu. All of these criteria' outputs are sent into an AND logic block. The conditions for Phase, magnitude and frequencies differences are once more examined after the system is connected to grid. The tolerance for difference in magnitude under these conditions is up to 0.3 pu. These criteria' outputs are sent into the AND logic. The OR logic receives the outputs from both AND logics, and produces the ultimate synchronization decision, Dsync. Grid linked mode is indicated by Dsync=1, and islanded operation is indicated by Dsyn=0.

Hysteresis controller:

Fig.6. The literature has a thorough description of basic hysteretic self-oscillating controllers [1, 2]. Either a voltage loop or a current loop can be used to create the hysteresis controller. The straight sloped saw tooth carrier and the infinite PSRR value, which occurs if the supply fluctuation is deemed to be very sluggish in relation to the switching frequency. Higher frequency power supply changes result in sum and difference products between the power supply variation and the reference signal but they nevertheless fulfill high suppression standards since they are not completely suppressed. The hysteresis controller is very attractive for use in audio amplifier applications because of its simple design and strong linearity. Nevertheless, the switching frequency of hysteresis controllers is reliant on the amplifier's modulation index, or M. This phenomenon affects all other fundamental varieties of self-oscillating modulators as well.

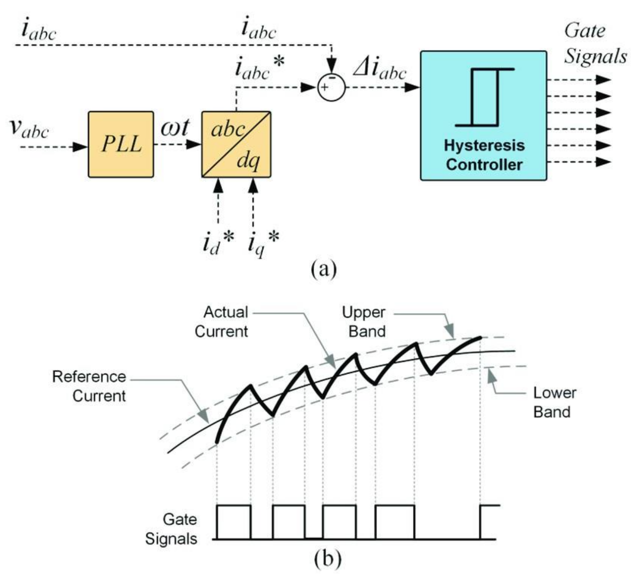

Fig.6 **(a) Schematic diagram & (b) gate signal generation for Hysteresis current controller.**

Fig. shows the fundamental hysteresis regulator in current mode and voltage mode executions. The primary function of the continuous mode hysteresis regulator is: The differential voltage between the speaker's result and the power stage's result is coordinated by the result inductor. The voltage mode hysteresis regulator is different from the present mode regulator in that it uses a working integrator to coordinate the difference between the power stage's result voltage and the information reference voltage. This results in another sawtooth-shaped transporter that is handled within a hysteresis window. The continuing mode regulator, which has an integrated result channel and is a voltage-controlled current source, is the primary functional difference between the two. Without a yield channel, the voltage mode regulator is a voltage-controlled voltage source. The non-consistent exchange recurrence is the most severe drawback of basic hysteresis regulators, which are used in sound and a lot of other applications. In the ideal model for a hysteresis regulator, the exchanging recurrence is subject to the balance record, M, by:

$$f_s(M) = f_{s,0} \cdot (1 - M^2)$$

The two primary practical issues brought about by the variety in exchanging recurrence are: diminished open circle data transfer capacity and - circle gain, which likewise prompts expanded mutilation; and expanded high recurrence swell voltage on the result at high balance record, which is brought about by less weakening of the lower exchanging recurrence's sounds. Past examination has recommended an inconsistent hysteresis window that follows M, or the information sign's outright worth [3]. The variable hysteresis window can be acclimated to follow both the subsidiary of the info signal and the square of the outright worth. This will increment framework intricacy essentially and make it difficult to keep a steady changing recurrence in contrast with the fundamental plan. outright worth as well as the subsidiary of the information signal, the exchanging recurrence can be made steady.

B. Series Compensator Control

Fig. 7 illustrates how the synchronous reference frame control-based series compensator works. In grid connected mode, the Series Compensator controls the voltage at the load point to prevent the variations in PCC voltage values. The Series Compensator is omitted from islanded operation under grid outages since the Shunt compensator manages voltage during individual operation. The SEC injects voltage to maintain the same phase between the PCC and load voltages. The d-q domain is created from the load and PCC voltages. The SEC reference voltage in the d-domain is provided by the difference between VLd and Vsd, whereas the difference between VLd and Vsd provides actual SEC voltages. The voltage signals in the q domain go through a similar procedure..

$$V_{sed}^* = V_{Ld}^* - V_{sd}, V_{sed} = V_{Ld} - V_{sd} \qquad (9)$$

$$V_{seq}^* = V_{Lq}^* - V_{sd}, V_{seq}^* = V_{Lq} - V_{dq} \qquad (10)$$

The PI regulator ships off the SEC signs in d-q and generates appropriate control signals. These signals are fully converted to ABC space and routed through a logic switch that additionally provides a yield signal based on the selected synchronization. C. Control of Bidirectional DC Converter.

