

Performance Analysis Based On Hybrid Active Power Filter for Three Phase Four Wire System

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Abstract: This paper explains the dynamic behaviour based on under varying source/load conditions Hybrid Active Power Filter (HAPF) accomplished for harmonic compensation. ACO based controller is use from non-sinusoidal currents of the considered supply system to extract fundamental component of current. Ant colony optimization (ACO) is a novel searching technique used in optimization problems. This describes ACO approach for optimization of coefficients of digital filters. The order of a low pass filter and the parameters of its coefficients have been optimized in a discrete search space. AC analysis of the optimized filter has been conducted. Hybrid filter utilizing the merits of both shunt passive filter and shunt active filter for better compensation performance is applied in this work. Simulation and analysis of three phase four wire hybrid active power filter under distorted source conditions have been incorporated using MATLAB/ SIMULINK..

Keyword: Hybrid active power filter, THD, PI controller.

I. Introduction

The increasing use of power electronics based non linear loads continuously deteriorated quality of power. Many international standards define power quality as to maintain purely sinusoidal current waveform and many phase voltage waveform. Therefore, a power quality problem occurs if any of the voltage, current or frequency deviation from sinusoidal nature. Power quality problems are common in industrial, commercial and utility networks as power electronics appliances are more used in these fields. These appliances generate harmonics and reactive power. Therefore it is very important to compensate the dominant harmonics and thus Total Harmonic Distortion (THD) below 5% as specified in IEEE 519 harmonic standard [1]. The passive filtering is the simplest solution to eliminate the harmonic distortion and power factor improvement in the power system utilities. The passive filter suffer from many disadvantages such as tuning problems due to tolerance, resonance, fixed compensation characteristics for fixed value of L & C and their bulky size. To overcome this problem Active Power Filter (APF) is brought in effect. Active power filter is a dynamic and flexible solution for the mitigation of harmonic current due to their compact size, no requirement of tuning and stable operation. Active power filter acts as harmonic current source to provide emphatic result to compensate for harmonic currents as well as reactive power. It has the capability to inject harmonic current into the ac system with the same amplitude but in opposite phase of the load [2]. As the HAPF is complex with cost effective parameter control, the hybrid active power filter has been preferable in the subject of harmonic solution.

