Fuzzy Logic Knowledge Applied On Electrical Network For Nodal Detection Using Particle Swarm Neighborhood For Banks Capacitor Compensation

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Abstract: *Reactive power flow is one of the most problem of electrical distribution systems, It's cause reduction of active power transmission, diminish power losses, and augment the drop voltage in this research we described an efficiency approach FLC-PSO to solve the optimal power flow (OPF) combinatorial problem. The proposed approach employ tow algorithms, Fuzzy logic controller (FLC) algorithm for nodal detection and Particle Swarm Optimization (PSO) algorithm for optimal sizing capacitor of OPF combinatorial problem control variables. PSO method is more proficient in improving combinatory problem. The proposed approach has been examined and tested on the standard IEEE 57-bus test System with different objectives that reflect cost function minimization, voltage profile improvement, and voltage stability enhancement. The proposed approach results have been compared to those that reported in the literature recently. The results are promising and show the effectiveness and robustness of the proposed approach.*

Key words: *capacitor placement,, fuzzy logic ,particle swarm optimization (PSO) , capacitor seizing ,power flow.*

1. Introduction

Power distribution systems from electric power plants to ultimate consumers are accomplished via the transmission system, and distribution lines. Studies have indicated that as much as 13% of total power generated is consumed as RI^2 losses at the distribution level. The RI^2 losses can be separated to active and reactive component of branch current, where the losses produced by reactive current can be reduced by the installation of shunt capacitors. Capacitors are widely used in distribution systems to reduce energy and peak demand losses, release the KVA capacities of distribution apparatus and to maintain a voltage profile within permissible limits. The objective of optimal capacitor placement problem is to determine the size, type, and location of capacitor banks to be installed on radial distribution feeders to achieve positive economic response. The economic benefits obtained from the loss reduction weighted against capacitors costs while keeping the operational and power quality constraints within required limits.

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 [3, 4]. 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 logic 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.

Many of the previous strategies for capacitor allocation in the literature are also limited for the application to planning, expansion or operation of distribution systems. Very few of these capacitor allocation techniques have the flexibility of being applicable to more than one of the above problems. Hence, this paper presents a FLC_PSO approach to determine suitable locations for capacitor placement and the seizing of the capacitor. This approach has the versatility of being applied to the planning, expansion, and operation studies of distribution systems. The proposed method was tested on electrical distribution systems consisting of standard IEEE 57-bus test System.

The fuzzy logic controller is employs to detection the critical nodal. The PSO methods have been employed successfully to solve complex optimization problems. It used to seizing the optimal capacitor banks. Simulation results are given to show the effectiveness of FLC_PSO approach.

The structure of the work presented in this paper is organized in the following sequence: Mathematical formulation is set in section 2. Section 3 shows the Fuzzy Logic Controller. Section 4 shows the Particle Swarm Optimization (PSO). Section 5 shows the development space vector modulation technique based DTC for Electric vehicle motorization. The proposed structure of the studied propulsion system is given in the

section 6. The simulation results of the different studied cases are presented in Section 6.

2. Mathematical formulation

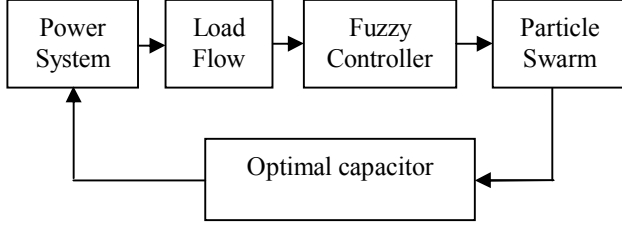The Principe of method is presented in figure1.

Fig. 1. Bloc of intelligent fuzzy-ant approach.

The objective function of placement to reduce the power loss and keep bus voltage within prescribed limits with minimum cost .The constraint are voltage limits .Following the above notation, the total annual cost function due to capacitor placement and power losses written as [10]:

$$Minimize \quad \left\{ F = K_{PL} P_L + \sum_{j=1}^{N} K_{Cj} B_J \right\} \quad (1)$$

Constraint of voltage

$$V_i^{min} \leq V_i^{min} \leq V_i^{max} \quad i = 2,3,....N \quad (2)$$

Where:

F : Total annual cost function ($).

K_{PL} : Annual cost per unit of power losses ($/KW).

P_L :Total active power loss (KW)

K_{Cj} :Total active power loss (KW)

B_j : Shunt capacitor size placed at bus j (KVAR).

N : Number of buses.