The bidirectional converter control process. Maintaining the bi-directional converter's DC-interface voltage under all circumstances is its primary function. Through a twofold circle control that consists of a voltage and current control circle, the framework controls the DC-connect voltage [10]. The battery current reference is generated by the voltage circle and used in the current circle to establish the obligation percentage needed to maintain the PV-B-UPQC framework's DC-connect voltage.

$$I_{bt}^* = \{K_{pv} + \frac{K_{iv}}{s}\}\{V_{dc}^* - V_{dc}\} \qquad (11)$$

$$d_{dc} = K_{pi}\{I_{bt}^* - I_{bt}\} \qquad (12)$$

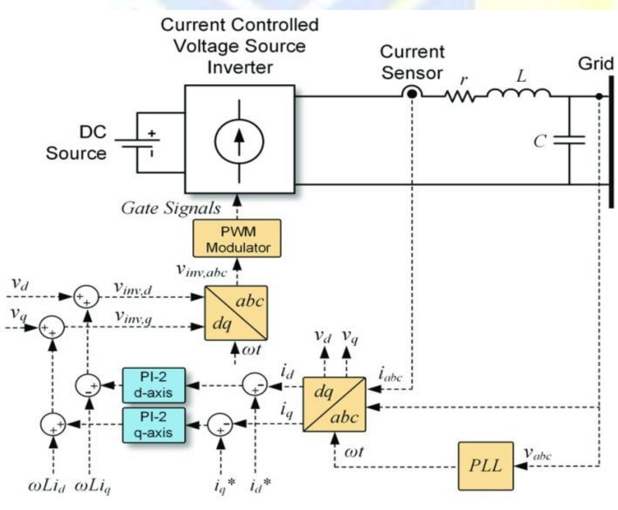

Fig. 7 (a). Series VSC Control Structure

After that, a PWM modulator receives the duty ratio generated and produces the proper gating signals for the bidirectional DC-DC converter.

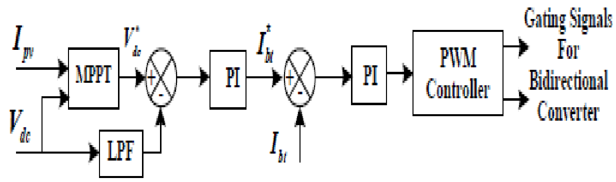

Fig. 7(b). Control Diagram of Bidirectional Converter

Pulse width Modulation (PWM) inverters are generally exploited in various applications. These inverters are capable of producing ac voltages with different recurrence and size. When comparing PWM inverters to square wave inverters, the quality of the output voltage is superior. Factor speed AC drives are the typical application for PWM inverters. By varying the supplied ac voltage's recurrence, a wide range of driving speeds can be obtained. The applied voltage and recurrence should be directly connected. There are single stage and three stage PWM inverter variants available for application. Depending on the methods of execution, there are many PWM strategies. Notwithstanding, in this multitude of procedures, the produced yield voltage in the wake of separating, get a decent quality sinusoidal voltage waveform having wanted key recurrence and greatness separately.
PWM inverters are utilized to control the voltage and to diminish the symphonious items in the result voltage.

Working of ANN controller:

An ANN regulator is a kind of control framework that uses a brain organization to learn and pursue choices in assessment of information.

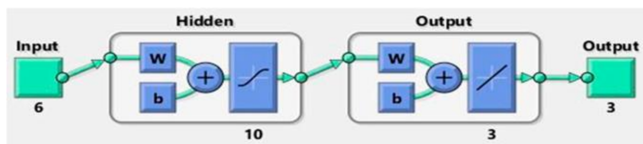

Fig.8. Final trained neural network

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The working of an ANN regulator includes gathering and preprocessing information, planning and preparing a brain organization, sending it in the control framework, and consistently observing and enhancing its presentation to work on the framework's expertise and precision.

Proposed Control Logic

The PV battery storage system sourced UPQC requires both series and shunt voltage source converters as crucial parts. The system is clever enough to address load quality issues like harmonics and reactive power by employing a shunt voltage source converter. For UPQC, which is based on PV solar systems and battery storage systems, shunt voltage source converters are used in addition to PV solar systems as the power source. The shunt voltage source converter uses the neural network technique to provide a reference current that offers active power while reducing the harmonic issue caused by the load's nonlinearity and excessive swell and sag. To shield the load from grid-side power quality issues like voltage swings and sag, the serial voltage source converter adds a voltage that is in phase with the grid voltage. To shield the load from grid-side power quality issues like voltage swings and sag, the serial voltage source converter adds a voltage that is in phase with the grid voltage.

Control Logic of Shunt Voltage Source Converter

The neural network's output acts as a current reference. In an a-b-c synchronization frame, three-phase sine waves are multiplied by the amplitude of the reference current, and the resulting product is compared to the shunt voltage source converter current. The voltage source shunt converter's pulse is generated by the hysteresis controller, which also regulates the amount of current injected into the grid and reduces harmonic disturbances induced by the grid's nonlinear load.

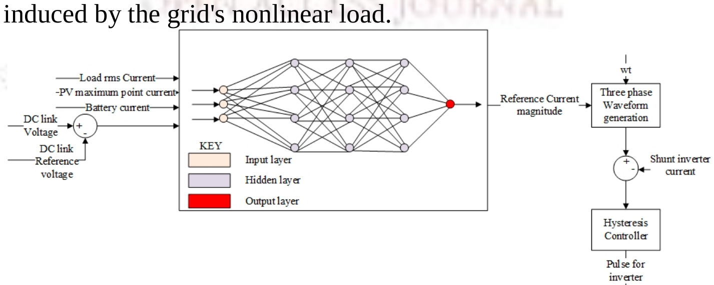

Fig 9 (a) Shunt Voltage Source Converter- Control Logic

Control Logic of Series Voltage Source Converter

Three control strategies are used by the serial voltage source converter: energy optimization, pre-compensation, and in-phase compensation. To obtain a minimum injection voltage in this study, a serial voltage source converter is used to add a voltage that is in phase with the mains voltage. In the event of an unstable line voltage, the control mechanism of the series voltage source converter aids in maintaining the rated load voltage, as illustrated in Figure 9(b). In this situation, the series voltage source compensator generates an unstable output voltage. The series voltage source compensator solves the problem in this scenario by providing an output voltage that is out of phase with the disturbance.