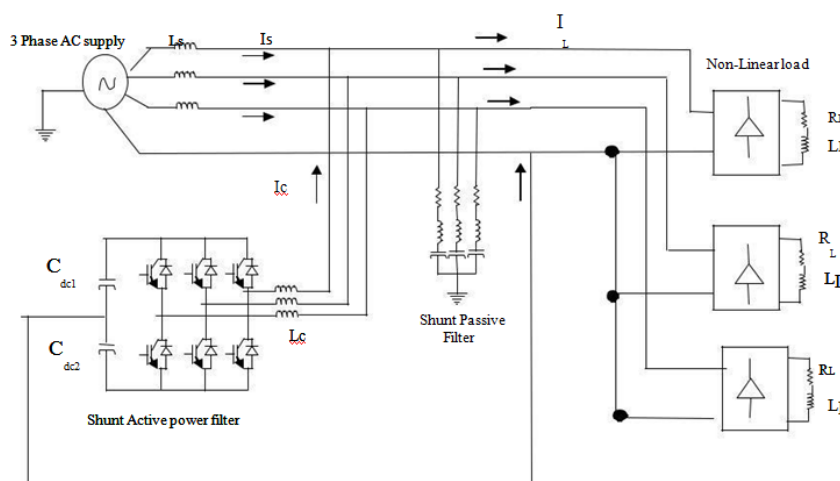


Figure1. Hybrid Filter Configuration

Accuracy of this hybrid active power filter is fundamental from non-ideal voltage source. The depending upon the calculation of harmonic current extracted fundamental currents are then subtracted and generation of reference current. In this paper, a from source current to evaluate the reference signal three phase three wire ACO controlled shunt hybrid i.e. harmonic current. The proposed controller has active power filter is proposed [3], [4], [5]. To make self-learning with high accuracy and simple the shunt active power filter model more dynamic and architecture and it can be successfully applied for robust in nature in this paper an ACO controller has harmonic filtering under various power system been used to facilitate the calculation of reference operating conditions. This paper, therefore, presents a currents. ACO controller is used to generate hybrid power filter using ACO -controller to control the harmonics under different non-sinusoidal source/load conditions for its performance. Three-phase three-wire loads generate positive-/negative sequence (pn-seq) current harmonics. These harmonics give rise to resonances, voltage distortion, overheating, increase in losses, malfunction and premature ageing of electrical equipments, etc. Single-phase nonlinear loads are usually connected between the phase and neutral conductors, and, additionally, originate zero sequence (z-seq) current harmonics—typically with 3rd, 9th, and 15th harmonic order. Harmonics with order of multiple of three resulting from several single-phase loads are summed up in the neutral conductor, which can result in a harmonic current in the neutral conductor up to three times higher than in the phase ones. Z-seq harmonic currents, also causing characteristic problems related to pn-seq harmonic currents, can give rise to neutral conductor overload, common mode neutral to earth voltages, increase of phase voltage distortion, and transformers overheating.

II. Study of The Harmonics

The electric parameters present on the networks (especially currents) are often disturbed and they are not perfectly sinusoidal. In the field of the power quality of energy, it is essential to know well all the energy exchanges between the network and various loads in order to be able to compensate for the possible disturbances. The mathematical concepts is used, which allow the decomposition of the disturbed electric signals (non sinusoidal) in ideal components and disturbances. The concept of harmonic introduced by Joseph Fourier [14], shows that any no sinusoidal periodic signal can be represented by a sum or series of sinusoids of discrete frequencies. Fourier is the component continues is component zero of the series known as of, the first component is called component fundamental. In the case of the systems connected to the supply, this one is a component at three Phase Shunt Hybrid Filters for the Current Harmonics Suppression and the Reactive Power Compensation the rated frequency of the supply (50Hz). The remainder of the components of the series are called harmonic and are multiple fundamental frequency.

III. Proposed Topology

Three phase four wire hybrid power filter. Shunt active power filter is used to generate compensation current in opposite phase. Power circuit for APF is proposed as an IGBT based three-phase voltage source inverter with 2 DC storage capacitor for better compensation of non-linear loads. Active power filter has two different control schemes; one is ACO based controller that accounts for reference current generation and second PI controller for DC voltage regulation. ACO extract the fundamental components of the three phase voltages from non-sinusoidal supply [6]. The capacitors are designed to limit the dc voltage ripple to a specified value, typically 1 to 2 %. In this case the capacitor should be designed for the worst case. Since the active filter will operate in several modes, then the injection of compensation current is done in order to nullify or mitigate the harmonic currents. Injection of this compensation current gives improved power quality. The performance of the active power filters is dependent to a great extent upon the method used for the calculation of reference current.

IV. Control Strategy

The main function of control scheme is shown in figure 2 to maintain supply current waveform sinusoidal, identification of harmonic content, regulation of DC voltage and controlling scheme of HSAPF is compulsory which provides compensating current to the power system as well as supplies harmonic currents to the three phase non-linear load at the same instant. For the proper response of APF the extraction of fundamental component of current from non-sinusoidal input, reference current generation, DC voltage regulation and injection of compensation currents are essential tasks [10]. These tasks can be achieved only by using various controlling schemes. The indirect method of current/voltage sensors is used. The three phase unit voltage vectors (v_{sa} , v_{sb} , v_{sc}) are obtained from the supply voltages. These unit vectors, when multiplied with reference supply current (I^*_{sm}), result in three phase reference supply currents (I^*_{sa} , I^*_{sb} , I^*_{sc}). The reference supply currents and sensed supply currents (I_{sa} , I_{sb} , I_{sc}) are the inputs for the pulse generator, which generates the firing pulses for the gating signals to the IGBT's of the active power filter [11], [12]. Hysteresis current

control is a method of controlling a voltage source inverter so that the output current is generated which follows a reference current waveform.

