

An Intelligent Fuzzy-Ant colony and Particle swarm Control of Shunt Active Power Filter based on three levels Converter for DC link voltage regulation

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Abstract- *Problematic: Harmonic propagation drawn by nonlinear loads contributes to a major pollution and amplification in a distribution line, good control can prevent distortion on the power supply voltages. Approach: Intelligent ant colony algorithm and particle swarm algorithm were proposed to search the optimal values fuzzy logic controller design parameters. The both proposed optimized controllers have been applied to DC link voltage control on shunt active power filter in order to improve the reactive power compensation and filtering quality. Simulations studies have been carried out using MATLAB Fuzzy Logic toolbox. Two approaches shunt active filter fuzzy logic controllers based on ant colony (SAF-FLC-ACO) and particle swarm optimization (SAF-FLC-PSO) were simulated in this work and their results were compared with conventional controller (SAF-FLC). Results and conclusion: The simulation results confirmed that the proposed optimized control design presents strongly control and best dynamic behaviour on power system. The optimized controllers are robust and more efficient in maintain DC link voltage constantly, Then consequently improvement on reducing currents harmonic and increase the power factor compared to the conventional Fuzzy logic controller.*

Keywords: *Shunt active filter SAF system, Harmonic compensation, three levels Converter, Fuzzy logic controller, Ant colony optimization, Particle swarm optimization.*

1. Introduction

The fast development of power electronic technology in the world is rather significant. The extensive use of power electronic devices and nonlinear loads such as electromagnetic cookers and fluorescent lights has depreciated the power quality by injecting current harmonics into line distribution and cause power system seriously polluted [1]. The passive power filter is habitually used at the point of common coupling (PCC) conventionally to minimize offending

harmonics. On the other hand, it has many inconveniences (mistuning, resonance, instability, ect.) which discourage its accomplishment [2]. The rapid progress in modern power electronic technology the researchers have developed the shunt active power filter as a reasonable solution to the troubles created by nonlinear loads. It is used to attenuate the harmonic currents in power system by injecting identical but opposite compensating currents and compensate Fundamental reactive power consumed by nonlinear loads. In the last years some modern heuristic tools have been developed which help solving optimization problems [18]. These tools contain tabu search, evolutionary computation, particle swarm algorithm, and genetic algorithm and ant colony optimization techniques. These techniques are finding popularity within research community as design tools and problem solvers because of their flexibility to optimize in complex multimodal search applied to non-differentiable cost functions. Ant colony algorithm (ACA), a novel evolutionary algorithm [3] proposed by Marco Dorigo. This approach is a paradigm for designing metaheuristic algorithms for combinatorial optimization problems. The essential trait of ACA algorithms is the combination of a priori information about the structure of a promising solution with a posteriori information about the structure of previously obtained good solutions [4]. The algorithm has solved traveling salesman problem (TSP), quadratic assignment problem (QAP) and job-shop scheduling problem (JSSP) and so on.

PSO is created in the mid 1990 which is inspired by the ability of flocks of birds, schools of fish, and herds of animals to adapt to their environment, find rich sources of food, and avoid predators by implementing an information allocation approach [5]. The PSO [6] approach utilizes a cooperative swarm of particles, where each particle represents a candidate solution, to

explore the space of possible solutions to an optimization problem. Each particle is randomly or heuristically initialized and then allowed to 'fly'. At each step of the optimization, each particle is allowed to evaluate its own fitness and the fitness of its neighboring particles. With the growth of power electronic in the industry, the shunt active power filter shown in Fig.1 is capable of controlling the currents harmonic, removing it from the electrical network and compensates reactive power [21]. In the present work, the design problem of DC link voltage SAPF-based Fuzzy Logic controller is considered to compare the performance and the computational effectiveness and efficiency of both ACO and PSO optimization techniques for designing a SAPF-based controller for power quality improvement. The main problem is to search for the optimal Fuzzy logic controller parameters using adopted both of PSO and ACO optimization techniques.

This paper presents a shunt APF that uses conventional and optimal fuzzy logic controllers for DC link voltage regulation. The active power filter is implanted with PWM multilevel inverter to generate harmonics currents reference. The APF system is validated through extensive simulation under nonlinear load. The design of shunt APF system architecture is presented in section2. Organization of fitness function of the proposed system is presented in section 4. Section 5, system performance has been modeled and analyzed from the obtained results under nonlinear load conditions. Finally, Section 6 describes the conclusions of this work.

2. Shunt active power filter design

The principal function of the shunt active power filter (SAPF) is to generate just enough reactive and harmonic current to compensate the nonlinear loads in the line. A multiplicity of methods is used for instantaneous current harmonics detection in active power filter such as FFT (fast Fourier technique) technique, instantaneous p-q theory, and synchronous d-q reference frame theory [7]. For the SAPF control, the reference current consists of the harmonic components of the load current which the active filter must supply. This reference current is fed through a controller and then the switching signal is generated to switch the power switching devices of the active filter such that the active filter will indeed produce the harmonics required by the load. Finally, the AC supply

will only need to provide the fundamental component for the load, resulting in a low harmonic sinusoidal supply. The identification theory that we have used on shunt APF is known as instantaneous power theory, or PQ theory. It is based on instantaneous values in three-phase power systems with or without neutral wire, and is valid for steady-state or transitory operations, as well as for generic voltage and current waveforms. The PQ theory consists of an algebraic transformation (Clarke transformation) of the three phase voltages and current in the abc coordinates to the $\alpha\beta$ coordinates [8].

