THREE PHASE CHBMLI BASED SHUNT ACTIVE FILTER FOR THD MITIGATION USING HYBRID CONTROL TECHNIQUES

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Abstract: *Nowadays, in power electronic devices the power quality associated problems are more preoccupied. Different methods of power devices are needed for compensating PQ disturbances. For increasing the PQ one of the power electronic devices used is active power filter (APF). The performance of Shunt APF must be improved by reducing the PQ disturbances. For increasing the behavior of SAPF and PQ compensation a hybrid controller is developed in this paper. The combination of GA and RBFNN method is utilized by deduce the source current for compensation of Shunt APF and decreasing PQ issues. By using SAPF the harmonic disturbances are decreased. The developed hybrid controller method is utilized to make constant DC voltage in the DC link capacitor of the developed MLI. Consequently, developed method uses Harmonic analysis for estimating the THD values. The developed technique is executed in matlab Simulink model. The behavior of developed technique is appraised and differentiated with PI and fuzzy logic controllers.*

Keywords: *Shunt APF, THD, Multilevel inverter, RBFNN, Fuzzy, PI controller, Genetic algorithm*

1 Introduction.

Owing to world wide usage of sensitive electronics equipment studies related to power quality have become significant. Arising competition between numerous power producers has deregulated power sector which has the necessity to develop electric supply quality. To improve the quality degradation must be scrutinized [6]. Issues related to power quality in hybrid system become a main problem during the past few years. Survey taken regarding quality of power specify the pre-occupation of issues regarding power quality and financial impact on consumer and utilities. Eventhough scrutinization of power quality is in progression no measure were taken to speculate the issues of power quality. Because of the sensitive loads non-linear behavior, current harmonics are generated, the network impedance along with current harmonic generate voltage distortion at consumer end. Hence hybrid power system output voltage harmonic content approximation is significant to increase the quality of power at consumer end. Combination of energy conversion devices are integrated to overcome the limitations of PQ problem. These power systems are commonly known as hybrid power systems. To supply a stable community level electricity services like remote electrification hybrid systems are used owing to its enhanced efficiency [5].

Power quality (PQ) has gained a lot of importance in recent years due to the rising need for clean power supply with the presence of non-sinusoidal waveforms. In the present scenario electric systems are mainly on the basis of microcontrollers with control units. Owing to the effects of disturbance, disturbances in PQ become more significant [9]. Capacitor bank application have become an important measure in the design of PQ system [2]. Voltage fluctuations produced by these capacitors bank reduces the quality of power system it causes various disturbances in the system which leads to malfunction of protective relays and the power electronic equipment which are sensitive to fluctuation voltage[8].

In order to reduce the harmonic issues many researches have been developed on active power filter (APF) [20]. To find reactive current and harmonic, shunt APF is developed and integrated in collateral with load and compensating current is injected into the system. Hence instantaneous current supply have fundamental current in which source voltage is in phase. Series active power filter is operated with shunt passive filter for the compensation of load current harmonic. Seven level cascaded inverter can be used as an active power filter for voltage sag compensation with non-linear load [14]. For correction of power factor, balancing of load mitigation with neutral current and voltage mitigation 3P-4W UPQC is investigated. Unit Vector Template (UVT) is the simple strategy for controlling UPQC for reduction of PQ issues [18]. A configuration of shunt active filter is developed, which utilizes tapped reactors for sharing of harmonic current. And the configuration is able to produce low levels of voltage by using three level flying capacitor methodology [19]. A multilevel cascaded H-bridge technique is proposed in this method which function at lower frequency [21]. Integration of high and low frequency hybrid APF is developed for parallel operation. Hybrid active filter is the series combination of LC filter with VSI. These inverters neglect harmonics [22].

To increase the behavior of shunt APF filter, this filter increasing the PQ of nonlinear load a developed hybrid control methodology is used. The mixture of RBNN and an optimization method called genetic algorithm is the proposed control strategy. The developed method is executed in the MATLAB simulation and harmonic eradication behavior is calculated.