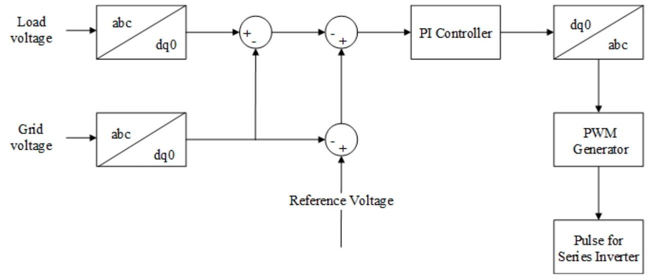

Fig.9(b). Series Voltage Source Converter control logic

The dq-0 reference axis is created by extracting a significant amount of the point of common coupling (PCC) voltage with a phase-locked loop (PLL). After the PLL has determined its phase and frequency, the PCC voltage is used to provide a reference load voltage. The conversion of the input voltages from the PCC to the load voltages yields a d-q-0 range. To get a peak value equal to its d-axis component, the load reference voltage must be phase-locked to the PCC voltage. On the q-axis, the components are kept at 0. The PCC voltage is subtracted from the load reference voltage to get the series compensator voltage. The real voltages of the series compensators are calculated by subtracting the PCC voltage from the load voltage. To provide exact reference signals, a PI controller must process the voltage difference between the voltages of the reference and real series compensators.. The a-b-c converter is then utilized to convert these signals into control signals for the series compensators via pulse width modulation (PWM).

EVALUTION OF ENHANCED PERFORMANCE OF PROPOSED SYSTEM WITH ANN CONTROLLER

Evaluation of the system's behavior and performance after the installation of an ANN controller for solar photovoltaic systems with battery-integrated unified power quality conditioners in both grid-connected and freestanding modes of operation for micro grid systems.

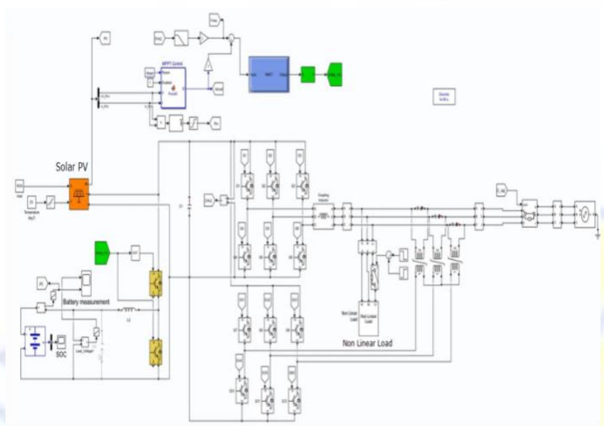

Fig-10 Simulation Model for Proposed System

This section uses MAT-LAB/Simulink software to assess the efficacy of the proposed control mechanism by examining the dynamic and steady-state performance of grid-connected solar PV systems as well as the battery storage-sourced UPQC model. A non-linear load (22% THD) is represented by a three-phase diode bridge rectifier with R-L load in the simulation. The system must adjust to changes in solar irradiation and PCC voltage in order to handle these dynamic conditions. Figure 10 displays the simulation created with MATLAB/Simulink.

Analysis of SIMULAITON RESULTS:

Case: -1: **During SAG in PCC Voltage:**

Performance analysis of voltage swells and sags for PV solar systems and battery-powered UPQCs. The temperature and photovoltaic irradiance in this part are kept constant at 1000 W/m2 and 25 °C, respectively. Figure 11 illustrates how the system parameters react to the voltage decrease.

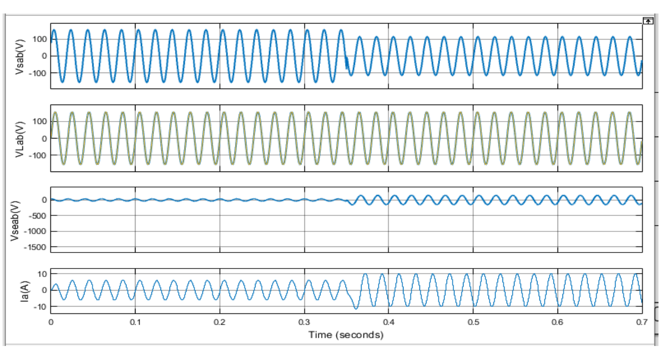

Fig:11 During SAG in PCC Voltage – Response of parameters

The effectiveness of a PV-battery-UPQC system using an ANN control technique is assessed in this scenario under two conditions: a distorted voltage supply and a voltage sag of 30%. Figure 11 illustrates the voltage Sag duration, which is from t = 0.35 s to t = 0.7 s. The series voltage converter of the UPQC system injects the voltage into the system and effectively maintained the sinusoidal voltage waveform at load side.