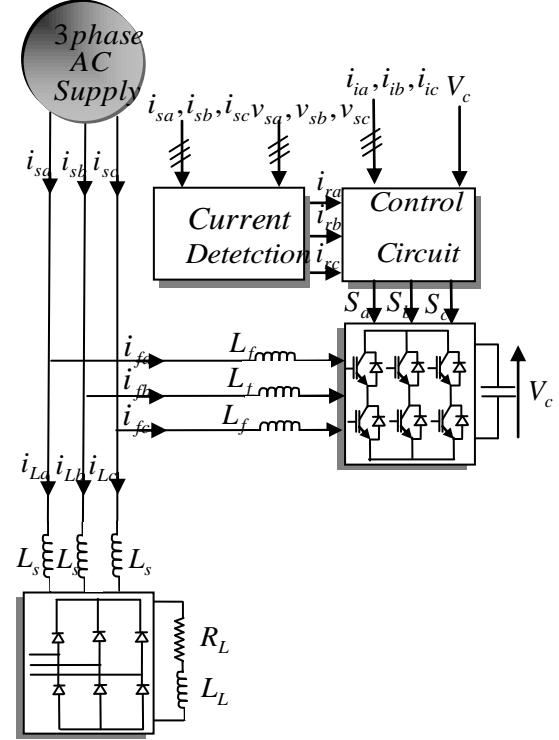


Fig.1 Equivalent schematic of shunt SAPF

$$\begin{bmatrix} v_\alpha \\ v_\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & -1/2 & -1/2 \\ 0 & \sqrt{3}/2 & -\sqrt{3}/2 \end{bmatrix} \begin{bmatrix} v_a \\ v_b \\ v_c \end{bmatrix} \quad (1)$$

$$\begin{bmatrix} i_{ca} \\ i_{cb} \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & -1/2 & -1/2 \\ 0 & \sqrt{3}/2 & -\sqrt{3}/2 \end{bmatrix} \begin{bmatrix} i_{ca} \\ i_{cb} \\ i_{cc} \end{bmatrix} \quad (2)$$

The instantaneous power is calculated as:

$$\begin{bmatrix} p \\ q \end{bmatrix} = \begin{bmatrix} v_\alpha & v_\beta \\ -v_\beta & v_\alpha \end{bmatrix} \begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} \quad (3)$$

The harmonic component of the total power can be extracted as:

$$P_L = \bar{P}_L + \tilde{P}_L \quad (4)$$

Where,

\bar{p}_L : The DC component and \tilde{p}_L : Harmonic component
Similarly,

$$q_L = \bar{q}_L + \tilde{q}_L \quad (5)$$

Finally, we can calculate reference current as:

$$\begin{bmatrix} i_{fa}^* \\ i_{fb}^* \\ i_{fc}^* \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & 0 \\ -1/2 & \sqrt{3}/2 \\ -1/2 & -\sqrt{3}/2 \end{bmatrix} \begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} \quad (6)$$

Here,

$$\begin{bmatrix} p \\ q \end{bmatrix} = \frac{1}{v_\alpha^2 + v_\beta^2} \begin{bmatrix} v_\alpha & -v_\beta \\ v_\beta & v_\alpha \end{bmatrix} \begin{bmatrix} \tilde{p} \\ \tilde{q} \end{bmatrix} \quad (7)$$

Two control loops are studied, the internal loop responsible for the ac current control and the external loop responsible of dc voltage control with the consideration that the power is flowing from the capacitor source voltage to the grid. In the order to progress the effectiveness of shunt active power filter, a multilevel converter has been used in this study.

2.1 Three levels three phase converter

The converters transmission the high powers through the components which constitute them undergo considerable constraints during the control of the opening and closing as well. The idea is to keep a power raised without to oversize the switches and to associate structures in series of the part concerning DC-AC conversion. Association in series of converters, certainly, make the analysis of interaction related phenomenon more complex but it offers in return. A reasonable distribution and acceptable constraints, in this configuration, the constraints due to the phenomena of commutation requesting the switches are decreased by half [11]. To avoid the problems of this type of grouping, we start to use the multilevel converters. For the three levels PWM inverter, the condition of control implies that the transition between the configurations do not depend any more of the internal commands (electric quantities) but only the transistors commands (external order) [12].

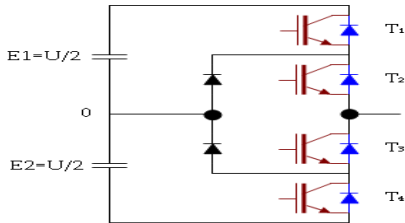


Fig.2 Three levels bridge VSI NPC structure

Introducing the functions of connection of the half arm we obtain:

$$\begin{bmatrix} U_{AB} \\ U_{BC} \\ U_{CA} \end{bmatrix} = \begin{bmatrix} 0 & -1 & 0 \\ 0 & 1 & -1 \\ -1 & 0 & 1 \end{bmatrix} \begin{bmatrix} F_{11}^b \\ F_{21}^b \\ F_{31}^b \end{bmatrix} U_{C1} - \begin{bmatrix} F_{10}^b \\ F_{20}^b \\ F_{30}^b \end{bmatrix} U_{C2} \quad (8)$$

The outputs voltages are given as follows:

$$\begin{bmatrix} V_A \\ V_B \\ V_C \end{bmatrix} = \frac{1}{3} U_C \begin{bmatrix} 2 & -1 & -1 \\ -1 & 2 & -1 \\ -1 & -1 & 2 \end{bmatrix} \begin{bmatrix} F_{11}^b - F_{10}^b \\ F_{21}^b - F_{20}^b \\ F_{31}^b - F_{30}^b \end{bmatrix} \quad (9)$$

The three levels inverter control is based on the triangular-sinusoidal with two carrying which exploits the fact that a three levels inverter is equivalent to two levels inverters in series [13]. We can use two identical carrying diphas a half period of chopping one compared to the other from one another in order to improve harmonic rate of outputs voltages.