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2. The Proposed Hybrid Controller based Shunt Active Filter

The three phase source voltage is fed to the nonlinear load. This nonlinear load produce voltage stability problems and increase the source current THD, also this load increases the reactive power. The uncompensated reactive power damages the electrical equipment. For reactive power compensation, shunt active power filter is proposed. In Shunt APG generally voltage fed three phase inverters are used, This type of inverter produces slightly high voltage harmonics in the PCC. This problem is rectified in this paper with three phase symmetrical five level inverter. Two normal inverters are serially connected for the arrangement of five level inverter. The three phase cascaded five level inverter includes totally six single phase inverters, in order to control the harmonics in the current need to generate reference current from the source current. This current is generated in this paper by using hybrid algorithms it includes RBFNN and genetic algorithm. The electrical strategy of hybrid Shunt APF for a 3Ø power system can remunerate the current harmonics is represented in this section. The harmonic and reactive current is detected by hybrid SAPF and the exceeded current is given into a system of the active filter, with nonlinear load SAPF is connected in parallel. The 3Ø source voltages are Vsabc and currents are Isabc The 3Ø load currents are Ilabc and inductances are L_1, L_2, L_3. To calculate the reference currents proposed hybrid controller needs inverter to provide compensation currents. The shunt active filter fundamental principle is making the input current is merely a sine wave by producing the same and unlike current in sign to the load strained by harmonic current and connecting to main coupling node. The strange characteristic of the SAPF is it does not need any energy storage units because no active power is consumed from the resource. In order to accomplish this function it uses an effective compensation policy. Here, the proposed controller needs the instantaneous active and reactive current. Produced reference current signals are injected as input with support of reference current generator to hysteresis controller. The Shunt APF gate signals are generated. The evaluation is elaborated and discussed as follows. Representation of instantaneous phase current and load current are shown below,

$$I_s(t) = I_L(t) - I_c(t) \quad (1)$$

$$I_L(t) = \sum_{n=1}^{\infty} I_n \sin(n\omega t + \Phi_n) \quad (2)$$

The shunt active filter compensation current is represented as,

$$I_c(t) = I_L(t) - I_s(t) \quad (3)$$

Here, Fundamental component load current is calculated by APF and harmonic current and reactive power is compensated.

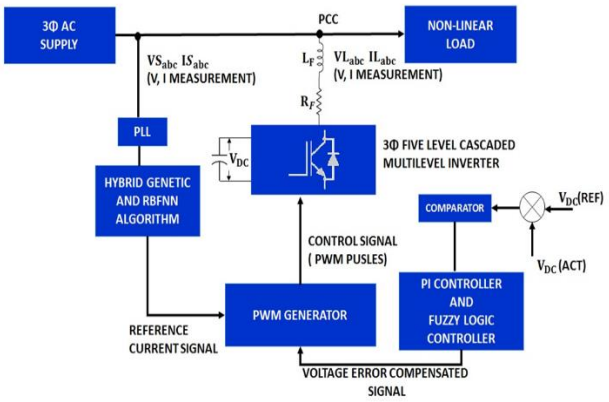


Fig.1: Proposed CHBMLI based Shunt APF block diagram

3. Reference current generation using Hybrid Control technique

At this part, by applying proposed controller extract the reference currents with the I_d-Iq approach. At this point, through the nonlinear loads' I_d-I_q current component the reference currents are produced. At the beginning, the nonlinear loads' reactive current and instantaneous active are obtained from the active filter currents. Expression of alpha, beta components to direct and quadrature components transformation is shown below:

$$\begin{bmatrix} i_0 \\ i_d \\ i_q \end{bmatrix} = \frac{1}{v_{\alpha\beta}} \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\theta & \sin\theta \\ 0 & \sin\theta & \cos\theta \end{bmatrix} \begin{bmatrix} i_0 \\ i_\alpha \\ i_\beta \end{bmatrix} \quad (4)$$

Then, d q components are converted into modify positive sequences fundamental current harmonic of dc quantities. The higher harmonic current and the average current components are considered. The harmonics are altered into non dc quantity that undergoes oscillatory spectra constituting frequency shift with the first harmonic current with negative sequence.