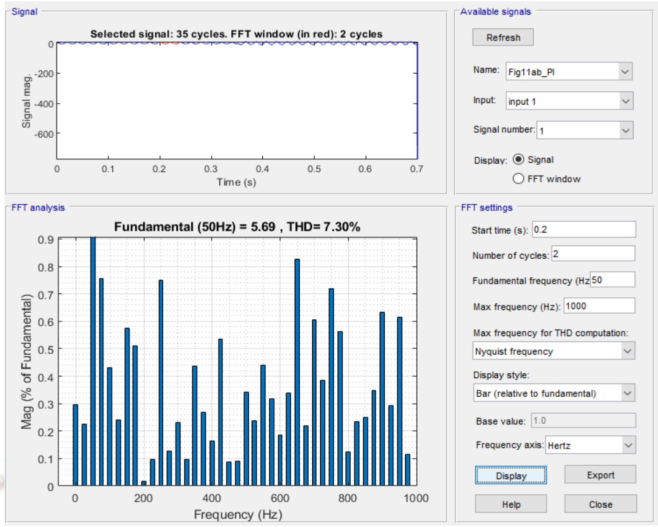

Fig.12.(a) During Voltage Sag- Load Side & PCC Voltages with PI Controller

The simulation results and % THD as shown in figures 11, 12(a) &(b). It is observed that PV array and battery-integrated Unified Power Quality Conditioner (UPQC) for micro grid systems with an ANN controller has yielded promising results and significant insights.

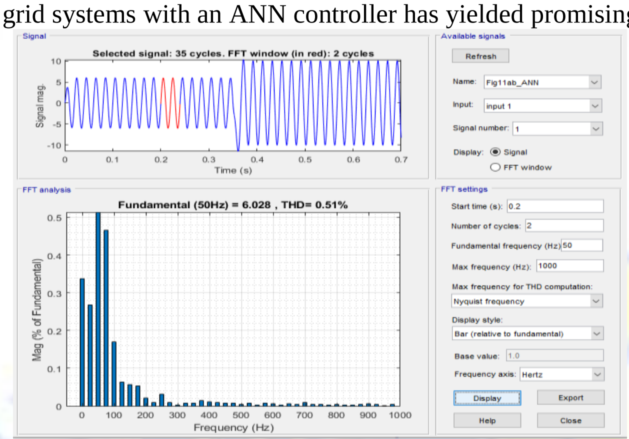

Fig.12.(b) During Voltage Sag- Load Side & PCC Voltages with ANN Controller.

Case:-II: **During SWELL in PCC Voltage:**

In this analysis, the performance of the PV-battery-UPQC system with an Artificial Neural Network (ANN) control technique is evaluated under a distorted voltage supply and a 30% voltage swell. The duration of the swell is from t = 0.35 s to t = 0.7 s, as shown in Figure 13. The supply voltage increases from 115 V to 120 V, and the series converter, aided by the dc-link capacitor, effectively mitigates the elevated voltage. Additionally, the maintenance of a sinusoidal voltage waveform is ensured by the effective compensation of the amplified voltage swell by the ANN-based UPQC system.

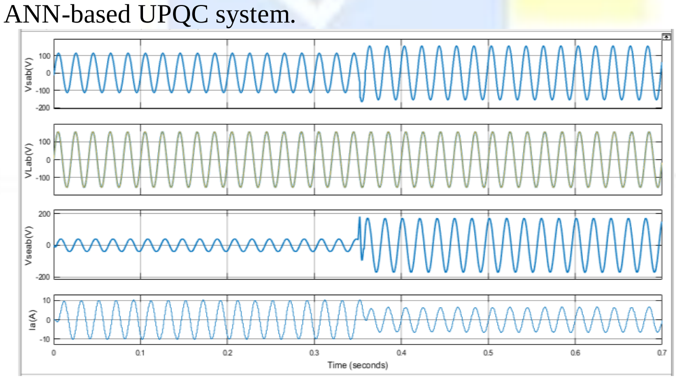

Fig.13 During SWELL in PCC Voltage – Response of parameters.

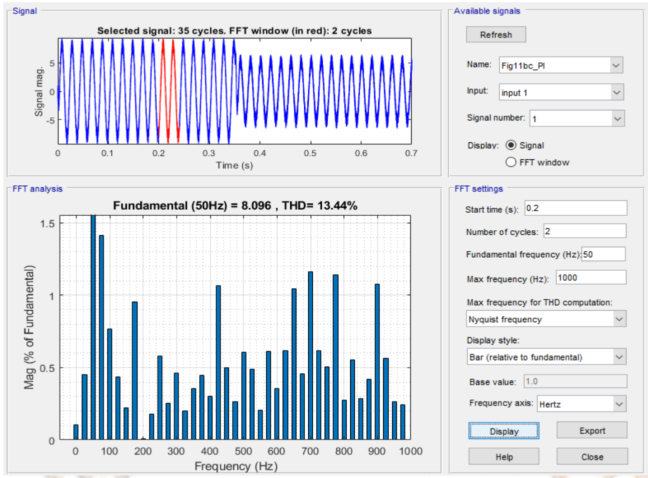

Fig.14.(a) During Voltage swell-Load Side & PCC Voltages with PI Controller.

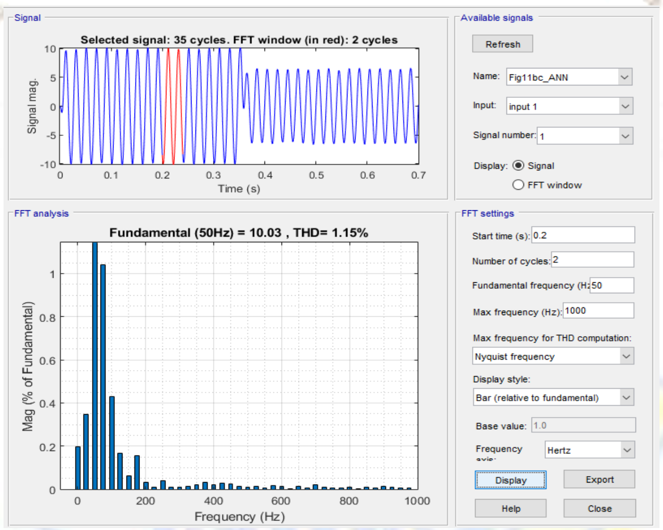

Fig.14.(b) During voltage swell-Load Side & PCC Voltages with ANN Controller.