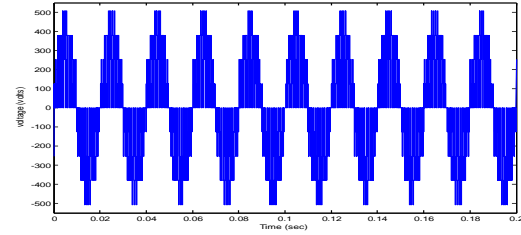


Fig.3 Output voltage of the first phase Va of multilevel inverter

2.2 SAPF Technique Control

The output currents of the inverter must track the reference currents produced by the current identification block. Consequently a regulation block is required and must be designed. In this work, the inverter is controlled using a PI regulator with a PWM modulator [14]; the control circuit system is shown in Fig. 4.

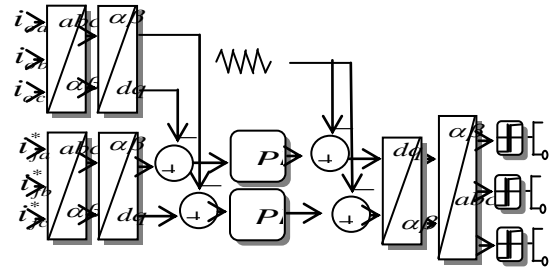


Fig.4 PI inverter controller block

i_{on} and i_{fn}^* $n=(a,b,c)$ are correspondingly the active power filter output currents and reference currents. The DC-link voltage of SAPF can be adjusted to a great extent so as to provide easy control and high

performance Fuzzy theory was first proposed and investigated by Prof. Zadeh in 1965. The Mamdani fuzzy inference system was presented to control a steam engine and boiler combination by linguistic rules [9]-[10]. Fuzzy logic is expressed by means of if-then rules with the human language. In the design of a fuzzy logic controller, the mathematical model is not necessary. Therefore the fuzzy controller is of good robustness. Owing to its easy application, it has been widely used in industry.. However, the rules and the membership functions of a fuzzy logic controller are based on expert experience or knowledge database. The control circuit system is shown in Fig. 5.

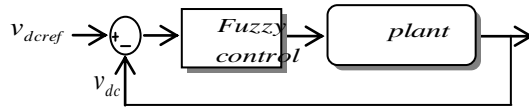


Fig.5 Dc voltage control block

3. Synopsis of ACO and PSO optimization technique

3.1 Particle swarm optimization

The PSO technique is a part of ample category Swarm intelligence methods for solving the optimization problems. Population swarm based stochastic optimization was introduced by Kennedy and Eberhart in 1995 [6]. It can be attained high quality solutions within shorter calculation time and stable convergence characteristics. Each individual of population is referred to as particle and represents a candidate solution. Each particle in PSO fly in search space at a certain velocity can be adjusted in light of proceeding flight experiences. PSO is initialized with a group of random particles (solutions) and then searches for optima by updating generations. For each iteration, every particle is updated by following two "best" values. The first one is the best solution (fitness) it has achieved so far. (The fitness value is also stored.) 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} . For example, 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 and represented as:

$$Pbest_i = (Pbest_{i1}, Pbest_{i2}, \dots, Pbest_{id}) \quad (10)$$

The index of best particle among all of the particles in the group is $gbest$. The velocity for particle i is represented as: $v_i = (v_{i1}, v_{i2}, \dots, v_{id})$. The modified velocity and position of each particle can be calculated using the current velocity and the distance from P_{bestid} to $gbestid$ as shown in the following formulas [17].

$$v_{i,m}^{(t+1)} = wv_{i,m}^{(t)} + c_1 rand() (Pbest_{i,m} - x_{i,m}^{(t)}) + c_2 rand() (gbest_m - x_{i,m}^{(t)}) \quad (11)$$

$$x_{i,m}^{(t+1)} = x_{i,m}^{(t)} + v_{i,m}^{(t+1)} \quad (12)$$

$$i = 1, 2, \dots, n; \quad m = 1, 2, \dots, d;$$

Where:

n - Number of particles in the group,

d - Dimension,

t - Pointer of iterations (generations),

$v_{i,m}^{(t)}$ - Velocity of particle i at iteration t ,

w - Inertia weight factor,

c_1, c_2 - Acceleration constant,

$rand()$ - Random number between 0 and 1,

$x_{i,d}^{(t)}$ - Current position of particle i at iterations,

$Pbest_i$ - Best previous position of the i .th Particle

$Gbest$ - Best particle among all the particles in the Population

3.2 Ant colony optimization

The main idea of ACO is to model the problem as the search for a minimum cost path in a graph that base the evolutionary meta-heuristic algorithm. The behavior of artificial ants is inspired from real ants. They lay pheromone trails and choose their path using transition probability. Ants prefer to move to nodes which are connected by short edges with a high amount of pheromone. The algorithm has solved traveling salesman problem (TSP), quadratic assignment problem (QAP) and job-shop scheduling problem (JSSP) and so on [16]. The problem must be mapped into a weighted graph, so the ants can cover the problem to find a solution. The ants are driven by a probability rule to choose their solution to the problem (called a tour). The probability rule (called Pseudo-

