PSO and GA Based Performance Optimization of PI Controller in Three Phase Shunt Hybrid Filter

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***Abstract* - This paper attempts to compare about the performance analysis of meta heuristic optimising techniques like PSO and GA for tuning the PI parameters in the implementation on shunt hybrid filter. The total Harmonic Distortion is taken as the objective to be reduced in this problem. The PI tuning using both the Zeiglers method and the PSO ,GA method is carried out and compared for the optimized THD value for a Shunt Active filter. Zeigler method is the traditional method of PI tuning and the PSO and GA are the method of optimization that would increase the accuracy of tuning. The optimization method proved to be better in the optimization of the PI parameters for the reduction of THD.This paper has also attempted in linking the PI value for THD reduction problem. Matlab based simulation is carried out and the results are compared for the THD and the voltage ripple.**

Keywords: *Shunt hybrid filter,Particle Swarm Optimization, Genetic Algorithm, Total harmonic distortion*.

1. INTRODUCTION

Harmonic compensations have become increasingly important in power systems due to the widespread use of adjustable-speed drives, arc furnace, switched-mode power supply, uninterruptible power supply, etc. Harmonics not only increase the losses but also produce unwanted disturbance to the communication network, more voltage and/or current stress, etc. Different mitigation solutions, e.g., passive filter, active power line conditioner, and also hybrid filter, have been proposed and used [1]–[8]. Recent technological advancement of switching devices and availability of cheaper controlling devices e.g., DSP-/field- programmable-gate array-based system, make active power line conditioner a natural choice to compensate for harmonics. Shunt-type active power filter (APF) is used to eliminate the current harmonics. The dynamic performance of an APF is mainly dependent on how quickly and how accurately the harmonic components are extracted from the load current. Many harmonic extraction techniques are available, and their responses have been explored. Proposed techniques include traditional $d-q$ [2] and $p-q$ theory [3]–[5] based approaches and application of adaptive filters [6], wavelet [7], genetic algorithm (GA), artificial neural network (ANN), etc., for quick estimation of the compensating current [8]. A critical evaluation of such techniques is recently reported by the authors [8]. Recently, ANNs have attracted much attention in different applications, including the APF [9].A thorough investigation of the experimental results reported in and [16], reveals that the total harmonic distortion (THD) in the supply currents cannot be brought down below 5% to satisfy the IEEE-519 standard. This is due to the presence of notches in the supply currents. The drawbacks can be eliminated by using the nonlinear control theory, ideally without exaggerating computational and implementation complexities. In addition, Youssef *et al.* [18] and Yacoubi *et.al.*, [19],[20] implemented very useful advanced nonlinear control techniques to active rectifiers with active filtering function. These control techniques can be applied to active filtering technology. In [21], a nonlinear control strategy of an SAPF based on the internal model principle is proposed. The stabilization of the dc-link voltage dynamics is addressed, along with the fulfillment of the harmonic load current compensation objective. The two-time scale behavior of the SAF is exploited to apply the averaging theory in the control design. In [22], a nonlinear control strategy for an active filter is proposed. It is based on the input–output linearization method implemented on a dq0 rotating current reference frame. The structure balances the load currents, obtains unity displacement power factor, and reduces the harmonic load currents in arbitrary loads. In [23], the current loop dynamics in the synchronous d–q frame are controlled using multiple-input– multiple-output optimal control based on the predictive control approach. The nonlinear control strategy does not require online optimization and overcomes the aforementioned difficulties by ensuring fast current tracking, current loop stability, and compensation robustness under nonideal load and/or supply conditions. The shunt active filter requires high dc link voltage in order to effectively compensate higher order harmonics. On the other hand, a series active filter requires a transformer that is capable to withstand full load current in order to balance for voltage distortion. Even the costs of such filters are relatively high for large scale system and are tedious to utilize in high-voltage grids. Also, the compensating performance is better in the harmonic current source load type than in the harmonic voltage source load type. One more solution for the harmonic problem is to adopt a hybrid APF. These Hybrid filters effectively mitigate the problems of a passive and an active filter and provide cost-effective harmonic compensation particularly for high power nonlinear loads. This paper presents the performance optimization of the neural network controlled three phase shunt hybrid filter. The performance of the Zieglers Nichols method ,GA and PSO implementation on the shunt hybrid filters is observed and inferred in this paper. The PSO and GA based implementation of the three phase hybrid filter is improved in terms of optimizing the parameters of PI controller. This implementation would decrease the time required for the calculation occurring in the Evolutionary programming techniques. The comparison of the implementation is taken in this paper between the GA and PSO methods. The P-Q theory based implementation is taken up and trained and checked for the output. Then the PSO and GA based optimization is implemented and compared for the parameters like the execution time and the error tolerance obtained after the iterations. Matlab based simulation is carried out and the results are tabulated and compared.