The fig. 14(a) & 14(b) shows The ANN controller effectively reduces the Total Harmonic Distortion (THD) of both the source voltage and load current, resulting in a more sinusoidal waveform and improved power quality.

Case:-III: **During Unbalanced Load Condition:**

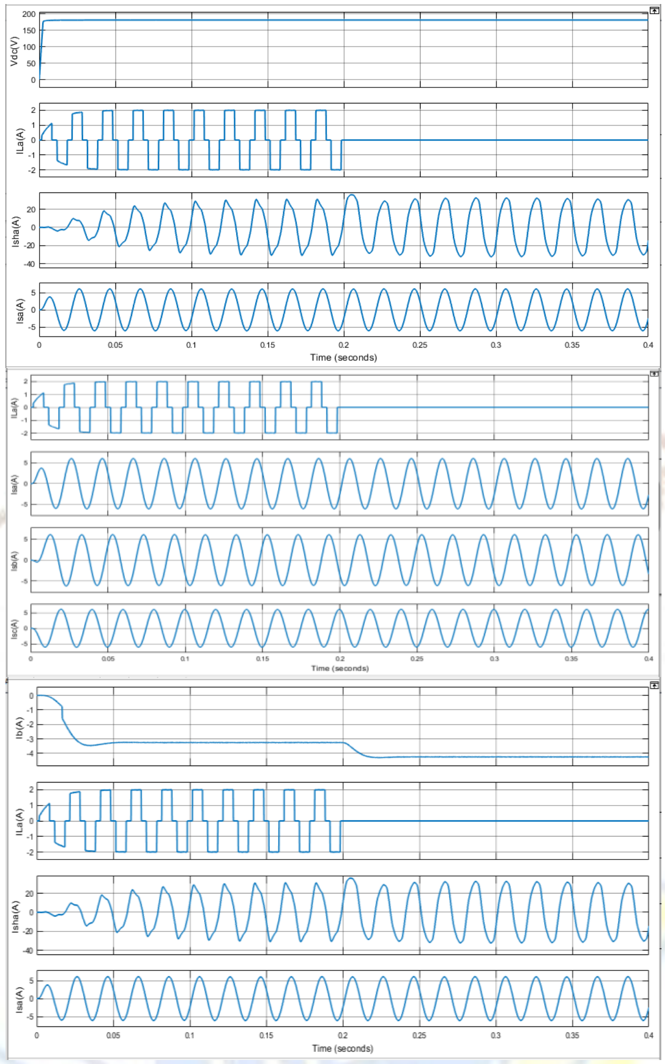

Fig.15.During Unbalanced Load Condition- Response of parameters

The simulation results shows in case of voltage sag, swell and unbalanced condition is shown in Fig. 15,16(a), and 16(b) . It can be observed that, the NN Controller has a good response and don't effect with the disturbances occurred on the grid side during the period of disturbances. The system is studied under voltage swells of 0.4 sec. duration the %THD also improved sag and swells associated with the system fault conditions. The simulation results and % THD as shown in below figures it observed that PV array and battery-integrated Unified Power Quality Conditioner (UPQC) for micro grid systems with an ANN controller has yielded promising results and significant insights.

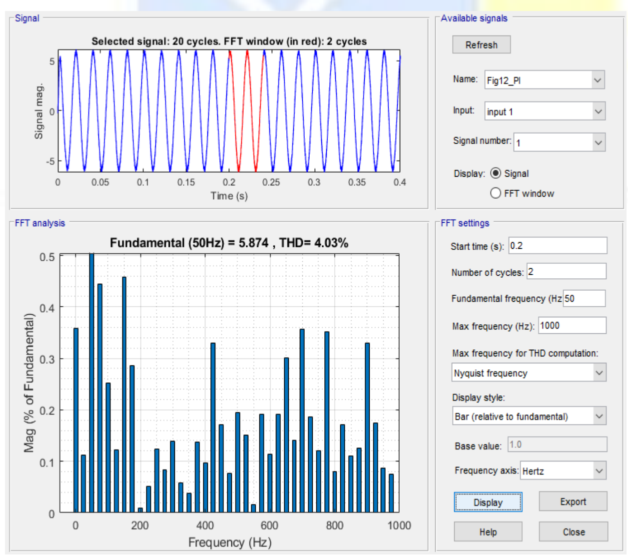

Fig.16. (a) During Load Unbalance Condition with PI Controller

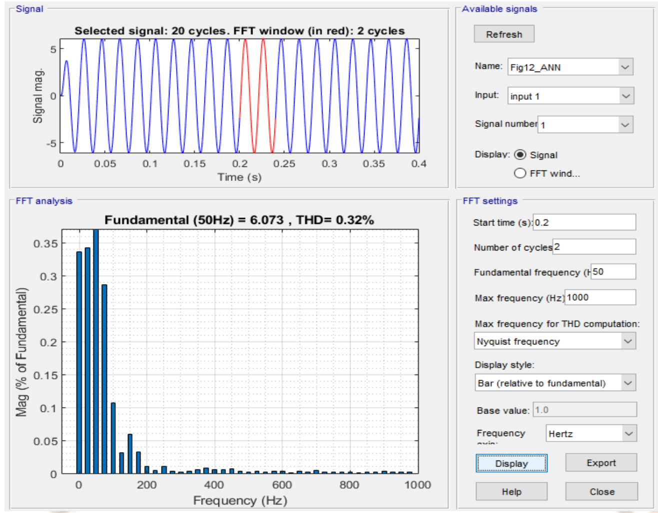

Fig.16. (b) During Load Unbalance Condition with ANN Controller.