$$P_{ij} = \frac{[\tau_{ij}]^\alpha [\eta_{ij}]^\beta}{\sum_{h \in s} [\tau_{ij}]^\alpha [\eta_{ih}]^\beta} \quad (13)$$

$$\tau_{ij} \rightarrow (1 - \rho) \tau_{ij} \quad \forall (i, j) \in L \quad (14)$$

$$\tau_{ij} \rightarrow \tau_{ij} + \sum_{k=1}^m \Delta \tau_{ij}^k \quad \forall (i, j) \in L \quad (15)$$

$$\Delta \tau_{ij} = \frac{1}{C^k} \text{ if } \text{arc}(i, j) \text{ belong to } T^k \quad (16)$$

$$0 \quad \text{otherwise}$$

4. Establishment of objective function

$$F = \lambda_{\delta}(f_{\delta}/f_{\delta}^*) + \lambda_{tr}(f_{tr}/f_{tr}^*) + \lambda_{eia}(f_{eia}/f_{eia}^*) + \lambda_{ts}(f_{ts}/f_{ts}^*) \quad (17)$$
$$f_{\delta} = y_{\max} - y_{ss} \quad (18)$$

f_{tr} represent the function of rise time which is

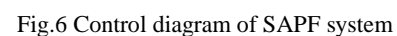
feia The integral of the absolute magnitude of control error is written as:

The weight coefficients (λ_{δ} , λ_{tr} , λ_{eia} and λ_{ts}) values of (δ , tr , eia and ts) are set respectively 0.25, 0.25, 0.5 and 0.25. The constraint condition is as follow:

$f_{\delta}^*, f_{tr}^*, f_{eia}^*$ and f_{ts}^* are the parameter indexes corresponded to the primal system.

5.1 Application and comparison of PSO and ACO

For the purpose of optimization (17), schedules from PSO and ACO are used. The shunt active power filter (SAPF) as controlled plant fig.6, the estimation of the reference currents from the measured DC bus voltage is the basic idea behind the PI controller based operation of the SAPF. The capacitor voltage is compared with its reference value in order to maintain the energy stored in the capacitor constant. The DC link voltage discretely at the positive zero-crossing point of respective phase source voltage, computes the variation of power according to difference of DC link voltage between two sampling points. The regulation of the error between the capacitor voltage and its reference is assured by The Fuzz logic controller (FLC) which its output is multiplied by the mains voltage waveform V_{s1} , V_{s2} , V_{s3} in order to obtain the supply reference currents found.



This study for DC link voltage regulation, the proposed meta heuristics techniques (PSO and ACO) have been used to optimize the membership functions (e_1 to e_5 , de_1 to de_5 and u_1 to u_5) and scaling gains (k_e and k_{de}) of fuzzy logic controller. The computational flow charts of PSO and ACO algorithms are shown in Fig.10 (a) and (b), respectively, while applying PSO and ACO, a number of parameters are required to be specified. An appropriate choice of the parameters affects the speed of convergence of the algorithm. Table 1 shows the parameters used for Particle swarm and Ant colony optimization techniques. Optimization is terminated by the specified number of generations for both PSO and ACO. Typical converge of best fitness value as a function of generations is shown in fig.8.

Table.1 Parameters used for ant colony and particle swarm optimization

ACO parameters	PSO parameters
Ant size: 30	Swarm size: 30
Maximum number of generations: 100	Maximum number of generations: 100
Initial Value of Nodes Trail Intensity: 0.05	C1, C2= 2.0, 2.0
Coefficient $\rho = 0.4$	wstart , wend= 0.8, 0.4
Relative Important Parameter of Trail Intensity α and $\beta = 1.5, 2.0$	

Where for clearness only 80 generations are shown. It can be seen, in a typical ACO optimization process the best fitness value decreases rapidly and converges at about 29 generations, whereas for PSO it takes about 41 generations, from which it is obvious that ACO seems to perform better compared to PSO. So, for the present problem the performance of the ACO is better than PSO from an evolutionary point of view. For the computational time algorithm, the population size has been fixed to 30 for both PSO and ACO algorithms, the computational time is averaged over the 15 runs. It is clear from the graphis shown in fig.9 that the computational time for PSO is low compared to the ACO optimization algorithm. Moreover, for ACO it increases more rapidly with the number of generations.

The higher computational time for ACO is due to the communication by pheromone substance between ants after each generation. The more accuracy trails are updated after having constructed a complete path and the solution. A typical initial and final position of the ants and their transition towards noads in the graph

representation ACO is shown in fig.7.

