International Journal of Computational and Experimental Science and ENgineering
(IJCESEN)
Vol. 11-No.3 (2025) pp. 4479-4490
http://www.ijcesen.com
ISSN: 2149-9144

Research Article

Modelling and Regulating Active Harmonic Filters For Improve Power Quality In Transmission Line Environment

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Article Info:

DOI: 10.22399/ijcesen.2480
Received : 13 March 2025
Accepted : 17 May 2025

Keywords

Recurrent neural networks (RNNs),
Transmission and Distribution Systems ,
Shunt Active Power Filters (SAPFs),
Maximum Power Point Tracking (MPPT).

Abstract:

In distributed generation network configuration, power quality is the primary requirement for energy system transmission and distribution. Recent research has shown that in a single-phase system with non-linear loads, the quality of the power control unit needs to be improved for industrial and voltage compensation losses. Previous work has recognized the low harmonics and peak demand in the supplied voltage and current quality and limits the network's reaction to non-linear loads. To solve these power quality issues, active harmonic filters were proposed, and the balance between the source voltage and current components was balanced at the fundamental frequency. In this method, Maximum Power Point Tracking (MPPT) with Artificial Neural Networks (ANN) is used for the solar panels' current and voltage output, which are constantly evaluated, and the controller estimates electrical output. The active filters analyse the input source where the harmonics depend on the voltage regulation and distributed generation depending on the type of sources that create harmonics in the power system. A duty cycle of each switching device acts in an inverter that interfaces to the system through a system interface filter. The simulation output evaluated the peak over shoot, harmonic distortion, and power losses in the transmission Line and improve the output voltage.

1. Introduction

Power quality (PQ) is a growing concern for all users of the electricity system, with significant economic repercussions and complex issues to consider. The main source of the PQ problem in the transmission and distribution infrastructure is power conversion, which affects both utilities and customers. This issue is becoming increasingly prevalent and must be addressed. Another important factor to consider is the imbalance in load potential, which also needs to be addressed at the source [1]. For electrical systems to operate as efficiently as possible, power quality needs to be improved. The existence of harmonics, which are voltage or current components at frequencies. These harmonics can cause issues such as overheating, inefficiency, and equipment failure. The AHFs (Active power filters) continuously monitor the electrical system using sensors to analyze the voltage and current waveforms in real-time. The filter then identifies the precise frequencies and amplitudes of the harmonic components. The AHF produces compensatory currents that are out of phase with the observed harmonics, and currents are injected into the system, effectively reducing the harmonics. AHFs significantly improve overall power quality by lowering harmonic distortions, resulting in more reliable and stable electrical systems. Reducing harmonics can also lead to longer equipment lifespan and lower maintenance requirements. Furthermore, improved energy efficiency is achieved as lower energy losses caused by harmonic distortions contribute to higher power quality [2]. In a weak grid where grid impedance cannot be ignored, an unequal load might result in an uneven distribution of grid currents.

1.1 Harmonics Distoration

The optimistic sequence current element of the load can be create using the asymmetrical extraction component method. An imbalance in the load can significantly affect the grid's actual and reactive electricity (P and Q), which can then impact the inverter's performance as well as any other three-phase loads connected to the electrical system. In order to resolve this issue, this control architecture extracted the symmetrical parts of the load voltage using a symmetrical component extraction technique. Instead of comparing the inverter current, this approach compares the chosen current signal to the grid electrical currents. FACTS can maximize the use of the currently installed architecture to help integrate renewable energy sources and improve overall grid reliability [3].

1.2 Transmission System

Networks for the transmission of electrical power are better managed and more reliable thanks to these tools. Alternating Current (AC) energy conveyance is made more adaptable and efficient by the ways in which they control power flow. Value drops in RMS line voltage fall between 10 and 90 percent of the nominal line voltage. Grounding: The nominal line voltage is increased to 110–180 percent of the RMS line voltage for a duration of 0 points, 5 cycles to one minute. Due to the nonlinear characteristics of voltage and current, harmonics are produced. RMS line voltage usually varies by less than 5 percent, which causes flicker and voltage fluctuations. Two-way oscillations in the voltage, current, or both of a power line are called oscillatory transients. [4].
The shunt active power filters purpose as a current cause when the nonlinear load is connected in parallel to devices. In order to produce an identical but opposing potential to the reactive and harmonic currents created by the nonlinear utilization, the balancing current produced by the active power filtering is modified. The primary current under these conditions is continuous and in parallel with the primary voltages. Additionally, high voltages and currents caused by resonance with line impedance can result in a decrease in capacitive reactance and an increase in inductive reactance, leading to blown fuses on power factor correction capacitors. These issues can arise from abnormalities between phases, faults between a single phase and ground, or an uneven distribution of load [5].

1.3 Objective

To efficiently track the current and voltage from solar renewable energy sources under various environmental condition using Maximum Power Point Tracking (MPPT).
To get the real-time data of converter output using Artificial Neural Networks (ANN) for Increased accuracy and performance under multiple operating Conditions.
To minimize sage and swell in long power lines are essential for effective power transfer and control, particularly in managing power flow between different duty cycles in power distribution system PQ issues using Shunt Active Power Filters (SAPFs)
To reduce voltage flicker, reducing harmonics, and identifying power factor issues within the grid-connected transmission line system.