$$\begin{bmatrix} i_d \\ i_q \\ i_0 \end{bmatrix} = \frac{1}{V_{\alpha\beta}} \begin{pmatrix} V_\alpha & V_\beta & 0 \\ -V_\beta & V_\alpha & 0 \\ 0 & 0 & V_{\alpha\beta} \end{pmatrix} \begin{pmatrix} i_{l\alpha} \\ i_{l\beta} \\ i_{l0} \end{pmatrix} \quad (5)$$

The current components' dc and ac component expression is given below,

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$$i_d = \bar{i}_d + \tilde{i}_d$$
$$i_q = \bar{i}_q + \tilde{i}_q \qquad (6)$$

To decrease the neutral current, calculate $P_{l\alpha\beta}$ by ac and dc components of real and reactive power.

$$\frac{P_{l\alpha\beta}}{V_{\alpha\beta}} = \left(\frac{P_{l\alpha\beta}}{\sqrt{V_\alpha^2 + V_\beta^2}} \right) \qquad (7)$$

The average value of dc components is described in the above equation. Afterwards compensated the currents and the reference currents are given below,

$$\begin{bmatrix} i_{s\alpha}^{ref} \\ i_{s\beta}^{ref} \\ i_{s0}^{ref} \end{bmatrix} = \left(\frac{P_{L\alpha\beta}}{v_{\alpha\beta}} \right)_{dc} \frac{1}{v_{\alpha\beta}} \begin{bmatrix} v_\alpha \\ v_\beta \\ 0 \end{bmatrix} \qquad (8)$$

$$\begin{bmatrix} i_{s\alpha}^{ref} \\ i_{s\beta}^{ref} \\ i_{s0}^{ref} \end{bmatrix} = \left(\frac{P_{L\alpha\beta}}{\sqrt{v_\alpha^2 + v_\beta^2}} \right)_{dc} \frac{1}{\sqrt{v_\alpha^2 + v_\beta^2}} \begin{bmatrix} v_\alpha \\ v_\beta \\ 0 \end{bmatrix} \qquad (9)$$

Compensating the reference currents and managing the DC-link voltage by using the 3Ø SAPF. The brief explanation of the developed hybrid control strategy is given in the coming segment.

4.Enhance the DC link voltage by using proposed algorithm

A search heuristic **genetic algorithm** is stimulated by the theory of natural evolution by Charles Darwin. Natural selection process reflects this algorithm where picked out the fittest individuals for reproduction to produce the next generations' offspring. GAs fundamental techniques are developed to process simulation in natural systems needful for evolution. Particularly these follow the "survival of the fittest." principle. After all in nature, a result of canty resources for the competition with individuals for is the weakly ones dominated by the fittest individuals.

Based on natural selection

Three operators emerge through the algorithm ones the generation of initial population is completed

- **Selection**
- **Crossover**
- **Mutation**

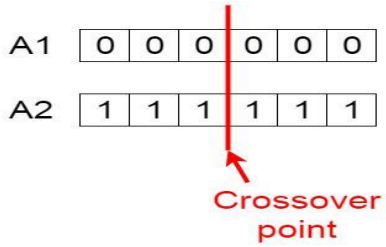
Selection

The aim of **this** selection operator is to let individuals to pass their genes to the next coming generations by choosing the fittest individuals. Based on fitness scores two pairs of individuals (**parents**) are selected. Individuals who have high fitness have high chances to be chosen for the reproduction.

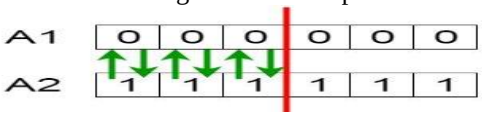
Crossover

In a genetic algorithm, this is the most important phase. For each pair of parents to be mated, randomly select a crossover point from within the genes.

For example, consider the crossover point to be 3 as shown below.



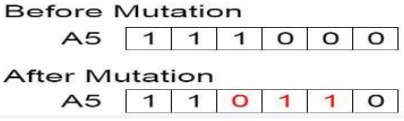
By using offspring exchange the genes of parents among themselves till reaching the crossover point.



To the population, the new current offspring is added.

Mutation

With a less random probability a few of the genes are subjected to a **mutation** in certain new offspring formed. This implies that from the bit string it flip some of the bits.



To manage diversity, mutation occurs in the population also it prevents premature convergence.