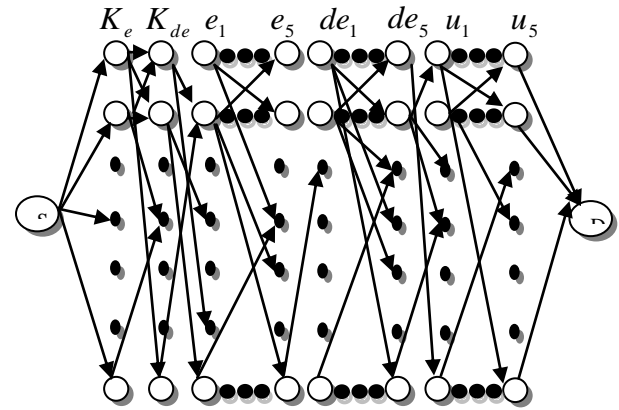


Fig.7 ACO graph representation for parameters FLC controller

Each path defines the performance indexes on the load disturbance response and transient response for a set of K_e , K_{de} , e_1 e_5 , de_1 de_5 and u_1 u_5 .

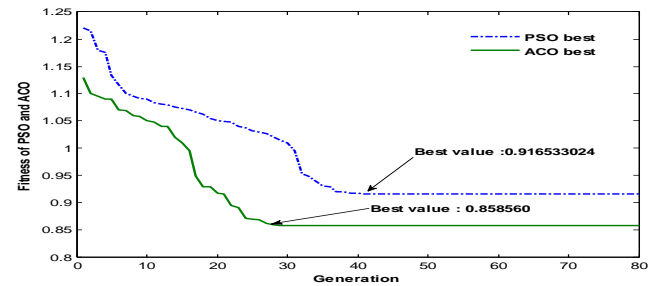


Fig. 8 Convergence of best fitness for PSO and ACO Optimization technique

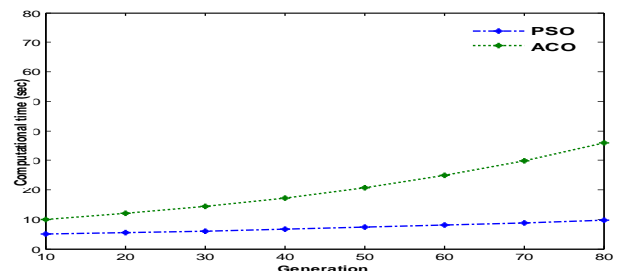


Fig. 9. Variation of computational time for PSO and ACO with generations

To assess the performance of the proposed approaches ACO and PSO optimized fuzzy logic controller on dc link voltage of shunt active power filter (SAPF), the simulations of the system are conducted using Power System Blockset in MATLAB/SIMULINK environment. The relevant parameters of the SAPF system are given in Appendix A.