2. Literature Survey

An Adaptive Neuro-Fuzzy Inference System (ANFIS)-adjusted PI controller is used to maintain the connection voltage across the capacitor, which is another important aspect of this study. The capacitor's connection voltage is also maintained by implementing a PI controller that is tuned using ANFIS as opposed to standard PI and fuzzy. There are very few switching losses with the 7Lb-ANPC inverter. The generation of the reference current using RBFNN yields a THD of 0.89 percent for the source current. [6]. In order to improve the power quality, a shunt active power filter is used. A mathematical model is developed for the suggested system. Here, a control approach based on particle swarm optimization is used, which improves system reliability over traditional methods. For enhanced power quality in the distribution system, a three-phase SAPF is suggested. Reactive power and current resonance adjustment are required for linear and nonlinear load conditions. When there are no payouts, the THD of the source voltage is 23.90%; however, when balanced, out-of-balance and nonlinear loads are used using the suggested management technique, the THD is decreased to 4.01% and 5.39%, respectively [7].
SAPF functions as a source of controlled current. A SAPF comprises a Voltage Source Inverter (VSI) and the Point of Common Coupling (PCC) coupled by a series inductor. Although a capacitor is the only component supporting the DC bus, this filter can only generate non-active power DSP-based active power filters, highlighting the suggested management strategy's better performance and efficacy. Under steady-state conditions, the Total Harmonic Distortion (THD) of grid current is reduced from 22% to 3% using the suggested control

approach. On the other hand, the low pass filter is digitally implemented using low cut-off frequency and deficient order filtration [8].

An exponential increase has been observed in the development of grid-connected photovoltaic systems, which use power converters to supply electricity to the electrical grid. However, these electrical transformation devices are considered nonlinear loads for the power infrastructure because they generate large harmonics and reactive currents that react with the grid's impedance to produce harmonic values and harm all users connected to the same Point of Common Coupling (PCC). The power infrastructure consists of three-phase continuous voltage sources connected in series with external obstacles made up of a resistor and an inductor. [9].

The user base is created at random and split up into the right numbers and whole player population is created at random and split up into the proper units. During this process, the APLs of the losing team, referred to as the mutation operator. The parameters of both proportional-integral controllers adjusted by the SOL algorithm and fuzzy logic controller are adapted by the developed controller. This is satisfied by optimally tuning the shunt and series controllers, which are regarded as variable controls and lower the overall distortion due to harmonics to 2.06% [10].

The performance of a 3 Ø grid-connected Photovoltaic (PV) based Shunts Active Power Filter (SAPF) using quantum calculus-based least mean fourth (q-LMF) management. The suggested solution makes use of a PV array. The filtered point of standard coupling (PCC) voltage under a weak and distorted grid is extracted using a modified complex coefficient filter and the q-LMF-based controlling technique. Enhancement learning and control systems employ the Adaptive Q-Learning Model-Free (Q-LMF) control methodology, which is particularly helpful in handling dynamic and unpredictable contexts. A method lets the controller modify its settings in response to changes in the surroundings or the dynamics of the whole system [11].

For this investigation, the shunt HAPF architecture was used. Together with an inductor (L f) and a capacitor (Cf) passive filter, a three-phase PWM voltage-source converter forms its components. In order to drop the majority of the grid voltage across it, the filter capacitor, Cf, has a high impedance to the line frequency. This leads to the primary voltage between the APFs. Terminals used in the shunt HAPF seem to be few or nonexistent. Electrical power converters, such as DC/AC converters driven by solar and wind energy, traction and power converters, and high-voltage direct current power converters, etc. through a line-side conversion, is able to convert energy and exercise control over systems that were linked to the single feeder during SAPF's functioning [12].

SAPFs can detect and lessen harmonic currents generated by nonlinear loads due to the harmonic compensation current waveform's closeness to a pure sinusoid. Reactive power compensation: SAPFs help maintain voltage stability in a distribution chain by supplying or absorbing reactive electrical energy. This is crucial because inductive demands in systems can lead to the following power factors. SAPFs can boost efficiency and reduce losses by load balancing, which divides loads equally among a distribution network's three phases. A control algorithm uses the information provided to calculate the appropriate compensation [13].

In order to decrease current distortion and increase the utility power factor, a shunt active power filter (shunt-APF) connects in parallel with nonlinear loads and adds a negative current harmonic to the grid. Through the production of a specific reference current for the IGBT bridge, a three-phase voltage source inverter known as a shunt-APF reduces random harmonics and compensates for power factors up to unity. A series active power filter, also known as a series APF, removes harmful voltage harmonics from the grid by canceling out the effects of the load voltage. The voltage's APF THD increases to 11.3 percent with an additional 8.3 percent. [14].

Shunt active power filter (shunt-APF): this sort of filter, which is linked in parallel to nonlinear loads, introduces a negative current harmonic into the grid to lower distortion in current and raise the utility power factor. Series active power filter (series-APF): this kind of filter is employed in parallel with the loading and is intended to reduce grid voltage harmonics by canceling out the effects of the load voltage through the generation of damaging voltage harmonics. Several control strategies, including PI, fuzzy controllers, and a state of control, can be used to assess the reference currents in both phases of this two-phase waveform. The voltage APF THD is measured at 1.3% before and 8.3% after adding APF [15].