2. SHUNT ACTIVE FILTER TOPOLOGY

The Three phase shunt hybrid filter is connected in between the source and the nonlinear load which is three phase diode bridge rectifier. The hybrid filter act as a controlled current source connected in parallel with nonlinear load shown in Fig.1. It consists of a full bridge voltage source PWM inverter, high frequency inductors and dc side capacitors that are required to shape the compensator currents. The Shunt active power filter is represented as A.

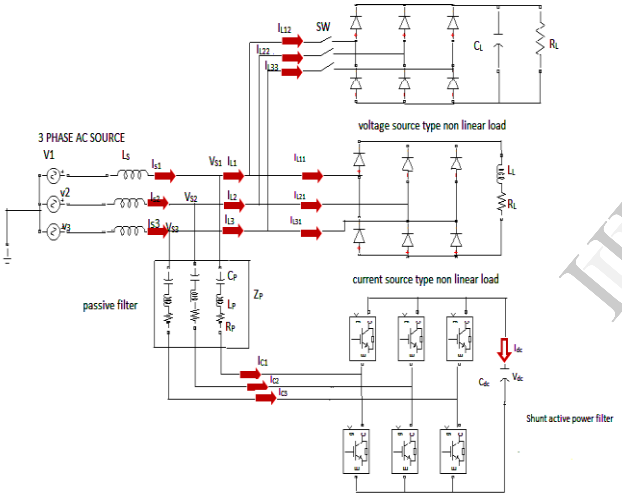

Fig.1. Basic circuit of Shunt Hybrid Power filter

3. APPROACHES WITH ZEIGLERS NICHOLS METHOD, PSO & GA

The performance of different active filtering techniques in Shunt Hybrid Power Filter using the intelligent techniques which is supported by GA and PSO for fast convergence. The PI tuning using Zeiglers Nichols method, Particle Swarm optimization and Genetic algorithm is carried out and compared for the optimized THD value for a Shunt hybrid filter. The objective function for GA and PSO is to minimize the mean square error. The block diagram of Shunt hybrid filter using Zeiglers Nichols method, PSO and GA as shown in Fig.2.

Problem Formulation:

Minimization $\{ mean(\text{THD})\}_{t=0.03s}$

Constraints:

$0<Kp< kp(ZN)$

$0<ki<Ki(ZN)$

3.1 ZIEGLERS NICHOLS METHOD

The Ziegler Nichols tuning method is a heuristic method of tuning a PI controller. It is performed by setting the integral value and derivative gains to zero. The proportional gain is then increased from zero until it reaches the ultimate gain, at which the output of the control loop oscillates with constant amplitude.

It is a simple method of tuning PI controllers and can be developed to give better approximations of the controller. The Ziegler-Nichols closed-loop tuning method is limited to tuning processes that cannot run in open-loop systems. Determining the definitive gain value is accomplished by finding the value of the proportional-only gain that causes the control loop to oscillate indefinitely at steady state. This states that the gains from the Integral and Derivative controller are set to zero so that the influence of P can be determined. Another important value associated with this proportional-only control tuning method is the ultimate period. The ultimate period is the time required to complete one full oscillation while the system is at steady state. These two parameters, Ultimate gain value and ultimate period of oscillation, are used to find the loop-tuning constants of the PI controller.