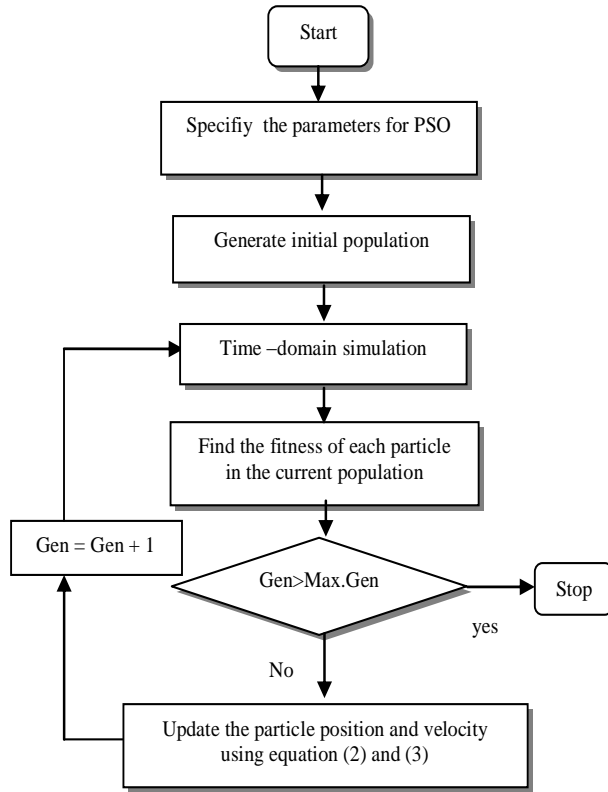


Fig.10-a. Flowcharts of particle swarm algorithm

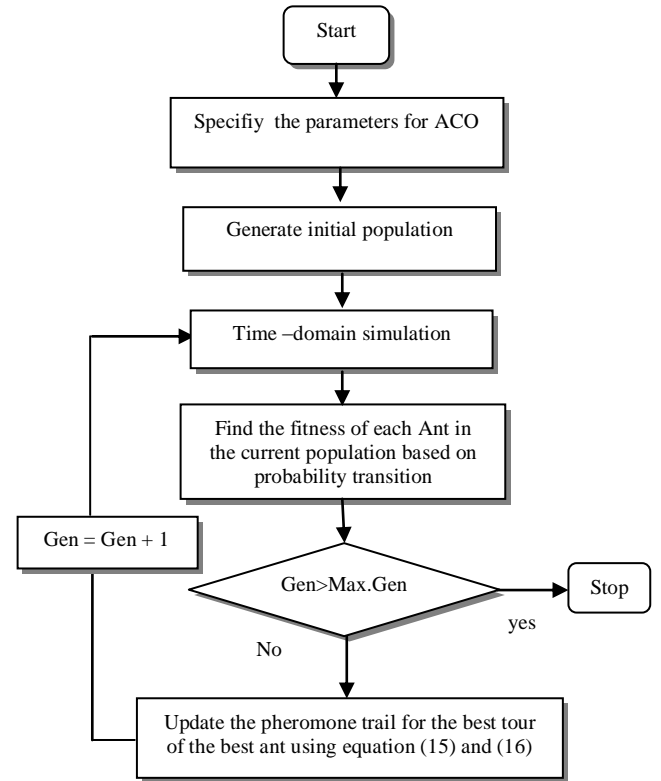


Fig.10-b. Flowcharts of ant colony algorithm

5.1.1 Case study-I: Conventional fuzzy logic controller

The fuzzy logic proportional-derivative controller consist mainly a reference to a fuzzy logic inference system. The inference system has three linguistic variables which are the two inputs (error signal and error derivative) and the output (control signal) The fuzzy logic inference system for the fuzzy proportional-derivative controller contains a set of fuzzy logic rules that define the behavior of the system in relation between the error signal, error derivative signal and the control signal of the controller [19]. The first input to the fuzzy logic inference system is the error signal which is the difference between the desired voltage V_{dc}^* and the actual V_{dc} of the converter capacitor. The error derivative signal is achieved by differentiating the error signal before passing it to the fuzzy logic controller block. Since the fuzzy logic controller block expects two inputs, a multiplexer is used to combine the error signal and the error derivative signals as input into the block fig.11.

The tuning of the fuzzy logic controller can be achieved by either adjusting the range of the universe

variables are defined as {NB, NS, Z, PS, PB} meaning negative big, negative small, zero, positive small and positive big respectively, adjusting the input and output scaling gains of the controller or adjusting the number, type and positions of the membership functions used. The membership functions of the conventional fuzzy logic controller are shown in Fig. 12. The type of fuzzy inference engine used in this study is Mamdani. Fuzzy rules are summarized in Table.2. The shunt active power filter is connected in parallel with nonlinear load, for this case the Conventional FLC controller is used to see the voltage regulation of dc link and its effect in damping harmonics current and reducing total harmonic distortion [20].

Simulation results show the line currents and its spectrum before compensation Fig.13, Fig.14 and the line current and its total harmonic distortion (THD) after compensation Fig.15, Fig.16 using shunt active power filter based on conventional FLC controller, the total harmonic distortion (THD) has been reduced from 26.87 % to 3.98 %.

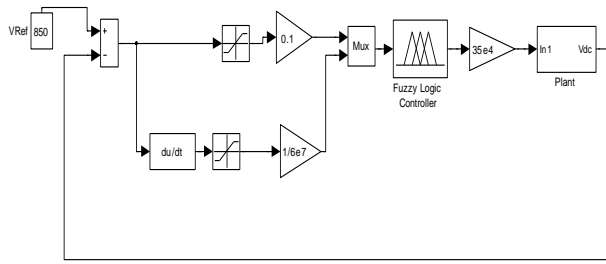


Fig. 11: Simulink model for fuzzy logic controller

Table.2 Fuzzy inference rule

$U(t)$		Error				
		NB	NS	Z	PS	PB
Derivative error	NB	NB	NB	NS	NS	Z
	NS	NB	NS	NS	Z	PS
	Z	NS	NS	Z	PS	PS
	PS	NS	Z	PS	PS	PB
	PB	Z	PS	PS	PB	PB

Where: NB: negative big, NS: negative small, Z: zero, PS: positive small, PB: positive big

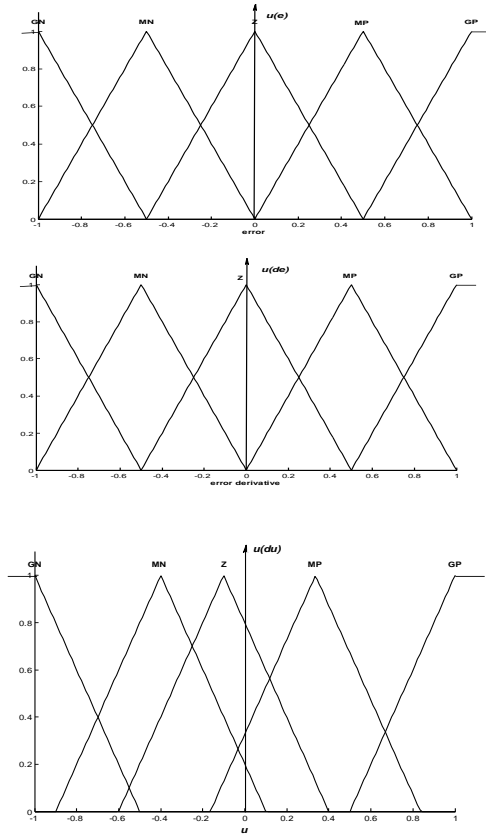


Fig. 12 Membership functions for conventional fuzzy logic controller

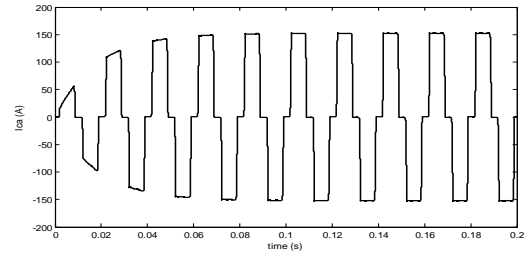


Fig.13 Supply current waveform of single phase

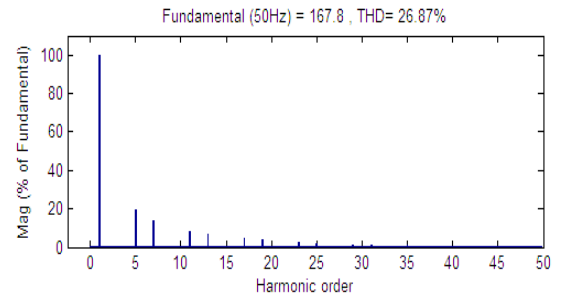


Fig.14 Harmonic spectrum of supply current

The dc link voltage V_{dc} is used in the voltage regulator to engender the control signal which forces the shunt active power filter to draw additional active current from the network, to compensate for losses in the power circuit of the shunt active filter. Fig.17 shows the dc link voltage regulation using conventional fuzzy logic controller.