Case:-IV: **During Synchronization**

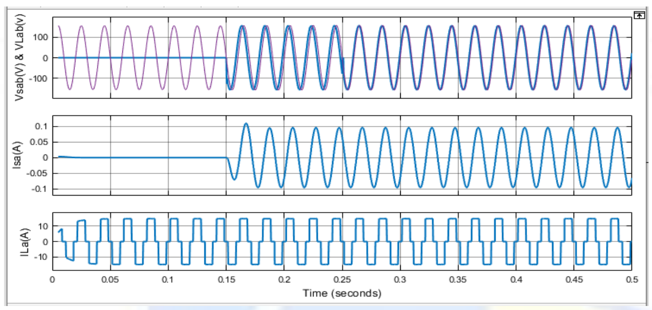

Fig.17 Synchoronization

Fig.17. During Synchronization- Response of parameters

The simulation results shows During Synchronization-Load Side & PCC voltage and current signals Fig.17 shows the PCC Voltage, load current and source currents during different conditions of a grid. It can be observed that NN Controller has a faster response and is not affected by the disturbances occurred on the grid side.

Case: - V: **During Grid Fault Conditions**

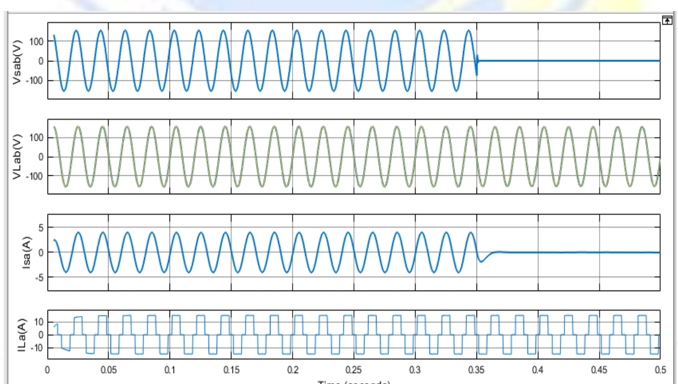

Fig.18. During Grid Fault Conditions-Response of parameters

The simulation results shows during Grid fault conditions in Fig.18 shows even after the grid fault occurred at 0.35 seconds, the load voltage remains sinusoidal and load currents are not affected. It can be observed that NN Controller has a faster response and is not affected by the disturbances occurred on the grid side.

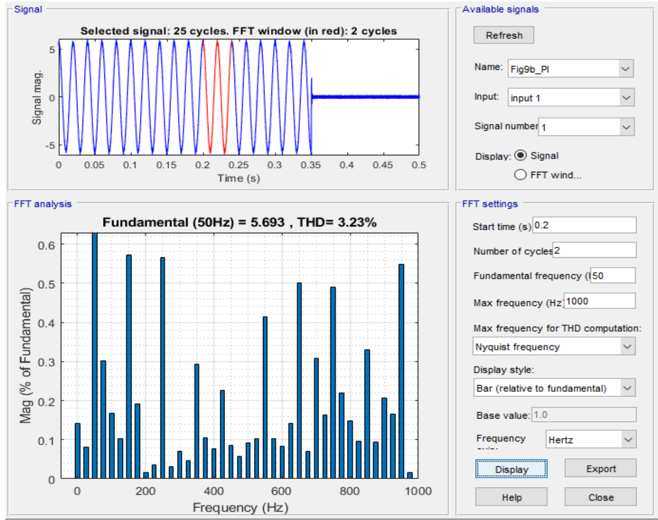

Fig.19.(a) Grid Current- THD- During Grid Fault Conditions Load Side & PCC Signals .

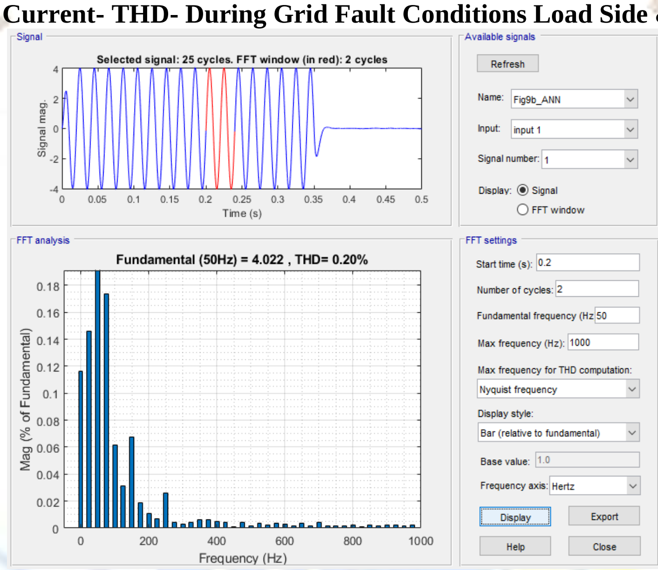

Fig.19.(b) Grid Current- THD- During Grid Fault Conditions Load Side & PCC Signals .

Case: - VI: **During Variation in Solar Irradiation**

The simulation results show in fig.20 reveals that the system currents are not affected even the variations in solar irradiation. It can be observed that NN Controller has a faster response and is not affected by the disturbances occurred due to variations in solar irradiations.