SAPFs can identify and compensate for the harmonic currents generated by nonlinear loads, such as rectifiers and inverters. By introducing opposing and equal currents into the system, they help to reduce overall harmonic distortion. Reactive power assistance is provided by the Reactive Power Compensation method, crucial for maintaining voltage levels and increasing the power system's efficiency. SAPFs may distribute the load evenly throughout the three phases in three-phase systems, lowering neutral currents and enhancing system stability overall. SAPFs adjust reactive power dynamically and compensate for voltage drops to help keep voltage levels within permitted limits [16].

An integrated SAPF and an enhanced incremental conductance (EINC) maximum power point tracking system are features of the PV module's construction. Demand, reactive power, and load could all be met by reducing the harmonics that NL produced and increasing the active power provided by the PV arrays. When there are fluctuating loads, traditional tuning PI controllers don't work well. NL harmonic current generation, reactive power demand, and load variations are all handled simultaneously by this intelligent nonlinear controller. By reducing the source current's Total Harmonic Distortion (THD) percentage below IEEE specifications, this control method prevents an NL and balanced/unbalanced load state. [17].

An initial attempt has been made to optimize the SAPF PI controller parameters, including Vdc, filter obstruction, filter inductance, and DC side inductance, using the Multi Sine Cosine Algorithm. Grid-connected solar power systems using optimally calibrated MPPT PI controller settings and optimally constructed SAPF parameters, obtained through simulation, operating at lab scale in real-time with IGBT. Complex oscillation instability and harmonic amplification events have been observed in large-scale photovoltaic systems that operate unstable when connected to a weak grid. [18].

In the majority of commercial, industrial, medical, and residential settings, anomalous behavior of end equipment can be caused by power quality issues in the distribution network. When using split capacitors in a DC connection, one phase is connected directly to the middle of the capacitors, meaning that fewer switches are needed. The recommended design lowers the DC link voltage in the H-bridge and connects it to the power distribution network by using an AC capacitor in series with the coupling inductors. This LC circuit is tuned to the sixth harmonic and functions as a passive filter, attenuating the fifth and seventh harmonics to some extent. A three-phase full-bridge rectifier's nonlinear load is made up of RL loads. [19].

Increased deployment of power-distributing structures for DC supplies, inverters, and converters can lead to downsizing in power supply networks, causing issues with voltage/current harmonics, power factor, and frequency. These harmonics are produced during power inverter switching and can be suppressed with filters. The existing harmonic components at the Point of Standard Coupling (PCC) are equivalent to, but opposite of, the current harmonic commission. Our technique has been compared to previous methodologies and has significantly reduced Total Harmonic Distortion (THD). Even with the recommended plan, the setback is less than 50% of the prime cycle and is comparable to the technique indicated in line with the International Rectifier Power Transistor (IRPT) [20].

Alternating Current (AC) can be converted from Direct Current (DC) to voltage source converter and vice versa. Power electronic switches, such as IGBTs or MOSFETs, are used in the conversion process. Applications requiring a regulated output voltage waveform, like Active Power Filters (APFs), benefit greatly from the use of VSCs. By adding compensatory currents to the system, these filters reduce reactive power and undesired harmonics. In order to neutralize harmonic elements, the VSC component of an APF detects them by monitoring the network's voltage and current signals and generates counteracting currents [21].

Coordinating the placement and sizing of shunt capacitors with DG determines the Distributed Generation (DG) units and battery banks inside the networks. Sometimes the load's consideration of the voltage's electrical current can have an impact on the quality of the voltage. Power factor correction is aided by the precise placement and sizing of shunt capacitors, which improve the low power factor usually associated with inductive loads, which increase power losses and lead to voltage instability. The reduced power loss (active and reactive) was 59.38 percent and 63.29 percent, respectively, for a 33-bus system [22].

Two input components of the load are the current and the voltage at the Point of Common Coupling (PCC). The output variables inverter's switching states (the on/off states of the switches). Shunt Active Power Filters (SAPF) have a large switching frequency variance when used for threshold DPC setting, which means the digital controller must have a high sampling frequency. In order to reduce the load on the controller and address problems with high sampling frequency requirements and switching rate fluctuation [23].

Shunt active power filters, or SAPFs, are a useful tool for distribution systems' harmonic distortion reduction and power quality enhancement. They operate using the ABC-ANN, or Artificial Bee Colony Optimized Artificial Neural Network Controller. The concept of Artificial Neural Networks (ANN) derived from Biological Neural Networks was first introduced in the human brain. The ANN performance is compared to that of other optimization algorithms, including the Differential Evolution (DE) algorithm, the PSO-tuned PI controller, and the conventional PI controller, in the output [24].

The optimal pathway for an ML model can be determined through automated machine learning (Auto ML) techniques, which involve searching through a space of 110 hyperparameters and considering more than 15 different ML models. In order to gather accurate data, it is essential to capture information under various operational conditions, including linear, nonlinear, and dynamic loads. The model and measurements of reaction time, reactive power compensation, and Total Harmonic Distortion (THD) should be taken. A mathematical model of the SAPF should also be created, considering its control schemes and electrical components [25].