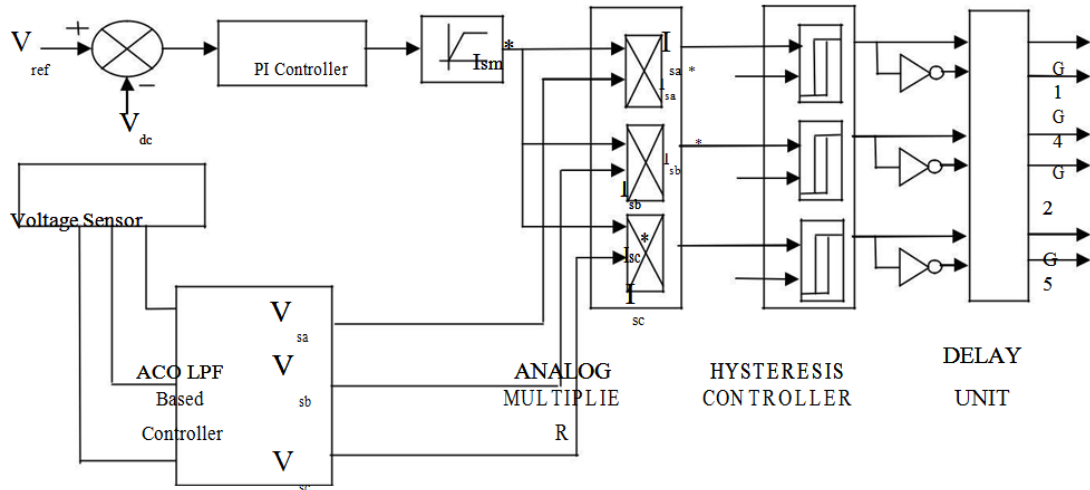


Figure 2. Block diagram of control strategy for shunt active power filter

4.1. Ant Colony Optimization based Controller

ACO takes inspiration from the foraging behaviour of some ant species. These deposit pheromone on the ground in order to mark some favourable path that should be followed by other members of the colony. As time passes by, most ants will take nearly optimal path in unison [14, 15]. Such property of the behaviour implies efficacious solutions to a range of combinatorial problems in circuit design. To utilize ACO, however, the search space must be a discrete one rather than continuous ones which are commonly encountered in the optimization of filters. For an ant A whose corresponding transfer function is HA, the average error of gain between HA and the design objectives in the pass band is estimated by

$$E_{pass} = \frac{20}{N_p} \sum_{f_p \in F_{pass}} \left| \log \left(\frac{g_{fp}}{g_{pass}} \right) \right|$$

where $g_{fp} = |HA(j2\pi f_p)|$ is the gain at frequency f_p . Note that the error is measured in dB.

The situation in the stop band is a bit more complicated, as gain below g_{stop} is satisfactory while gain above g_{stop} is not. Hence

$$E_{stop}(A) = \frac{20}{N_s} \sum_{f_s \in F_{stop}} \log \left(\frac{\sigma_s}{g_{stop}} \right)$$

in which $g_{fs} = |HA(j2\pi f_s)|$ is the gain at frequency f_s . Likewise, the gain in trans band should be below the straight line connecting the corner points $(lg f_{pass}, 20lg g_{pass})$ and $(lg f_{stop}, 20lg g_{stop})$ in the Bode plot, thus the error in trans band is estimated by

$$E_{trans}(A) = \frac{20}{N_t} \sum_{f_t \in F_{trans}} \log \left(\frac{\sigma_t}{g_{trans}} \right)$$

in which $g_{fs} = |HA(j2\pi f_t)|$ and

$$\log g_{trans} = \frac{\log \left(\frac{g_{stop}}{g_{pass}} \right)}{\log \left(\frac{f_{stop}}{f_{pass}} \right)} \log \left(\frac{f_t}{f_{pass}} \right) + \log g_{pass}$$

is the logarithm of desired gain at frequency f_t . Furthermore, by taking weighted sum of E_{pass} , E_{stop} , and E_{trans} , the overall error between HA and design objectives can be measured by $E(A) = C_{pass} E_{pass}(A) + C_{stop} E_{stop}(A) + C_{trans} E_{trans}(A)$

in which C_{pass} , C_{stop} and C_{trans} reflect the relative importance of design objectives. Thereby the performance of the filter denoted by ant A is defined as

$$\eta(A)=1/E(A)$$

indicating that an ant having lower error value performs better and thus have a higher value of η .

2) Calculation of the probabilities of selecting components. A probabilities table of components is calculated based on TN_{cxm} such that the probability of a component being selected is proportional to the amount of pheromone associated with it. If there is no pheromone distributed in a particular step, all components in that step will have equal chance of being selected.