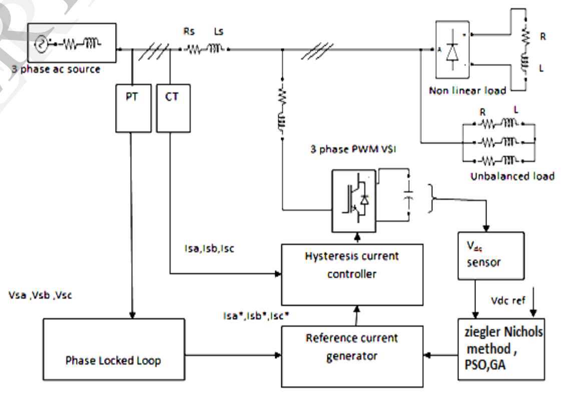

Fig.2. Block diagram of Shunt hybrid Filter with PSO, GA based ANN.

3.2 PARTICLE SWARM OPTIMIZATION

Particle swarm optimization is a population based stochastic optimization technique stimulated by social behavior of bird flocking or fish schooling. PSO helps to solve the optimization problems. In PSO, each solution is a "bird" in the search space described as "particle". All particles have fitness values which are evaluated by the fitness function to be optimized and have velocities which direct the flying of the particles. The particles fly through the problem space by following the current optimum particles. PSO is initialized with a group of random particles and then searches for optima by updating generations. In each iteration, every particle is updated by following two "best" values. The first one is the best solution (fitness) it has achieved so far. This value is called P_{best}. Another "best" value that is tracked by the particle swarm optimizer is the best value, obtained so far by any particle in the population. This best value is a global best and called g_{best}. The i_{th} particle is represented as $X_i=(X_{i1},X_{i2},\dots,X_{id})$ in the d-dimensional space. The best previous position of the i_{th} particle is recorded as represented as the following.

$Pbest_i = (Pbest_{i1}, Pbest_{i2} \dots Pbest_{id})$ …………(1)

The index of best particle among all of the particles in the group is g_{bestd}. The velocity for particle i is represented as

$V_i = (V_{i1}, V_{i2} \dots V_{id})$ ………………………(2)

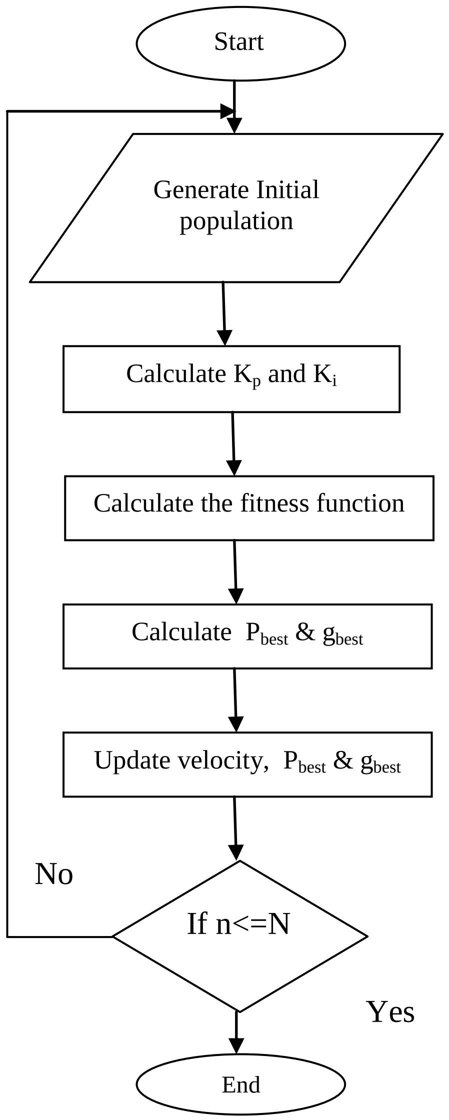

Figure.3 Flow chart of Particle swarm optimization

PARTICLE SWARM OPTIMISATION PARAMETERS:

1) Objective function: Mean (THD) in percent.
2) Population size =10.
3) Number of variables = 2 (Kp, Ki).
4) Inertia weight = 0.9 – 0.4.
5) Acceleration constant1 = 2.
6) Acceleration constant2 = 2.
7) Range of variables = [0 0.002].
8) Maximum epochs = 100.
9) Global best solution: Kp = 0.000531, Ki = 0.001658.
10) Global best THD = 4.7545.
11) Execution time = 912.268323 sec.