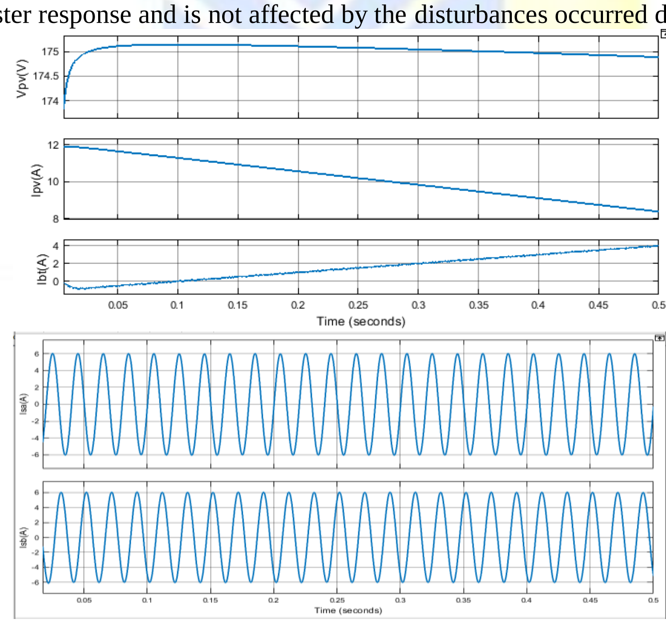

Fig.20. During Variation in Solar Irradiation- Response of parameters

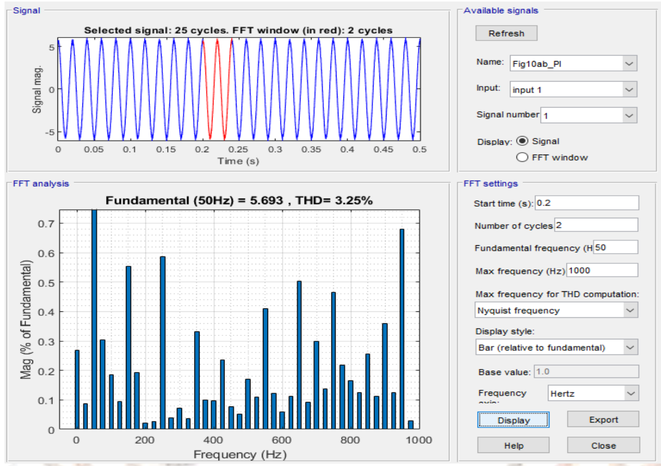

Fig. 21.(a) THD of Grid Current-During Solar Irradiation variation.

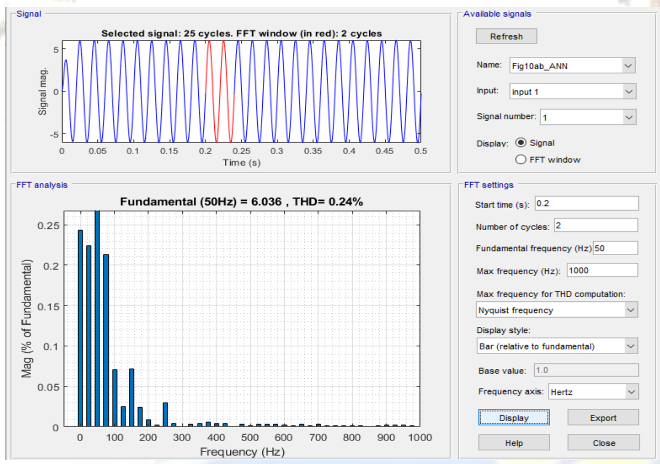

Fig. 21.(b) THD of Grid Current-During Solar Irradiation variation.

Total Harmonic Distortion (THD) of the SRF controller and ANN controller techniques is examined with the aid of simulation findings. It is noted that the THD level has been successfully lowered using both strategies. The ANN controller has demonstrated greater efficiency in reducing THD compared to the SRF controller for both current and voltage parameters. For the third, fifth, and seventh order harmonics, the percentage of THD attained in SRF is 8.64%, 8.64%, and 8.48%, respectively; for the same harmonics, the percentage attained in ANN is 2.64%, 2.64%, and 2.48%, respectively. Both of these percentages fall within the IEEE-519 limit. The percentage of THD value of source voltage has also decreased in the PV-battery-UPQC system with the proposed ANN over SRF controller. For the third, fifth, and seventh order harmonics, the percentage of THD attained in SRF is 3.54%, 3.64%, and 3.48%, respectively; for the same harmonics, the percentage attained in ANN is 0.72%, 0.71%, and 0.71%, respectively, and both fall within the IEEE-519 limit. Higher-order harmonics on the 15th, 21st, and 23rd power quality obtained by employing an ANN (Artificial Neural Network) controller in contrast to a traditional SRF controller were also examined for the PV-battery-UPQC system. On the fifteenth, twenty-first, and twenty-third, the PV-battery-UPQC system was also examined for higher-order harmonics. The load current waveform becomes more sinusoidal and the power quality increases as the fraction of THD drops. When compared to a traditional SRF controller, the ANN controller worked well in lowering the load current's THD value, as seen by the rise of the average harmonic reduction for the above-specified harmonics by 24.1%.

Using SRF (Sinusoidal Reference Frame) and ANN (Artificial Neural Network) controller approaches, the Total Harmonic Distortion (THD). The THD level has been successfully reduced by both methods; however, in terms of both current and voltage parameters, the ANN controller has shown a more effective reduction of THD than PQ. This shows how well the ANN controller works to mitigate excessive THD levels.

CONCLUSIONS

This research focuses on the battery-integrated Unified Power Quality Conditioner (UPQC) and solar PV array's improved performance analysis for micro grid systems with an Artificial Neural Network (ANN) controller has yielded promising results and significant insights. Through extensive research Simulink model successfully demonstrated the improved efficiency and reliability of micro grid systems. The integration of a solar PV array, battery storage, and UPQC, controlled by an ANN controller, showcased enhanced power quality, reduced grid disturbances, and optimal energy management. This innovative approach holds great potential for addressing the growing demand for reliable and clean energy in micro grid systems. The use of ANN as a controller has proven to be a robust and adaptive solution for real-time management, improving system response and stability. These findings have extensive implications for sustainable energy integration, grid resilience and the adoption of micro grids as a key factor of the future energy landscape. The project contributes to advancing the field of renewable energy and micro grid technology, flagging the way for more efficient, cleaner, and reliable power distribution systems.