3) Construction of solutions

First, calculate the initial η for all ants when no component is selected. Then for all $i < N$: repeatedly select components for ant A_i according to the table described in step 2), until a newly selected component cannot improve $\eta(A_i)$.

4) Update pheromone distribution

In each iteration, the pheromone value $\tau_{i,j}$ associated with component $c_{i,j}$ is multiplied by a decay factor ρ . In the r th iteration, the ant will release pheromone

ΔT_k on the components it selects. In order to improve performance and attenuate excessive complexity of filters, the incremental pheromone is designated as $\Delta T_k^{(r)} = \eta(A_k^{(r)}) / L_k^{(r)}$

where L_k is the number of coefficients selected by and $\eta(A_k)$ is the normalized performance of A_k and the pheromone in the next iteration is updated as

$$\tau_{i,j}^{(r+1)} = \rho \tau_{i,j}^{(r)} + \sum_{k \in A_i, j \in I} \Delta T_k$$

5) Evaluation of the colony

The optimization process ends if termination conditions are met, e.g. the colony converges or the maximal iteration number r_{max} is reached; otherwise go to 2).

PI controller algorithm involves two separate parameters; the Proportional and the Integral. The Proportional value determines the reaction to the current error; the Integral determines the reaction based on the sum of recent errors. A comparison of the average and the reference values of the dc bus voltage for the shunt AF results in a voltage error, which is fed to a proportional integral (PI) controller and the output of the PI controller is multiplied by the mains voltage waveform V_{sa} , V_{sb} , V_{sc} in order to obtain the supply reference currents i_{sa}^* , i_{sb}^* , i_{sc}^* . A PI controller used to control the DC-bus voltage is shown in Figure 6 whose transfer function can be represented as

$$H(S) = k_p + k_i/s$$

Where, k_p is the proportional constant that determines the dynamic response of the DC-bus voltage control, and k_i is the integration constant that determines its settling time.

It can be noted that if k_p and k_i are large, the DC-bus voltage regulation is dominant, and the steady state DC-bus voltage error is low. On the hand, if k_p and k_i are small, the real power unbalance gives little effect to the transient performance. Therefore, the proper selection of k_p and k_i is essentially important to satisfy above mentioned two control performances. The computed three-phase supply reference currents are compared with the sensed supply currents and are given to a hysteresis current controller to generate the switching signals to the switches of the shunt AF which makes the supply currents follow its reference values.

V. Result

The system parameters: Load resistance $R_L=50\Omega$, Load inductance $L_L=80mH$, Supply Phase voltage= $162.63V$ (rms),and peak voltage of $230V$, Supply line parameters $R_s =1 \Omega$, $L_s =0.05mH$, Filter coupling inductance $R_c=5\Omega$, $L_c=3mH$, Inverter DC bus capacitor is of $1000\mu F$ each, Reference Voltage = $480V$, Hysteresis band limit = $0.2A$ and Switching frequency = $10kHz$, PI controller parameters are $K_i =10$, $K_p = 0.5$.

5.1 STEADY STATE RESPONSES

In static load condition the source current is getting sinusoidal and smooth at around 0.08 sec., neutral wire current is reaching zero at around 0.05 sec..