3.3 SHPF DESIGN WITH GA

The shunt hybrid filter is controlled by using hysteresis current control method. In this paper, the Genetic algorithm is applied to determine the parameters of Hybrid Power filter. The parameters for switching are DC link voltage, inductor filter, and the hysteresis band are general optimization techniques based on real time process as selection, cross over and mutation. They are applied to find global optimum of complex non linear optimization problems. More complex optimization problems involving non linear and multivariable objective functions require extension of the elementary algorithm by intruding among other improved selection methods, advanced representation schemes and fitness function scaling.

GENETIC ALGORITHM PARAMETERS:

1) Objective function: Mean (THD) in percent.
2) Population size = 20.
3) Number of variables = 2 (Kp, Ki).
4) Range of variables = [0 0.002].
5) Maximum epochs =100.
6) Global best solution: Kp = 0.000979, Ki = 0.001306.
7) Global best THD = 4.776955.
8) Execution time = 937.220997 sec

4. RESULTS AND DISCUSSION

Tuning of PI controller play significant role in Power electronics. There are many approaches proposed for obtaining the parameters of K_p and K_i. Based on Ziegler Nichols method of tuning the parameters of K_p and K_i were chosen. The THD value is nearly 8.38% ,but the IEEE standard of THD value is less than 5% is recommended. So a new problem is formed by minimization of THD value in the time domain simulation. The samples of THD is taken at 0.03 sec and the mean value of THD data is achieved from time domain simulation and the values are passed to the GA solver and PSO solver as objective function. The K_p and K_i values are randomly populated and the minimization of objective function is made. The GA and PSO gives better results compared to Ziegler Nichols method and it makes the THD value less than the IEEE standard value.

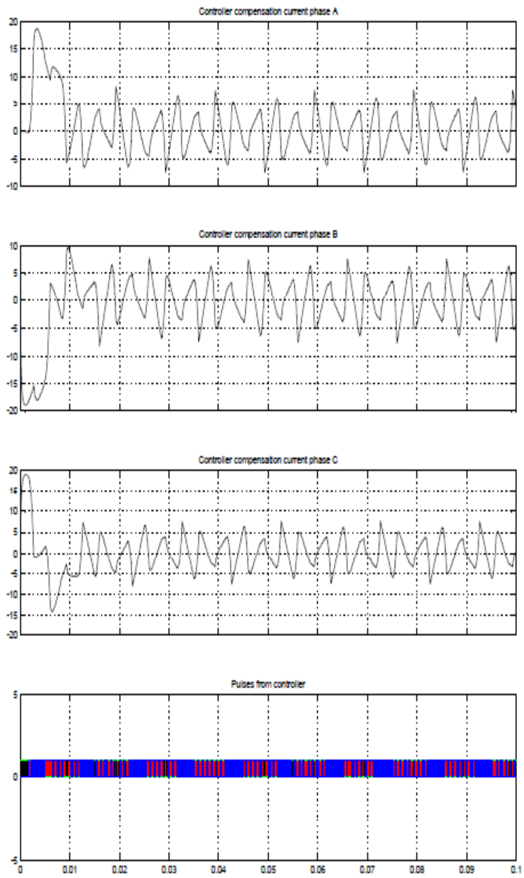

Fig.4. Compensation current in phase a,b,c

Fig.4. represents the phase current in three phases a, b and c derived by the controller. The currents in each phase are in phase with each other. The derived PWM pulses derived by the controllers are explicitly shown which has been given to the inverter for the optimal switching states.