Real-time controller adaptation is enabled by the linear Active Disturbance Rejection Controller (ADRC), which also identifies the disturbances affecting the system. Examples of adaptive observer design strategies involve adjusting the observer to more precisely estimate states and disturbances, as well as modifying the system dynamics. adjusting Parameters: Transient responsiveness and resilience can be increased by adjusting controller settings systematically. With this method, the load side A-phase current waveform is slightly variable at ±220 A, the grid side A-phase voltage is consistently maintained at ±50 V, the harmonic distortion rate is 4%, and the SAPF DC side voltage curve is kept between actual set values, about 820 V [26].

Although the capacitor may charge or discharge as a result of this active current, the power drawn from the source and the actual power used will be equal if the capacitor voltage on the DC link is maintained at the reference value. This active current allows the capacitor to be charged as well as discharged. Maintaining the capacitor voltage at the reference value results in a positive dynamic response when the source and actual power used in the DC link are equal. Capacitor for energy storage on the DC side of the inverter; Units for control; Voltage Source Inverter (VSI) for converting electrical power; Inductance for connecting the inverter phase to the grid and acting as a transmission element [27].

An internal impedance made up of a series connection between a resistor (R) and an inductor (L) can be used to represent a single-phase electrical network. The whole bridge capacitor is a nonlinear load that is parallel to loads R and L. Two identical capacitors installed on the DC side of a single-phase inverter equipped with IGBTs make up an APF. A parallel connection is established between the APF and the nonlinear load from the AC side. The backtracking technique is employed to create the inner loop, which addresses the compensation issue by utilizing the energy stored in the PV-SAPF components [28].

Shunt Active Power Filters are used to measure the harmonic level in electrical systems that combine solar and wind PV (SAPF). The SAPF makes use of an adaptive hysteresis current controller technique, a conventional proportional and integral-based voltage regulator, and modified synchronous reference frame technology. Under a range of load and source conditions, the proposed SAPF effectively suppresses harmonics. The SAPF can lower the source current harmonic under optimal source conditions from 26.74 percent to 1.56 percent, and for capacitive and sensitive load cases, from 20.25 percent to 1.80 percent. Non-ideal resource conditions allow the SAPF to reduce overtones from 30.05 percent to 30.82% for inductive load cases and from 25.25 percent to 35.66% for capacitance load scenarios [29].

The voltage source amplifier is the sole component of the single-phase SAPF. The inverter receives a constant voltage from a DC link capacitor and generates a negative sequence compensation voltage. This compensatory current is then introduced into the network at the point of standard coupling. Maintaining a stable voltage for the DC link capacitor is crucial to extracting harmonics effectively. The solutions are shifted to the margin if the controller parameters exceed the specified constraints. If a mutant solution yields better results than the current one, it is replaced with the variant [30].

2.1. Problem Statement

In the previous work Frequent drops and rises in voltage have the potential to disrupt sensitive loads and cause malfunctions. Harmonic distortions are brought on by non-linear loads and affect the power system overall, leading to inefficiencies and overheating. Power factor issues include increased energy costs and strain on the electrical system due to low power factor. An uneven distribution of loads can cause stress on equipment and increase system damage.

2.1.1 Voltage Sag

In a transmission line, shunt and series compensation are combined to improve power quality. To address various power quality issues, it consists of a series inverter and a shunt inverter working together. The term "voltage sag" refers to a transient decrease in voltage magnitude that usually lasts two to three minutes.

$$Sag(\%)=(VnomVnom/Vactual)\times 100 \quad .... \quad (1)$$

In equation 1 V_nom = rated voltage in load or problems with the power grid. During a voltage sag, the UPQC's series inverter injects the essential voltage to maintain the load voltage at a level that is acceptable. Making sure that the voltage applied to the load is steady and constant is the aim of the waveform generated during sag mitigation

2.1.2 Voltage Swell

Voltage swell is the term used to describe a prolonged voltage rise that lasts for a few cycles to several minutes and exceeds high percent of the standard voltage. Voltage swells, also referred to as the opposite of voltage dips, are spikes in voltage of 10% or more above recommended or typical usage.

$$Swell(\%)=(VnomVactual/Vnom)\times 100 \quad ... \qquad (2)$$

In equation 2 V_(actual =)Swells condition that can occur when a large engine or other heavy load is turned off and the power line's voltage briefly rises. A surge lasting more than a minute is called overvoltage, and it can be caused by loads that are nearly at the beginning of a power distribution system, improperly adjusted transformer taps, or the network connection of renewable energy sources, such as solar panels.

3. Materials

In this method, the input source is a grid, and bidirectional solar panel light photons form pairs of electrons and holes at the p-n junction in solar cells, which produces a voltage that may drive current over a connected output. Shunt active filter currents into the power supply. The shunt active filter works and recognizes the harmonic currents that nonlinear loads are drawing and creates the appropriate countercurrents to offset them at all times. Load current analyzes the converter voltage by a load linked to a circuit, and compensation current is the actual current flowing through the circuit when the load is operational.

Power electronic converters that run in parallel with a load or the power grid are known as shunt inverters. Through integration with Maximum Power Point Tracking (MPPT) technology and photovoltaic (PV) systems, it becomes possible to effectively manage the energy harvested from solar panels. In parallel with the load and the grid is connected the shunt inverter. It can feed extra energy back into the grid or directly supply power to the load. To ensure maximum performance, the MPPT algorithm dynamically modifies the operating point in response to changes in environmental conditions, such as temperature fluctuations or shade. The current drawn by a load linked to a circuit is called load current and design illustrates the current that passes through the circuit when the load is used. Reactive power problems and other undesired consequences of inductive or capacitive loads are mitigated in power systems using compensation current. An electrical load that draws current non-linearly is one in which the voltage waveform is not followed by the current waveform, which is not a perfect sine wave. Adjusting for power factor: installing equipment such as capacitors to increase power ratio.