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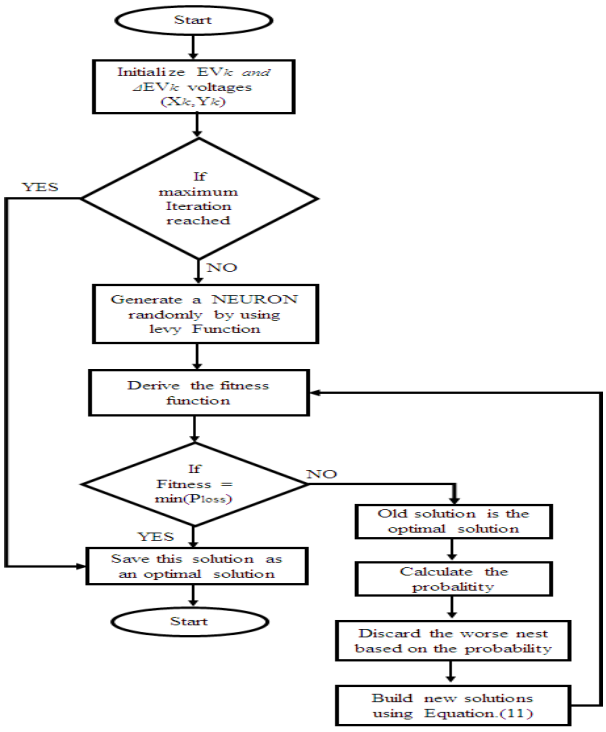


Fig.2: Flow chart for proposed hybrid algorithm

5.Extraction of Reference current using RBFNN

For evaluating the output training NN artificial intelligence technique is used and there is no need of any numerical model. It comprises of triple layers, namely input layer, output layer, and hidden layers. The developed RBFNN outline is represented in the Fig.4. To eliminate the reference current RBFNN is utilized to remunerate the shunt APF in the juncture. The optimized sources were connected to RBFNN input, is demonstrated as X_i . Consequently, by using back propagation training method neurons are trained. The source of error voltage (EV), change in error voltage (ΔEV).

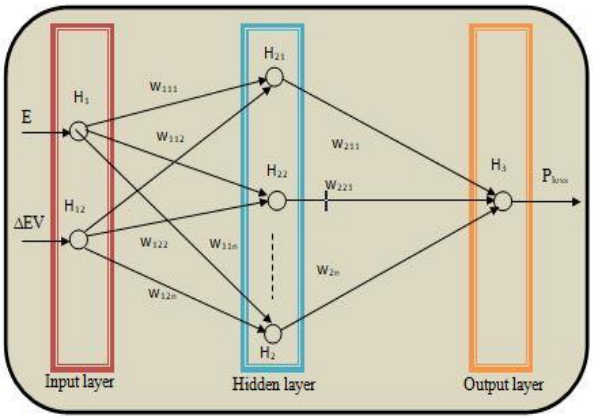


Fig.3: Proposed RBFNN layers representation

Steps for RBFNN based hybrid algorithm

Step 1: Initialization of inputs

Initialization of input layer, output layer and hidden layer of the neural network weights are made. Here $X_i = (x_1, x_2, \ldots\ldots x_n)$ is the represented input. In the particular interval hidden layers neuron weights, output layers are initialized $[w_{\min}, w_{\max}]$. Weighted hidden layer of input layer are described as $(w_{111}, w_{112}, \ldots.. w_{11n})$. Consequently, regarding input and corresponding target the network learning is done.

Step 2: Determination of Back propagation error

This equation determines the target of back propagation error (output) $Y_p = P_{loss}$

$$BP_{Error}^{p} = (Y_p^N)_T - (Y_p^N)_{out} \qquad (10)$$

Where, pth node network target is $\left(Y_p^N\right)_T$ and $(Y_p^N)_{out}$, is the pth node current output network. If output value of the network is ±10% of the needed output and optimal results are produced. The following equation determines networks' current output.

$$(Y_p^N)_{out} = f(Y_p) + \sum_{n=1}^{N} W_{pr} Y_p^N(n) \qquad (11)$$

Where, $p = 1$ and in p^{th} node the bias function is $f(Y_1)$.