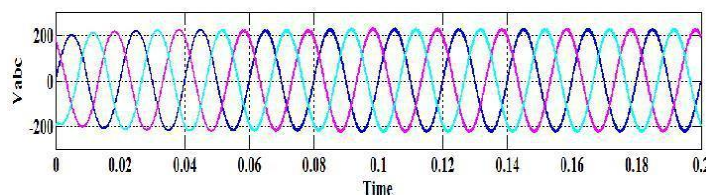


Fig 5. 3-phase source voltages

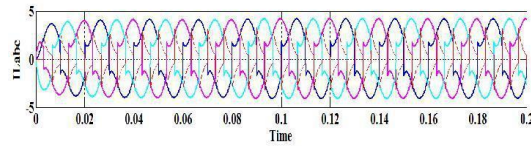


Fig 6. 3-phase load currents

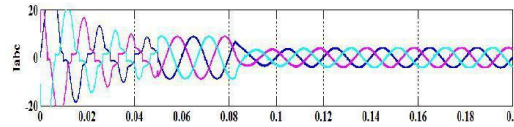


Fig 7. 3-phase source currents

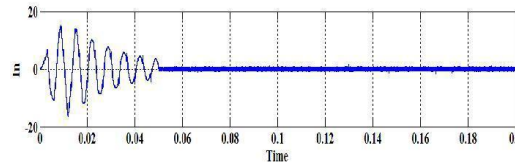


Fig 8. Neutral wire current

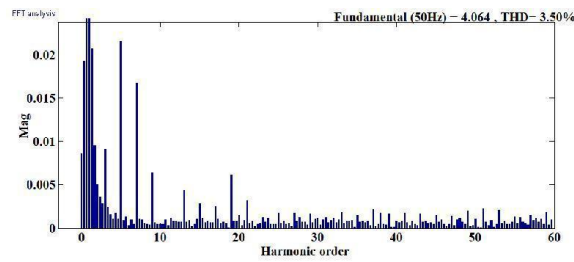


Fig.9 FFT analysis of %THD

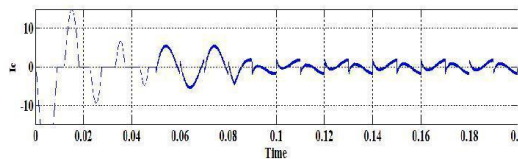


Fig.10. Phase 'c' compensating current

5.2 DYNAMIC STATE RESPONSES

After adding the dynamic load of $RL = 50\Omega$, Load inductance $LL=80mH$, in parallel with static load at 0.16sec., the THD% is reducing and source and load current is higher than the static source current. We can observe that the smoothing work of active power filter is not affected due to dynamic load.

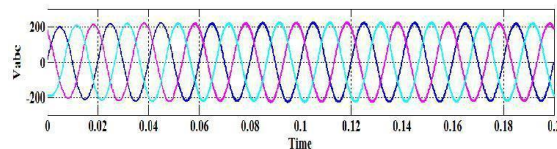


Fig 11. 3-phase source voltages

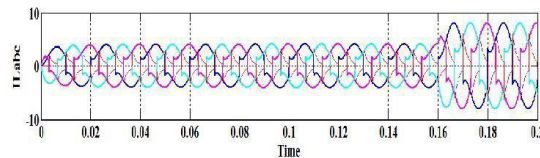


Fig 12. 3-phase load currents

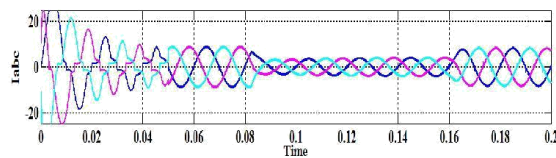


Fig 13. 3-phase source currents

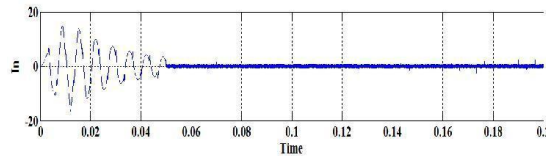


Fig 14. Neutral wire current

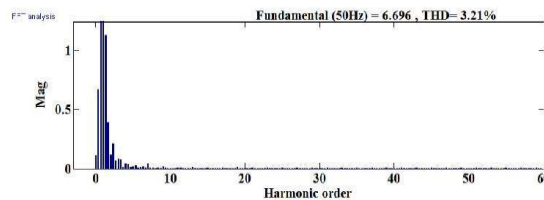


Fig.15 FFT analysis of %THD

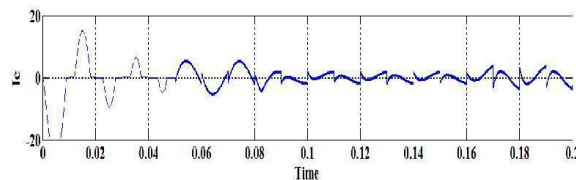


Fig.16. phase 'c' compensating current

VI. Conclusion

In this paper, an analysis of reduction in size and cost of the active filtering unit with the passive tuned filters inserted for partial compensation. The estimation is done for varying passive filter VAR compensation. ACO techniques has been proposed for the novel approach which based on intelligent. The performance of the proposed ACO will be verified through simulation studies with MATLAB. Proposed controller provides the fundamental component from distorted supply accurately. The estimation further strengthens the fact that the shunt active filtering system based on the ACO control scheme can be made quite cost-effective with the addition of a passive counterpart, as required in practical applications, for power quality improvement in retrofit systems.

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