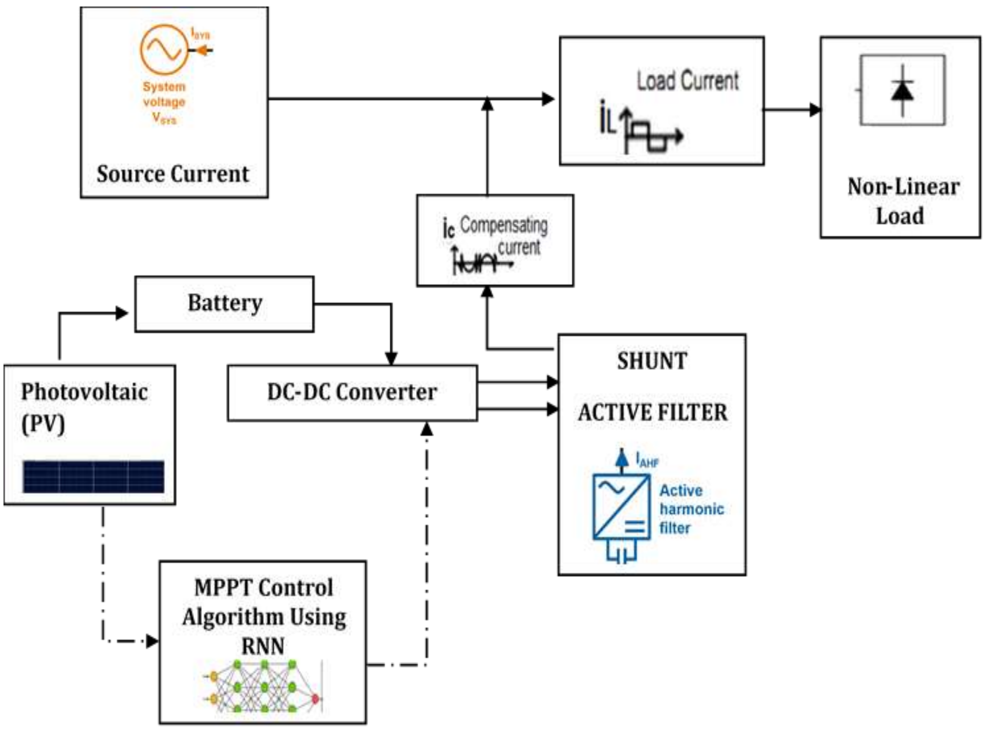

Figure 1. *Active Harmonic Filter transmission line proposed block diagram*

3.1 Photovoltaic (PV)

PV systems use silicon-based solar panels to convert sunlight into energy. Figure 1 PV circuits provide voltage support at night with the full rated capacity of the converter and uses the remaining inverter capacity during the day in addition to the PV system's real power generation capability at whether condition.

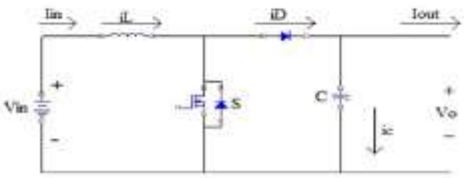

Figure 2. *Equivalent circuit of Photovoltaic Cell*

$$I= I\_pv- I\_d- \ I\_sh \quad .... \quad (3)$$

The PV system acts as a shunt device to provide voltage support and active power filter from the solar panel compensates for the harmonics produced by the fixed and balanced converter loads. In equation 3 irradiance and temperature cell dependent photo generated current I_pv are closely linked ang photo generated voltage I_sh and the open-circuit voltage V_(oc)equal the current in a short circuit I_(sc).

3.2 Shunt Active Filter

A converter generates a reference current signal based on the input data. The figure 3 represent the compensatory current needed to analyze unwanted harmonics and supply the required reactive power based on Figure 3, the Schematic Diagram. Reference current identifies that it uses a bidirectional DC source to monitor the electrical transmission load current continuously.

$$I\_c= I\_ref- \ I\_L \quad .... \quad (4)$$

In equation 4 I_c is optimal power ratio and I_ref sinusoidal will be achieved by adjusting the detected waveforms using a neural network algorithm that analyzes the data and provides the appropriate adjustment. The injection of Compensation Voltage is SAPF, which produces a compensating current, which is injected into the outline via a power converter, and electric current removes unwanted harmonics and reactive power mechanisms.

