Power Quality Issues Compensation using ANN Techniques

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Abstract. This idea is to propose an active filter which adapts to power quality issues and to solve this through Artificial intelligence techniques. This proposed active filter is combined to shunt active filter (SAF) which is controlled by neuro fuzzy interference system (ANFIS). This proposed adaptive filter performance is enhanced by ANFIS tool. This ANFIS is a class of adaptive system these functions are equivalent to fuzzy based systems. The purpose of ANFIS is to control the discharging time of dc-link capacitor in SAF there by reduces the power quality issues. The dc-link voltage values are get affected by the load fluctuation and these fluctuations can be suppressed by measuring and regulating the reference voltage. The purpose of ANFIS base adaptive shunt active filter is to achieve enhanced power quality there by reducing dc link voltage and current fluctuations very quickly. The proposed technique implemented and results are obtained using MATLAB its performance is evaluated through reference value.

Keywords: Power Quality (PQ issue), Shunt Active Filter (SAF), Artificial Neuro Inference System ANFIS, Direct Current (DC), link capacitor

Introduction
Power Quality is a major issue due to the increase of high frequency power electronic devices [6]. These day’s power quality is definitely a big issue due to inclusion of advanced power devices, whose functioning is non linearity and also it leads to affect in power supply, which makes us to look this issue seriously [17] [13]. Due to the increasing in non-linearity of supply it affects the waveform of input of fundamental supplying to non-sinusoidal waveforms, power quality (PQ) has major role in these day to solve those problems. [9]. Tremendous non-direct loads and generators on the matrix, which helped by power hardware like variable speed drives, power supplies for IT-gear and high effectiveness lighting and inverter frameworks, causes us to deliver power from sustainable power sources which made electrical energy frameworks, voltages and evaluated flows appraisals to incredibly sporadic [8] [7] [11]. Corruption or debilitation can happen in the electrical hardware's associated with those frameworks because of low quality of intensity [12].

1. ANFIS based proposed Shunt Active Filter
ANFIS is a cross breed delicate figuring structure of both the Artificial Neural Network (ANN) and Fuzzy Interference System (FIS) [9]. For the most part ANN is a learning calculation that models human cerebrum and comprises of various counterfeit neurons. Every neuron present in the ANN has various sources of info. The neurons are initiated dependent on the info and the relating yield, which is called as preparing models. The FIS is rules based calculation, which defines the standards as indicated by the issue. To classify data in gatherings and discover the examples, ANFIS has the neural organization's ability and
further extend a straightforward fluffy master framework. Furthermore, ANFIS has the ability to part and adjust these gatherings to put together a best participation work that can gather and work out the required yield inside a base number of periods.

![Diagram](image)

**Figure 1: Structure of Proposed SAF based on ANFIS**

Fig. 1 shows the structure of the proposed ANFIS based SAF. In the proposed system, this part depicts the tweaking cycle of the proposed procedure, which is utilized to upgrade the yield of the ANFIS. The boundaries utilized in the ANFIS are not equivalent however same. So it requires a tuning cycle to improve the precision of the proposed strategy. In the tuning cycle n-level inverter THD esteem and the yield voltage is thought of. Contingent upon the assessment cycle the blunder between the objective qualities and the first qualities are resolved. From the mistake esteem, the yield exchanging point is chosen. The means for calibrating cycle can be depicted in the accompanying.

\[ V_{inj,a} = \sqrt{2} V_{inj} \sin (\omega t + \beta) \]  
\[ V_{inj,b} = \sqrt{2} V_{inj} \sin \left( \omega t + \frac{2\pi}{3} + \beta \right) \]  
\[ V_{inj,c} = \sqrt{2} V_{inj} \sin \left( \omega t - \frac{2\pi}{3} + \beta \right) \]

Where, \( V_{inj,a} \), \( V_{inj,b} \), and \( V_{inj,c} \) Three cycles like information base age, ANFIS preparing and adjusting are presented in the half and half strategy. Here, the information based age method is utilized to produce the arbitrary number of exchanging points at various time spans and the comparable yield voltages. At that point the ANFIS is prepared dependent on the objective exchanging points and the comparing input esteem of the THD range the proposed regulator ideally predicts the ideal changing points to work the n-level inverter switches. By utilizing the calibrating cycle, the ANFIS yield exchanging points are tuned, which is utilized to improve the presentation of the proposed technique. It can diminish the consonant substance present in the inverter yield. The instantaneous voltage of AC source is expressed as.