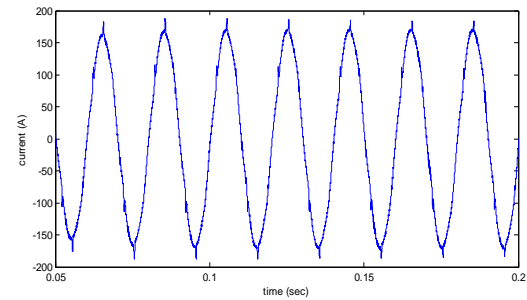


Fig.15 Supply current waveform of single phase after compensation using conventional FLC control

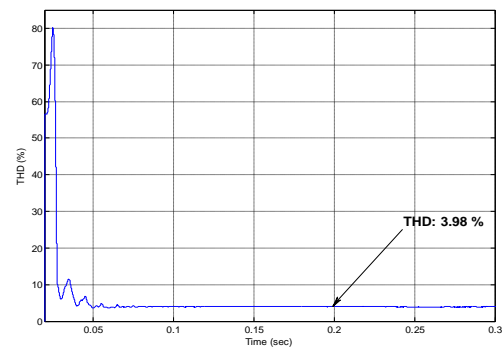


Fig.16 Total harmonic distortion after compensation using conventional FLC control

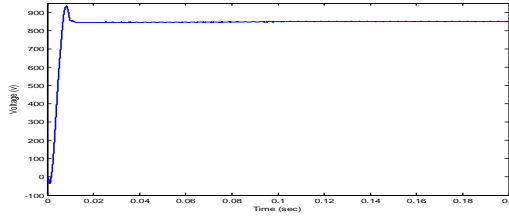


Fig.17 DC link voltage waveform using conventional FLC control

5.1.2 Case study-II: Optimal fuzzy logic controller based on PSO and ACO algorithm

In order to verify and compare the efficiency of the optimized controllers, the performance of both the PSO-FLC and ACO-FLC are applied for dc link control to shunt active power filter. In this proposed method, the optimization of the fuzzy logic controller is done by ACO and PSO approach to define a control performance indexes. Here, we use; the system indexes overshoot σ (%), rise time t_r , settling time t_s and integral absolute error e_{ia} as a performance indexes. Since the parameter vector $K = (f\delta, ftr, feia, fts)$ has effects on control performance of a manipulator, $F = f(K)$ is describe to describe the response. Both particle swarm and ant colony algorithm are used to optimize the membership functions and the scaling gains for desired control performance in self-organizing process.

Optimization results: The resulting optimized scaling gains are given in Table.3. The PSO and ACO-optimized membership functions for the three linguistic variables are shown in Fig.18

Table.3. Comparisons of SAPF indexes between used and unused particle swarm and ant colony optimization

Parameter and indexes	Conventional FLC controller	Optimized FLC controller with PSO	Optimized FLC controller with ACO
Proportional Error input scale	0.1	0.9965	0.9931
Error Derivative input scale	$1/6e^7$	$1/6.321e^7$	$1/6.053e^7$
Output Scale	$35e^4$	$37.432e^4$	$37.2206e^4$
Overshoot (%)	11.0247	3.7918	2.1126
Rise time (sec)	0.0068	0.006789	0.006787
Settling time	0.0211	0.01089	0.00988
Integral absolute error	$4.4628e^{+00}$	$4.0337e^{+00}$	$3.9636e^{+00}$