$$Y_p^N(n) = \frac{1}{1+\exp(-w_{11n}Y_p - w_{111}Y_p)} \qquad (12)$$

Output and hidden layers activation function is given in equation (18)

Step 3: Radial function

Equation of radial bias is shown below

$$f(Y_p) = \sum_{k=1}^{N} w_{pk} H_i(Y_p) \qquad (13)$$

Where, N is the neuron numbers, w_{pi} , i^{th} weight of neuron and $H_k(Y_p)$ is the i^{th} neuron response in hidden layer. Following equation determines the function of hidden layer.

$$H_i(Y_m) = \exp\left(\frac{-\|Y_m - C_p\|^2}{R_p}\right) \qquad (14)$$

In equation (19), p^{th} neuron centre value is C_p and, the scalar factor is R_p .

Step 4: Neuron weights updation

The following equation updates all the neurons, new weights of the network.

$$w_{new} = w_{previous} + \Delta w \qquad (15)$$

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Where, $\Delta w = \delta . Y_p . BP_{Error}^p$ is the weight change, with δ as rate of learning (0.2 to 0.5).

Step 6: The above steps are repeated till the BP_{Error}^p is reduced ($BP_{Error}^p < 0.1$).

After training procedure is finished, the system is prepared well to produce the objective output. The framework power loss is limited and on following the current signal, particular outcome node exhibits a most extreme output. In this way, PQ can be improved with developed hybrid controller SAPF utilization. The reference and actual Dc link voltages are compared and error voltage is disposed to PI and fuzzy logic controller, theses controller generates the reference signal for the proposed inverter pulse generation. The inverter transforms the DC voltage into five level AC voltage, this voltage is fed to the PCC through low pass filter.

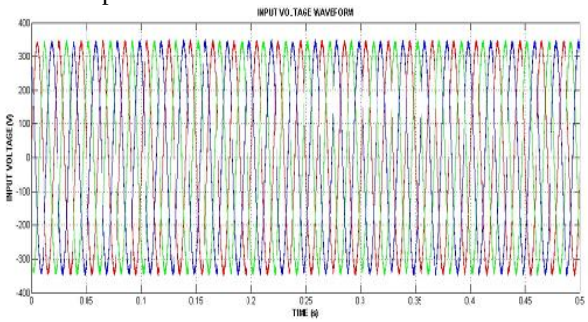
6.Result and Discussion

Representation of the developed hybrid controller using, the implementation values of parameters are exhibited in Table 1.

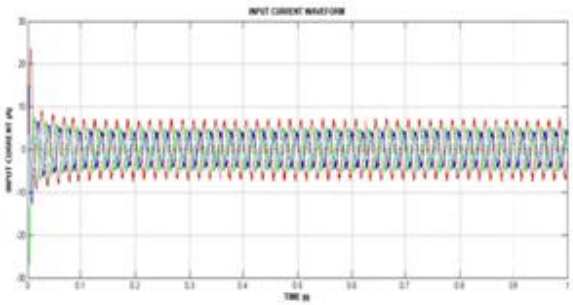
Table.1: Initial parameters for proposed development

S.No	Details	Range
1	No of hidden layers	20
2	$W = (w_{min}, w_{max})$	(0,1)
3	Number of nests for RBFNN	250
4	Number of Iteration	2500
5	DC link voltage	1000V

The figure 4 shows the three phase source voltage and current waveform, Harmonic distortion is present in the measured value and the converters engross the active & reactive powers.

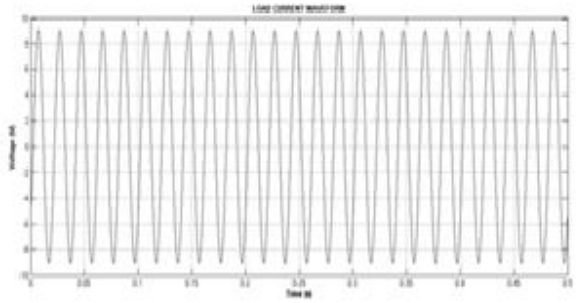


(a)