\[ V_a(t) = V_m \sin \sin (\omega t) \]  
\[ V_b(t) = V_m \sin \sin \left( \omega t - \frac{2\pi}{3} \right) \]  
\[ V_c(t) = V_m \sin \sin \left( \omega t - \frac{4\pi}{3} \right) \]
The voltage equation for the shunt active power filter is given as follow,

\[ V_s = V_f + L \frac{di}{dt} \]  

(8)

The reference filter current is given by follow,

\[ i_c = i_s^* + i_l \]  

(9)

Where \( i_l \) is the measured load current and \( i_s^* \) is the reference source current is obtained in each phase by the following equation,

\[ i_a^*(t) = I_m \sin \sin (\omega t) \]  

(10)

\[ i_b^*(t) = I_m \sin \sin (\omega t - 120^\circ) \]  

(11)

\[ i_c^*(t) = I_m \sin \sin (\omega t + 120^\circ) \]  

(12)

The shunt dynamic force channel with load current discovery just not requires estimating remuneration current and source current. The remuneration current is produced dependent on guideline of capacitor voltage by utilizing ANFIS regulator. The time needed to release the capacitor to a specific voltage is given by follow,

\[ t_{dc} = -\tau \times \ln \left( \frac{V_{\text{target}} - V_D}{V_c(0) - V_D} \right) \]  

(13)

Where, \( \tau \) is the time constant,

\( V_D \) is the discharge voltage,

\( V_c(0) \) is the charge voltage,

\( V_{\text{target}} \) is the achieved voltage,

Accordingly, least imbuement of dynamic power is cultivated by coordinating the dc-interface voltage of the system. The rule voltage of the DC-interface capacitor depends upon the shunt dynamic channel. Here, ANFIS based FIS is used for dealing with the DC-associate voltage.

[1] Adaptive neuro fuzzy controller (ANFIS) for regulating DC link capacitor voltage

The principle point of this exploration is to create proficient drive with minimized inverter geography and to decrease the symphonious substance present in the staggered inverters utilizing another crossover regulator strategy with adaptiveness. The portrays the proposed H-Bridge inverter utilizing single DC source rather than numerous sources, which lessen more space. Lately streamlining calculation utilizing neuro fluffy has become the appealing arrangement as a result of its minimization, cost viability, unwavering quality and simple advancement even at low end DSP regulators. Also, the consolidated technique for fluffy rationale and neural organization to wipe out the symphonious substance is produced in the inverter on account of non-direct loads. The absolute symphonious bending and consonant substance present in the terminal voltage will be specifically disposed of utilizing ideal exchanging points. To decide the ideal exchanging points, fluffy rationale and neural organization will be used. To achieve this, fluffy standards will at first create irregular terminating esteem dependent on the consonant substance that should be disposed of and ideal exchanging points.

[1] Training stage:
The ANFIS editorial manager structure is shown in the above figure 5. The FIS editorial manager: ANFIS structure comprises of two information sources participation capacities, i.e., 7-level inverter likewise it is conceivable to create for proposed 5-level inverter yield voltages, THD and exchanging point is the yield.

[2] Testing stage:
The yield layer speaks to the THEN piece of the fluffy guideline. The complete of the information signs can be determined, which is marked as . The all out yield of the layer is given in the accompanying condition.

[3] ANFIS Attribute:
The stator twisting of three-stage acceptance engine and three-stage brushless DC engine are for all intents and purposes indistinguishable. The basic contrast between the two machines is with rotor. At the point when three-stage acceptance engine is energized with three-stage power supply, force is delivered at beginning, which makes the engine turns over under burden. On account of ideal brushless DC engine, transition created by the lasting magnet (Flux thickness B) can be changed. At the point when the most extreme force is required particularly at low speeds the attractive field strength is changed in accordance with greatest force. Yet, essentially it is absurd to expect to change motion thickness.