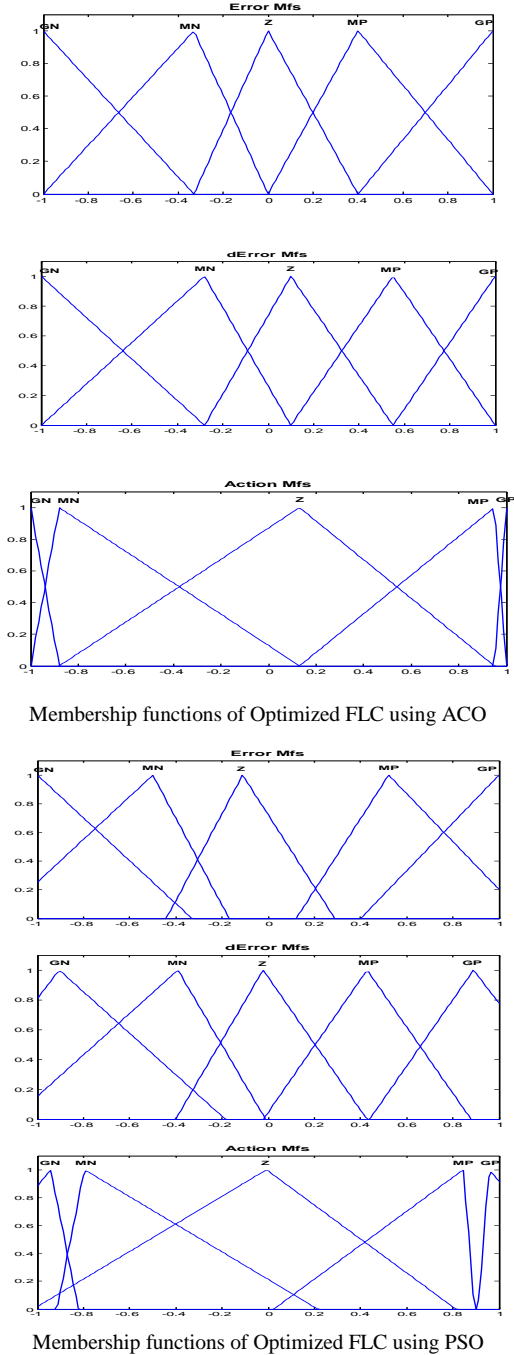


Fig. 18: Modified Membership plot Function for input variable (Error-dError) and output variable (Control action) using PSO and ACO Algorithm

In fig. 19, for dc link voltage control, the responses with conventional fuzzy logic controller, proposed PSO optimized FLC controller and proposed ACO optimized FLC controller are shown with legends conventional FLC, optimized FLC-PSO and optimized FLC-ACO, respectively.

It is clear from Fig. 21 that FLC-PSO and FLC-ACO go one better than conventional-FLC. The responses with proposed methods are much faster, with less overshoot, rise time and settling time compared to the conventional controller Tab.3. In the other hand, the last simulations show the effectiveness of shunt active power filter using new optimal approach (PSO and ACO algorithm) for harmonics injection control under balanced voltages. The THD has considerably decreased from 3.98 % (conventional control) to 2.31 % and 1.90 % respectively by PSO technique and ACO technique

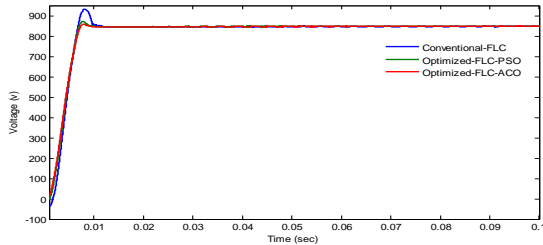


Fig.19 DC link voltage response curve of Optimal SAPF based PSO and ACO optimization

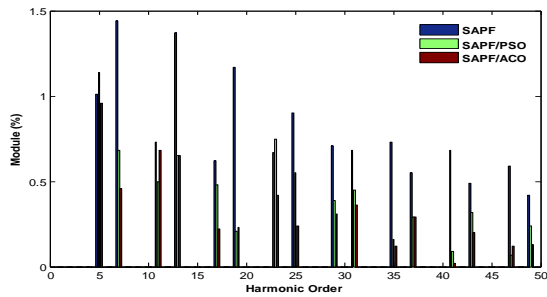


Fig.21 Comparative harmonics contents of supply currents for proposed approach methods

Fig. 20 show the supply current waveforms after optimal harmonic compensation which is improved compared to the primal system. It is observed that the optimal control using ant colony algorithm performs well in reducing harmonics compared the other methods.

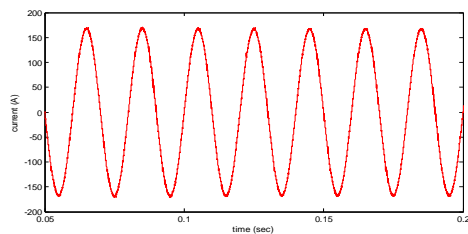


Fig.20 Supply current waveform of single phase after compensation using Optimized FLC control

The harmonic contents repartition in the supply current before and after optimal compensation using the two methods, under balanced voltage source conditions is presented in fig.21. It is observed that the optimal control using ant colony algorithm performs well in reducing harmonics compared the other methods.

6. Conclusion

Stochastic methods (PSO and ACO algorithm) used in the present work are inspired by nature, and has proved themselves to solving optimization problems. The main objective of this contribution is to compare the effectiveness of these two optimization techniques for SAPF based FLC-PSO and ACO controller design.

The simulation results indicate that the ant colony optimization has a good sharp for finding optimal fitness function (F: 0.85856) compared to particle swarm technique (F: 0.916533), and has demonstrated that the control strategy with both PSO and ACO for DC link voltage regulation is effective for power quality improvement, it can be seen that after SAPF with FLC-PSO and FLC-ACO controllers runs, the current total harmonic distortion has decreased from 3.98% to 2.31% (PSO), 1.90%(ACO) and the power factor from factor from 0.87 to 0.92(PSO), 0.95(ACO) Tab.4.

Table.4 THD and Power factor are measured under various methods

	Without APF	With APF		
	Vdc controller	FLC	FLC-/PSO	FLC-ACO
THD (%)	26.87	3.98	2.31	1.90
Power factor		0.87	0.92	0.95
Robustness		3.55	4.65	5.03

The proposed most favorable fuzzy controller based ant colony algorithm is giving better performance than conventional FLC controller in terms of Vdc setting time, reactive power compensation (PF) and THD. The FFT analysis of the optimal active filter confirms that the THD of the source current is less than 7 % that is in compliance with IEEE-519 and IEC 61000-3 harmonic standards.

Generally, the proposed stochastic approach applied to the shunt active power filter control has best dynamic performance and good robustness.

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