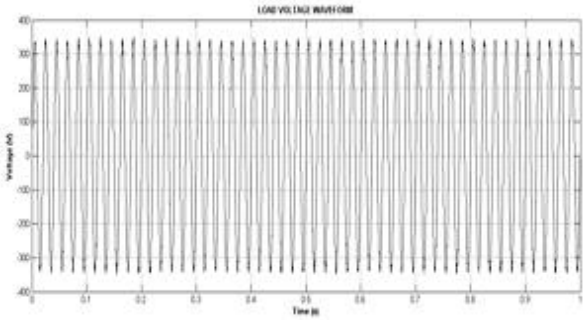


(b)

Fig 4: Waveforms of (a) 3 phase voltage source and (b) source current



(a)



(b)

Fig.5: Load current and voltage waveform using Proposed Shunt APF

The figure 6 shows the DC link voltage in the capacitor using PI and fuzzy logic controller. Compared to PI controller, fuzzy logic controller reduces the ripples and maintain constant voltage to the three phase multilevel inverter.

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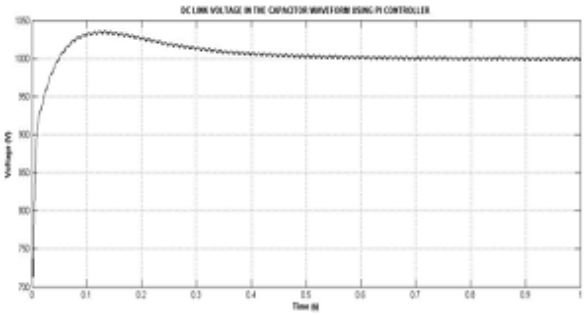


Fig.6(a**)**: Capacitor DC link voltage using PI compensation

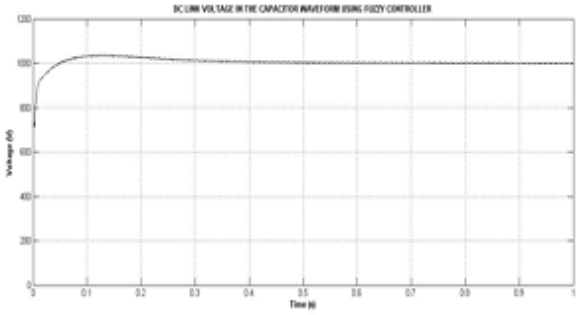


Fig.6(b): Capacitor DC link voltage using fuzzy compensation

Under all disturbances sustain the Shunt APF dc link voltage to reference value. The three phase multilevel inverter transforms the DC voltage into three phase five level output voltage, the gate pulses to the multilevel inverters are produced with the reference current waveform and DC link controllers. The figure 7 shows the injected five level output voltage in the PCC.

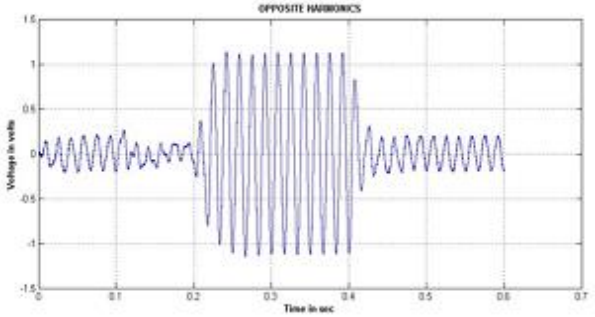
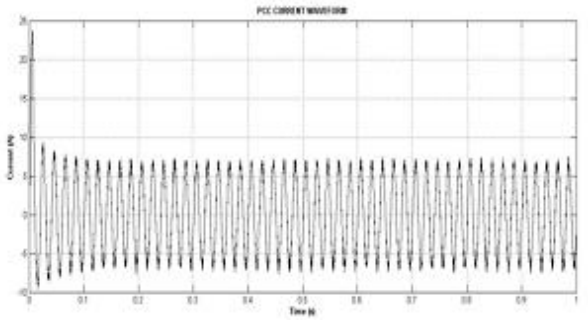


Fig.7**:**Voltage injected in the PCC with three phase five level inverter

The figure 8 shows the PCC voltage and current waveform. The proposed inverter maintains constant voltage to the load through multilevel inverter.