[4] ANFIS Formation:
For the most part ANN is a learning calculation that models human cerebrum and comprises of various fake neurons. Every neuron present in the ANN has various information sources. The neurons are initiated dependent on the information and the relating yield, which is called as preparing models. The FIS is rules based calculation, which figures the standards as indicated by the issue. To arrange data in gatherings and discover the examples, ANFIS has the neural organization’s ability and further extend a straightforward fluffy master framework. What’s more, ANFIS has the ability to part and adapt these gatherings to arrange a best participation work that can gather and work out the required yield inside a base number of periods.

Figure 2: Two input Sugeno fuzzy model.

Here, the hubs are spoken to as both versatile and fixed hubs, i.e., the square hubs are versatile hubs and the circle hubs are fixed hubs. The preparation cycle of the ANFIS is performed by setting the yield target, which is exchanging plots for the information sources like voltage and THD. Here, the fluffy impedance rules are produced by the sources of info and yield. During the testing time ANFIS give the ideal changing heartbeats to lessen the sounds of the n-level inverter yield voltage. The contributions of the ANFIS are voltage
In Fig 3, the rotor position was followed by estimating the pace of progress of engine stator flows when low-voltage test vectors are applied utilizing the H-Bridges. Along these lines, the engine current mutilation presented by the sensor less control conspire was diminished contrasted with that utilizing a two-level converter. The proposed approach could consequently be applied to high-control engine drives, and car drive frameworks. The investigation introduced a hypothetical determination of the calculation and test results which show that the engine current quality accomplished utilizing the new method is better contrasted with sensor less strategies actualized on a two-level inverter.

\[
O^n_{layer 1} = \mu_{A_i}(e_v)
\]

\[
O^n_{layer 1} = \mu_{B_i}(\Delta e_v)
\]

Where, \(e_v\) is the input to node \(i\) and \(A_i\) is the etymological mark identified with that hub work. The participation function \(O^n_{layer 1}\) demonstrates the degree to which the predefined \(e_v\) fulfills the quantifier . For the most part, a chime formed \(\mu_{A_i}(e_v)\) that has a limit of 1 and at least 0 is viewed as which is demonstrated as follows.

\[
\mu_{A_i}(e_v) = \frac{1}{1 + \left(\frac{e_v - c_i}{a_i}\right)^{2b_i}} = \exp\left\{\left(\frac{e_v - c_i}{a_i}\right)^{2b_i}\right\}
\]

Where, the boundary set \(\{a_i, b_i, c_i\}\) which adjusts the participation capacities on phonetic mark \(A_i\) is known as reason boundary. Additionally, the estimation of \(\mu_{B_i}(\Delta e_v)\) is chosen.

Layer 2: By increasing the info signals and conveying the item by every hub of the layer, the terminating strength of the standard is determined.

\[
O^n_{layer 2} = w_i = \mu_{A_i}(e_v) \mu_{B_i}(\Delta e_v), i = 1,2
\]

Layer 3: The \(i^{'th}\) center of this layer is used to choose the extent between the ending strength of the \(i^{'th}\) rule and the measure of ending characteristics, taking everything into account.

\[
O^n_{layer 3} = w_i = \frac{w_i}{w_1 + w_2}, \quad i = 1,2
\]

The yield of this layer is indicated regarding standardized terminating qualities.

[5] Results and Discussion
The proposed versatile SAF was actualized in MATLAB reenactment stage. At that point, the exhibition of proposed versatile channel was trying with nonlinear force gadgets load. A three stage R-L burden which is considered as a nonlinear burden is associated with the AC mains to exhibit the adequacy of the proposed versatile force channel. The simulink model of source with nonlinear burden, with SAF and proposed versatile channel are shown in Figure 5, Figure 6 and Figure 7 separately. The usage boundaries are classified.