Future Scope:

After Implementation of ANN Controller to enhance the performance of Solar PV and battery integrated Unified Power Quality Conditioner for Micro Grid Systems opens up exciting avenues for future research and applications. Some potential future scopes include:

- **Advanced Control Algorithms:** Further research can focus on developing advanced control algorithms that leverage machine learning and AI techniques for even more precise and adaptive control of the micro grid system. This can lead to improved energy management and grid stability.
- **Scalability and Grid Integration:** Future work can address the scalability of the micro grid system to accommodate larger loads and seamlessly integrate with the main grid. This is essential for the practical deployment of micro grids in urban and industrial settings.
- **Energy Storage Innovations:** Investigating advanced battery technologies and energy storage solutions can enhance the overall performance of the micro grid, enabling longer-term energy storage and improved energy utilization.
- **Cyber security and Resilience:** As micro grids become more widespread, research can focus on enhancing the cyber security and resilience of these systems to protect against potential cyber threats and ensure robust operation.
- **Economic Viability and Policy Considerations:** Assessing the economic viability and regulatory aspects of implementing such micro grid systems is essential to encourage their adoption. Future research can explore the financial models, incentives, and policies that support their widespread deployment.

REFERENCES

[1] S. Singh, B. Singh, G. Bhuvaneswari, and V. Bist, “A power quality improved bridgeless converter-based computer power supply,” IEEE Transactions on Industry Applications, vol. 52, no. 5, pp. 4385–4394, Sep. 2016.

[2] A. K. Giri, S. R. Arya, and R. Maurya, “Compensation of power quality problems in wind-based renewable energy system for small consumer as isolated loads,” IEEE Transactions on Industrial Electronics, vol. 66, no. 11, pp. 9023–9031, Nov. 2019.

[3] N. Saxena, I. Hussain, B. Singh, and A. L. Vyas, “Implementation of a grid-integrated pv-battery system for residential and electrical vehicle applications,” IEEE Transactions on Industrial Electronics, vol. 65, no. 8, pp. 6592–6601, Aug. 2018.

[4] S. Roy Ghatak, S. Sannigrahi, and P. Acharjee, “Multi-objective approach for strategic incorporation of solar energy source, battery storage system, and dstatcom in a smart grid environment,” IEEE Systems Journal, vol. 13, no. 3, pp. 3038–3049, Sep. 2019.

[5] K. K. Prasad, H. Myneni, and G. S. Kumar, “Power quality improvement and pv power injection by dstatcom with variable dc link voltage control from rsc-mlc,” IEEE Transactions on Sustainable Energy, vol. 10, no. 2, pp. 876–885, Apr. 2019.

[6] Q. Liu, Y. Li, L. Luo, Y. Peng, and Y. Cao, “Power quality management of pv power plant with transformer integrated filtering method,” IEEE Transactions on Power Delivery, vol. 34, DOI 10.1109/TPWRD. 2018.2881991, no. 3, pp. 941–949, Jun. 2019.

[7] T. A. Naidu, S. R. Arya, and R. Maurya, “Multiobjective dynamic voltage restorer with modified epll control and optimized pi-controller gains,” IEEE Transactions on Power Electronics, vol. 34, no. 3, pp. 2181–2192, Mar. 2019.

[8] K. Palanisamy, D. Kothari, M. K. Mishra, S. Meikandashivam, and I. J. Raglend, “Effective utilization of unified power quality conditioner for interconnecting PV modules with grid using power angle control method,” International Journal of Electrical Power and Energy Systems, vol. 48, DOI http://doi.org/10.1016/j.ijepes.2012.11.026, pp. 131 – 138, 2013.

[9] V. S. Cheung, R. S. Yeung, H. S. Chung, A. W. Lo, and W. Wu, ss“A transformer-less unified power quality conditioner with fast dynamic control,” IEEE Transactions on Power Electronics, vol. 33, no. 5, pp. 3926–3937, May. 2018.

[10] S. Devassy and B. Singh, “Performance evaluation of islanded and grid connected operation of solar pv-battery based universal active power filter,” in 2018 IEEE 8th Power India International Conference (PIICON), pp. 1–6, Dec. 2018.

[11] S. Devassy and B. Singh, "Performance Analysis of Solar PV Array and Battery Integrated Unified Power Quality Conditioner for Microgrid Systems," in *IEEE Transactions on Industrial Electronics*, vol. 68, no. 5, pp. 4027-4035, May 2021, doi: 10.1109/TIE.2020.2984439.

[12] B. Singh, A. Chandra and K. A. Haddad, Power Quality: Problems and Mitigation Techniques. London: Wiley, 2015.

[13] V. Khadkikar, “Fixed and variable power angle control methods for unified power quality conditioner: operation, control and impact assessment on shunt and series inverter kva loadings,” IET Power Electronics, vol. 6, no. 7, pp. 1299–1307, Aug. 2013.

[14] S. B. Karanki, N. Geddada, M. K. Mishra, and B. K. Kumar, “A modified three-phase four-wire upqc topology with reduced dc-link voltage rating,” IEEE Transactions on Industrial Electronics, vol. 60, no. 9, pp. 3555–3566, Sep. 2013.

[15] S. Devassy and B. Singh, “Implementation of solar photovoltaic system with universal active filtering capability,” in 2018 IEEMA Engineer Infinite Conference (eTechNxT), pp. 1–7, Mar. 2018.