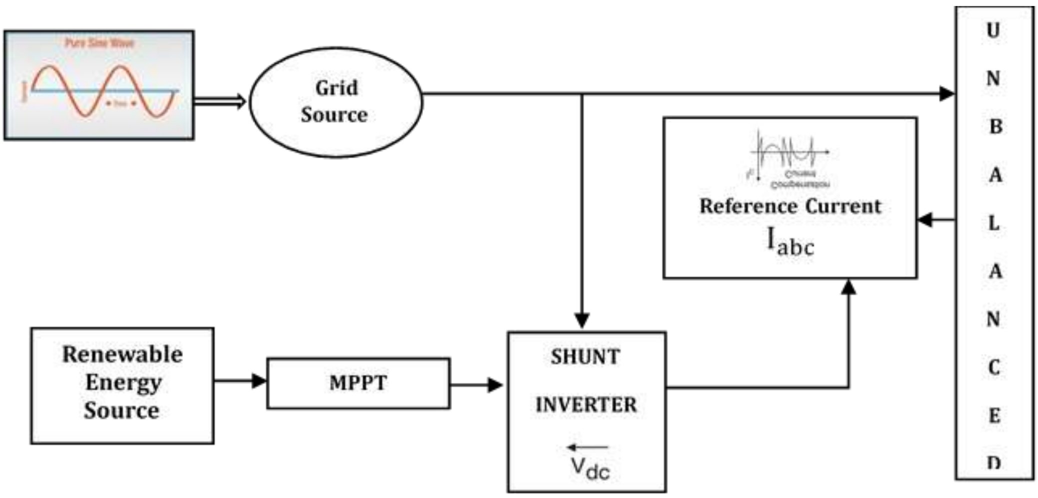

Figure 3*. Schematic Diagram of shunt active filter*

4. MPPT Control Technique Using RNN Procedure

The DC voltage controller and the MPPT controller make up the Maximum Power Point Tracking (MPPT) block. depending on the PV panels' VI feature while operating in the traditional PV mode. If slightly adjust the PV panel's operating voltage and the ensuing change in power, the MPP will continue to cause disturbances in that direction.,

$$p=1/(2\ ) \ (\upsilon\_\alpha \, i\_\alpha+ \ \upsilon\_b \, i\_b+ \ \upsilon\_c \, i\_c) \quad ... \quad (5)$$
$$q=1/(2\ ) \ (\upsilon\_\alpha \, i\_\alpha+ \ \upsilon\_b \, i\_b+ \ \upsilon\_c \, i\_c) \quad ... \quad (6)$$

According to Recurrent Neural Network (RNN) υ_α i_α is a signal can be transferred in both directions by using Active Power (p) and Reactive Power (q) feedback in their neural network connections. These networks are known for their ability to handle complex problems. To give the data analysis of memory effect, the consequences of previous computations are fed back. In networks with feedback, the dynamic states continuously alternate until a stable state is reached based on that figure 4 shows the flow chart of RNN using MPPT.

4.1. Algorithm steps of Recurrent Neural Network (RNN)

Step 1: Enter the output voltage (V) and output current (I) data in input source voltage
Step 2: Analyzing Input layer with regularize the data that has been gathered.
Step 3: Divide the data into sets for testing, validation, and training based on each RNN layer
Step 4: Estimate the power output and make system modifications (by altering the boost converter duty cycle, for example) to reach the maximum power specific.
Step 5: Integrate the RNN model with the MPPT controller to ensure that the architecture can handle real-time data management in output layer.
Step 6: output given to converter with proper duty Cyle ratio.

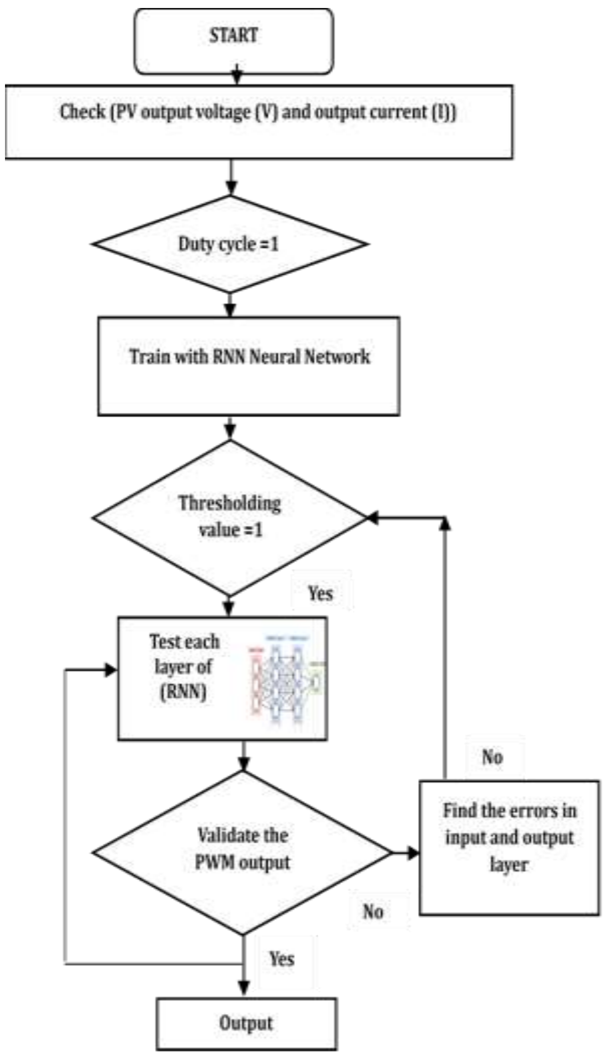

Figure 4. *Flow chart of proposed RNN for MPPT Algorithm.*

Continuous monitoring and updating is required for the maximum power point tracking, terminal voltage, and current if they diverge from the reference values. As previously indicated, the buck converter used in our design for MPPT matches the load for best power transfer and controls the input voltage at the PV MPP and Depending on the array factors, the dV_pv may be direct, indirect, on output voltage.

$$di\_pv/dV\_pv = 0 \text{ left MPP} \quad \ldots \quad (4)$$
$$di\_pv/dV\_pv = 0 \text{ Right MPP} \quad \ldots \quad (5)$$

Direct techniques that utilize PV voltage and current measurements boast a significant advantage. They are capable of self-regulating, thanks to their historical understanding of the PV array configuration and associated factor values. This ability ensures that the operating point remains unaffected by temperature fluctuations, light intensity variability, or stages of degradation, as represented by dV_pv.