**Table 1: Implementation parameter of ANFIS.**

| Parameters               | Values |
|--------------------------|--------|
| Node Numbers             | 75     |
| Linear parameters        | 75     |
| Non linear parameters    | 30     |
| Total parameters         | 105    |
| Training data pairs      | 194402 |
| Cheeking data pairs      | 0      |
| Fuzzy rule numbers       | 25     |

**Figure 4: Simulink model of nonlinear load without filter.**
From the simulink models, the voltage mutilation is applied in arbitrarily and distinctive time lengths. At that point, the presentation of voltage and current are dissected. The ostensible voltage and current execution is outlined in Fig 8 and 9. The exhibitions of voltage without channel, with SAF and with ANFIS-SAF at bending in 0.01 sec are given in Fig 10 to 12. Additionally, the genuine (P) and receptive (Q) intensity of a similar bending length is give from Figure 13 to 15. At that point, the voltage and current consonant exhibitions are delineated in Figure 16 and 17. The structure of ANFIS and sources of info participation work is given in Fig 18 and 19.
Figure 7: Performance of voltage.

Figure 8: Performance of current.

Figure 9: Performance of voltage distortion waveform without filter.
Figure 10: Performance of voltage with filter.

Figure 11: Performance of voltage with adaptive filter.
**Figure 12:** Performance of PQ power without filter.

**Figure 13:** Performance of PQ power with (SAF) filter.
Figure 14: Performance of PQ power with adaptive (ANFIS-SAF) filter.

Figure 15: Performance of Current Harmonics.

Figure 16: Performance of voltage harmonics.
Figure 17: Structure of ANFIS.

Figure 18: Membership functions of (a) error voltage and (b) change of error voltage.
From the voltage performances, the peak deviations of RMS voltage are calculated and the calculated values are tabulated in Table 2. Based on the peak voltage, the RMS voltage variations are analyzed.

**Table 2: Peak voltage deviation of different filter.**

| Duration of voltage distortion in sec | Peak voltage deviation in volts |
|---------------------------------------|-------------------------------|
|                                       | Without filter | With SAF | With ANFIS-SAF |
| 0.01 to 0.025                         | 75             | 85       | 98            |
| 0.02 to 0.035                         | 67             | 87.5     | 97.5          |
| 0.03 to 0.045                         | 78             | 85.8     | 96            |
| 0.04 to 0.055                         | 70             | 87       | 98            |
| 0.05 to 0.065                         | 73             | 86       | 96.5          |

From the voltage deviations, the roots mean square (RMS) voltage of without filter, with filter and proposed adaptive filter are evaluated. The evaluation of RMS voltage ($V_{RMS}$) is based on the voltage deviated from the reference peak voltage. Here, the reference peak voltage is selected as 100V. Then, the formula for calculating RMS voltage is expressed as following them,

$$V_{RMS} = \frac{V_p}{\sqrt{2}}$$

Where, $V_p$ is the peak voltage. Consequently, the peak voltage of 141.42V is equivalent to 100 RMS. At that point, the RMS voltage of various channel is contrasted with reference RMS voltage. The correlation graph of RMS voltage is portrayed as following them,

![Performance of RMS voltage](image)

From the examination graph Fig 19 the presentation of proposed versatile channel with ANFIS is uncovered. The RMS voltage of proposed versatile ANFIS based channel is shut to the base RMS voltage. Likewise, by the guideline of DC-interface voltage, the peak voltage deviation is decreased. The sounds of the nonlinear burden are decreased by the proposed versatile channel. Thus, the proposed DC-connect voltage guideline procedure is better for improving the presentation of SAF.

[2] **Conclusion**

A versatile channel was proposed for breaking down and remunerating the PQ issue of nonlinear burden. The proposed versatile channel was joined with SAF and ANFIS to assess the voltage and current sounds of the heap. The presentation of traditional SAF was improved by versatile keen organization. The mistake voltage and change of blunder voltage of the nonlinear burden was resolved from the ostensible voltage of
the framework. As indicated by the voltage varieties, the dc-connect capacitor voltage was controlled by utilizing ANFIS. At that point, in view of the managed voltage, the voltage was infused to the source to nonlinear burden line by infusion transformer. After the PQ issue redressing, the repaying execution of proposed versatile channel was contrasted and old style SAF. From the relative investigation, the proposed versatile regulator is decreased the voltage and current sounds of the framework. Thus, the PQ of the nonlinear burden is improved by proposed versatile regulator.

Acknowledgment
This research was supported by the department of electrical and electronics engineering that was provided bannari amman institute of technology, Sathyamangalam.

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