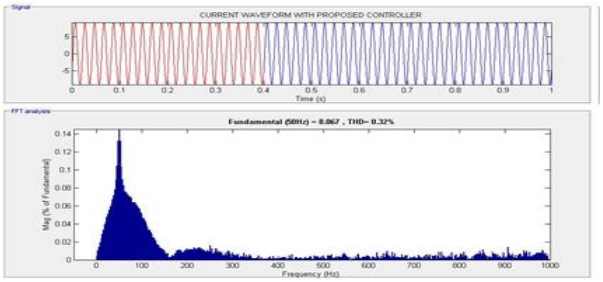


(a)

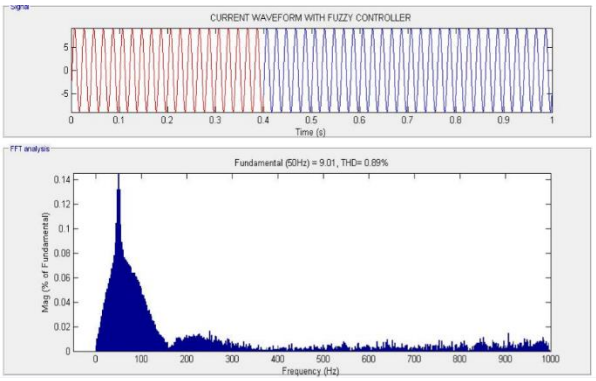


(b)

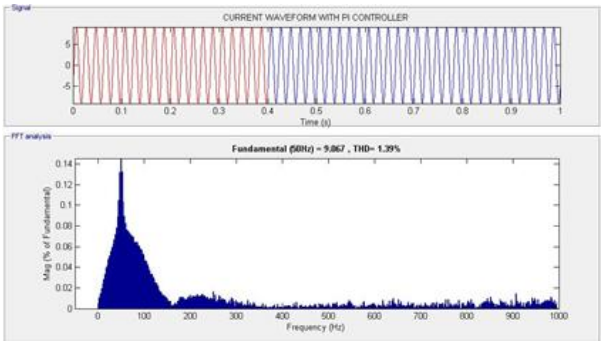
Fig.8: Current and voltage waveform in the PCC



(a)



(b)



(c)

Fig.9: THD values for proposed controller, PI and Fuzzy logic controller

Table.2:THD comparison table

CONTROLLERS	Phases	WITHOUT SAF	PI CONTROLLER	FUZZY CONTROLLER	PROPOSED TECHNIQUE
THD	A	27.6	1.38	0.89	0.32
	B	27.8	1.39	0.91	0.38
	C	27.65	1.37	0.895	0.36

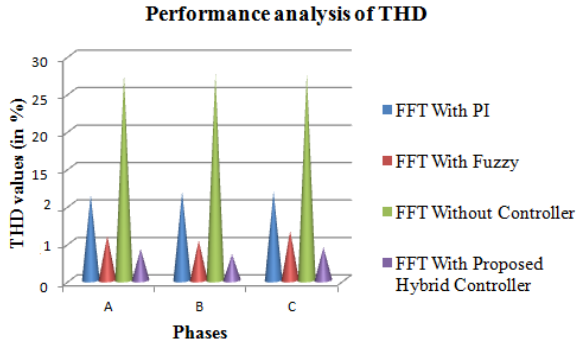


Fig.10: THD analysis with different control technique

The different control method current waveforms THDs are calculated using FFT analysis. In analysis of FFT, THD values of developed hybrid controller, PI controller and Fuzzy controller are 0.32%, 0.89% and 1.38% respectively. PQ problem is minimized tremendously by the developed method and its performance is analyzed.

Conclusion

In this paper hybrid controller based shunt APF has been investigated and its results are verified using matlab simulation. The proposed shunt APF with five level inverter reduce the source current THD with in the power quality limit. The hybrid current generation techniques RBFNN and genetic algorithm are very helpful to maintain the source current as pure sinusoidal wave. The capacitor link voltage is kept nearly stable by employing different controllers. The THD has reduced to 0.32 percentage using the proposed hybrid control techniques, these factors reduce the power quality issues.

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