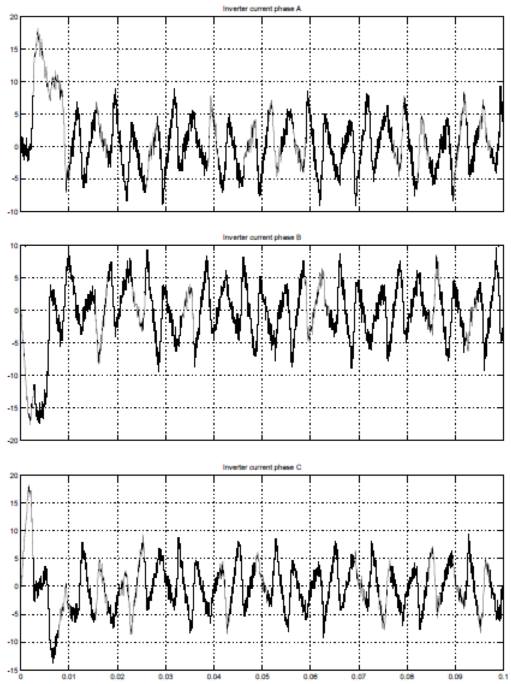

Fig.5 Inverter current in 3 phases

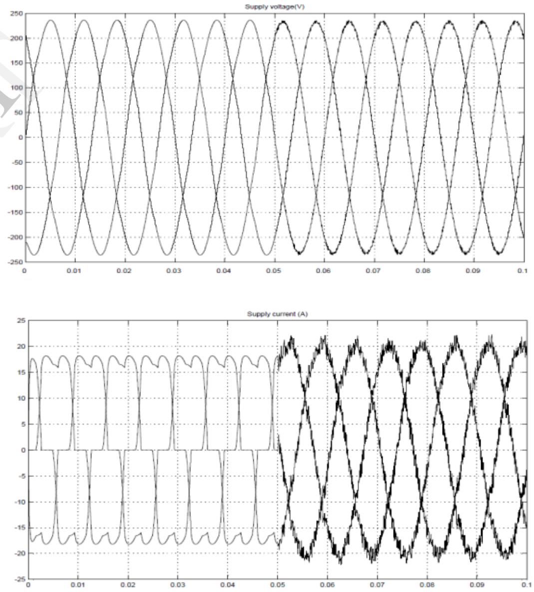

Fig.6 Supply voltage and supply current after compensation

Fig.5. represents inverter current in three phases. Fig.6 represents the supply voltage and supply current waveform after compensation by the Shunt Hybrid Filter. At t=0.05 it attains the steady state value. In fig.6 the THD value is 4.79 which is acceptable and it is derived from PI controller with the Particle swarm optimization technique. Using Genetic algorithm the THD value is 4.77 which is also recommended by IEEE 519 standards.

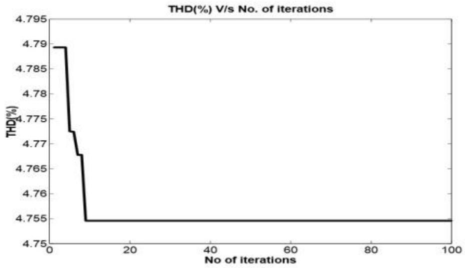

Fig.6. THD analysis with PSO.

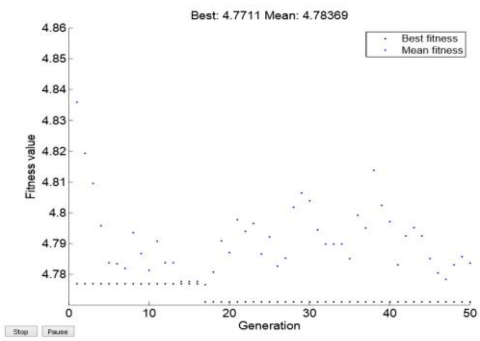

Fig.7. THD analysis with Genetic Algorithm

5. CONCLUSION

The problem of harmonic reduction is analyzed in this paper. PI tuning using both the Zeiglers method and the PSO ,GA method is carried out and compared for the optimized THD value for a Shunt Active filter. The influence of Objective functions on the result has been presented. Based on Zieglers Nichols method the Total Harmonic Distortion value is 8.38% whereas the Particle Swarm Optimization results the THD value is 4.75 and using GA it is 4.77 %.

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