5. Result and Discussion

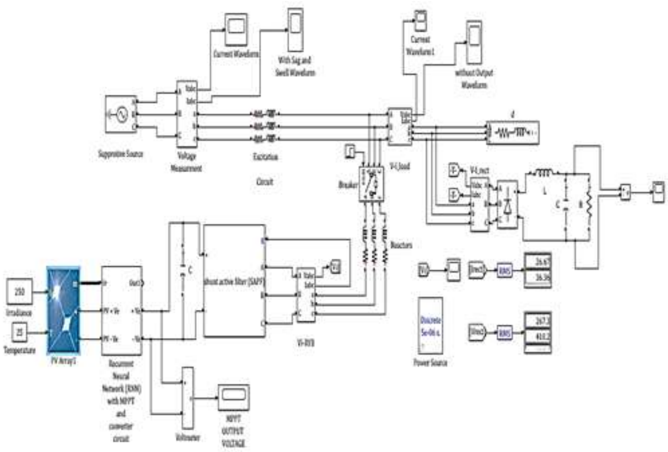

Figure 5. *Simulation output*

Figure 5 shows the simulation diagram of the proposed active harmonic filters in a transmission line. The diagram consists of a PV, an MPPT with RNN, and both linear and Non-linear loads and calculated outputs are displayed in the following below.

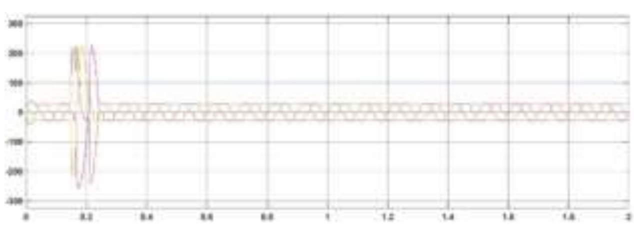

Figure 6. *Input source voltage with Sag and swell*

In Figure 6, the grid input source initiates a 40% voltage decrease from 0 points 2 to 0 points 4 seconds and a 70% voltage increase from 0 points 7 to 0 points 8 seconds.

Table 1. *Parameter Data of Bidirectional DC output*

Irradiance W/m2	Temperatures in °K	V_{mp} actual voltage
[600,202]	50	16.25
[400,202]	40	15.55
[114,188]	30	10.71
[330,178]	25	12.66

Table 1 displays the measurements of solar radiation power received per unit area, In equation 7 solar panel's V_actual actual voltage output can Tref fluctuate in response to variations in temperature and irradiance and In table 2 shows the parameter of DC -DC Converter voltage.

$$V\_actual = Voc - k \times (T - Tref) \quad \ldots \quad (7)$$

Figure 7 displays both the linear activation function of the output layer and the hidden layer. The network's hidden layer consists of thirty neurons that are trained on process data and Recurrent Neural Networks (RNNs) require several essential stages during training to enhance the model for tasks like sequence prediction

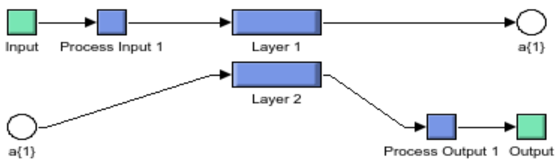

Figure 7. *Training of RNN neural Network*

Table 2. *Constraints of DC-DC Converter*

Parameters	Output range
Input Voltage V_{pv}	241–262 V
Input Voltage V_{dc}	700 V
Duty cycle	0-1
Switching Frequency f_{sc}	5Khz
Inductance L_{min}	$10^* L_{min} = 5$ mH

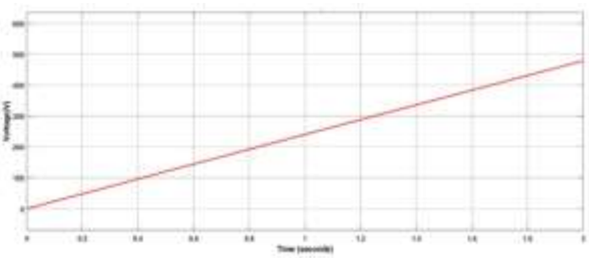

Figure 8. *DC Link output voltage*

Figure 8 illustrates that the Validation Set is linked to the output, which is connected to the input source with a lower voltage. The mathematical model for tracking improvement is continuously monitored and evaluated on a weekly basis using this set. As current flows from the input source through the inductance, the capacitor at the output charges in regulated based on output.

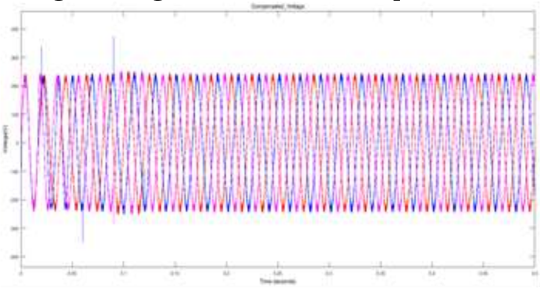

Figure 9. *Compensation voltage*

The voltage that is injected or absorbed by the grid from the STATCOM is known as the compensation voltage (V_com) shown in Figure 9. It is commonly visualized as a sinusoidal waveform superimposed on the grid voltage. Grid voltage, or V grid, is the voltage Point of Common Coupling (PCC) where the STATCOM is connected. The current that the STATCOM sends to the grid is recognized as the current output (I_out); this current can also indicate whether the STATCOM is supplying or absorbing reactive power.

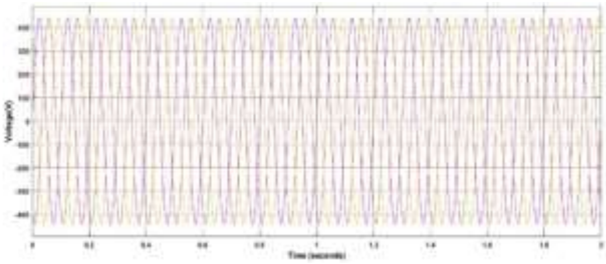

Figure 10. *Output load voltage without voltage with Sag and swell*

Figure 10 displays simulation results of a 230V load or offset voltage, proposed series filter with the PWM configuration to compensate for the bulging and slack response in the supply voltage. Energy from the sun provides the input voltage for the PWM inverter.

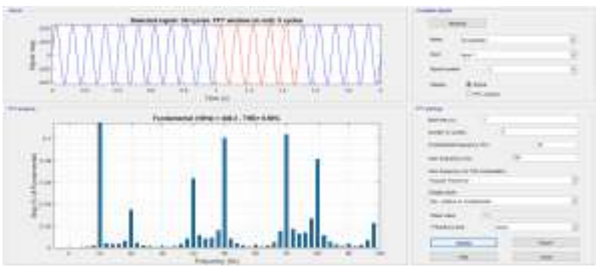

Figure 11. *THD output*

The proposed solar-based shunt active filter with total harmonic distortion in load voltage is shown in Figure 11 as the result of the simulation. The modeling result shows that the proposed system's THD is, in fact, below the IEEE specification's limit; at a frequency of 50 Hz, the load source voltage's THD value is 0.61 percent.

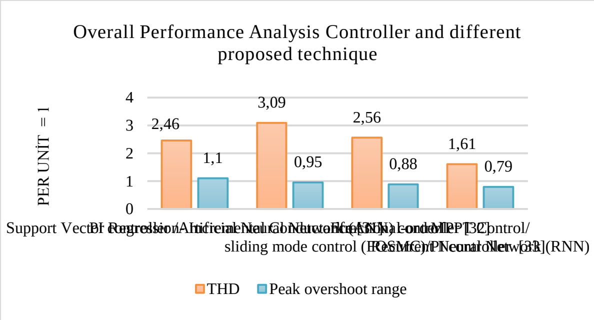

Figure 12. *Comparison analysis of THD and peak over shoot.*

In Figure 12, the performance analysis of THD (Total Harmonics Distortion) existing Support Vector Regression Incremental Conductance [31] 2.46 %, PI controller with apply Artificial Neural Network (ANN) controller [32] 3.09 %, Fractional order sliding mode control (FOSMC) with PI controller [33] 2.56 % and proposed MPPT control with Recurrent Neural Network (RNN) is 1.61 % that show the power quality improvement.

6. Conclusion

In conclusion, Active harmonic filters play a role in power quality improvement, harmonic distortion management in transmission lines, and the effective operation of electrical systems. The transmission network is bidirectionally connected to photovoltaic generating systems with MPPT Control, and the RNN neural network calculates the compensation voltage. The output maintains and controls the voltage in the grid-connected output system. The source output voltage generates the better gain in a three-phase output system with a proper duty cycle. With all of the current (I) and voltage (V) datasets, the Recurrent Neural Network (RNN) was tested and simulated. The output THD of 1.61 % and peak overshoot of 0.91 % isenhanced power quality for both linear and non-linear loads.

6.1. Future scope

In future integration of more renewable energy sources will require AHFs (Active harmonics filter) to help control the harmonics generated by inverters in solar and wind systems. Real-time monitoring and adaptive control for dynamic harmonic correction will be complete possible by the growing integration of advanced monitoring and control algorithm into smart grid technologies. The stability of the system is investigated using non-linear loads and an alternative controller technique. developed a design procedure for the voltage and current controllers to provide the highest level of harmonic mitigation capability. The optimal performance of Shunt multilevel inverter as a harmonics filter can be achieved by employing the Selective Harmonics Extraction method.

In conclusion, Active harmonic filters play a role in power quality improvement, harmonic distortion management in transmission lines, and the effective operation of electrical systems. The transmission network is bidirectionally connected

Author Statements:

- **Ethical approval:** The conducted research is not related to either human or animal use.
- **Conflict of interest:** The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper
- **Acknowledgement:** The authors declare that they have nobody or no-company to acknowledge.
- **Author contributions:** The authors declare that they have equal right on this paper.
- **Funding information:** The authors declare that there is no funding to be acknowledged.
- **Data availability statement:** The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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