V_{min} : Minimum permissible voltage

V_{max} : Maximum permissible voltage

3. Fuzzy Logic Controller

Fuzzy logic is expressed by means of the human language. Based on fuzzy logic, a fuzzy controller converts a linguistic control strategy into an automatic control strategy, and fuzzy rules are constructed by expert experience or knowledge database. First, set the power loss index PLI and the voltage V to be the input variables of the fuzzy logic controller. The Capacitor suitable index CSI is the output variable of the fuzzy logic controller. The linguistic variables are defined as

{L, LM, M, HM, H}, where L means low, LM means low medium ,M means medium HM means height medium and H means height. The membership functions of the fuzzy logic controller are shown in Fig. 3. The fuzzy rules are summarized in Table 1. The type of fuzzy inference engine is Mamdani. The fuzzy inference mechanism in this study follows as :

$$\mu_B(u(t)) = \max_{j=1}^{m} \left[\begin{array}{c} \mu_{A_1^j}(e(t)), \mu_{A_2^j}(de(t)), \\ \mu_{B^j}(u(t)) \end{array} \right] \quad (3)$$

where $\mu_{A_1^j}(PLI)$ is the membership function of PLI , $\mu_{A_2^j}(V)$ is the membership function of V , $\mu_{B^j}(CSI)$ is the membership function of SCI , j is an index of every membership function of fuzzy set, m is the number of rules and is the inference result. Fuzzy output CSI can be calculated by the centre of gravity defuzzification as :

$$u(t) = \frac{\sum_{i=1}^{m} \mu_B(u_i(t)).u_i}{\sum_{i=1}^{m} \mu_B(u_i(t))} \quad (4)$$

Where: i : is the output rule after inferring.

3.1 Fuzzy based capacitor location

Node voltages and power loss indices are the inputs to fuzzy controller to determine the suitability of a node in the capacitor placement problem. The suitability of a node is chosen from the capacitor suitability index (CSI) at each node. The higher values of CSI are chosen as best locations for capacitor placement [1, 2, 3, 4, 5].

The power loss indices are calculated as:

$$PLI(i) = \frac{(L_R - L_{MAX})}{(L_{MIN} - L_{MAXN})} \quad i = 2,3,...N \quad (5)$$

Where:

L_R : Loss reduction

L_{MIN} : Minimum reduction

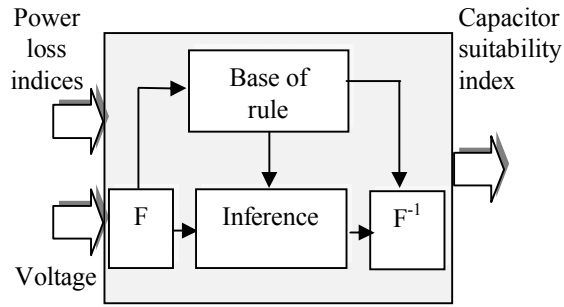L_{MAX} : Maximum reduction

N : Number of bus

Fig. 2. Structure of Fuzzy Controller.

Where:

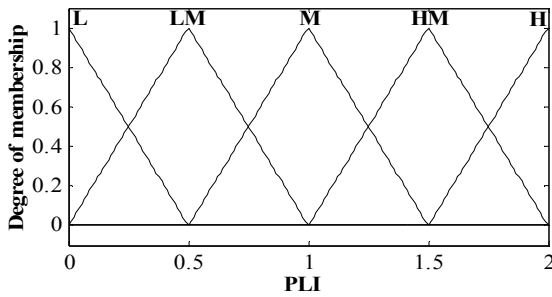F : Fuzziffication, F^{-1} :Defuzzification

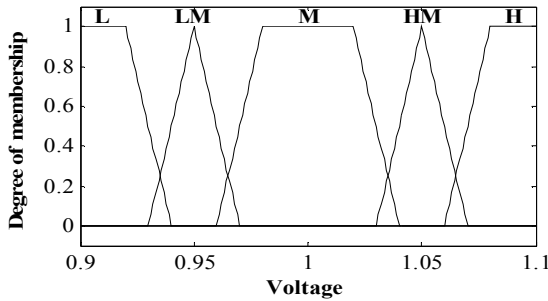Fig. 3. Power loss indices membership.

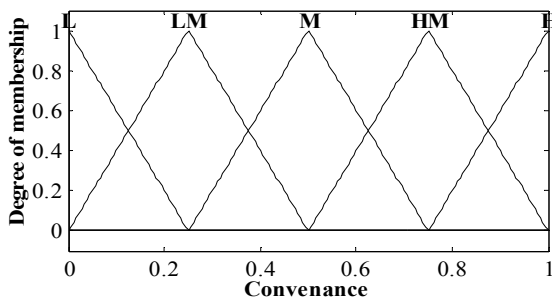Fig. 4. Voltage membership functions.

Fig . 5. Capacitor suitability index membership function.

To determine the critical busses the voltage and power loss index at each node shall be calculated and are represented in fuzzy membership function. By using

these voltages and PLI, rules are framed and are summarized in the fuzzy decision matrix as given in table.1.

Table 1

Decision matrix for determining suitable capacitor

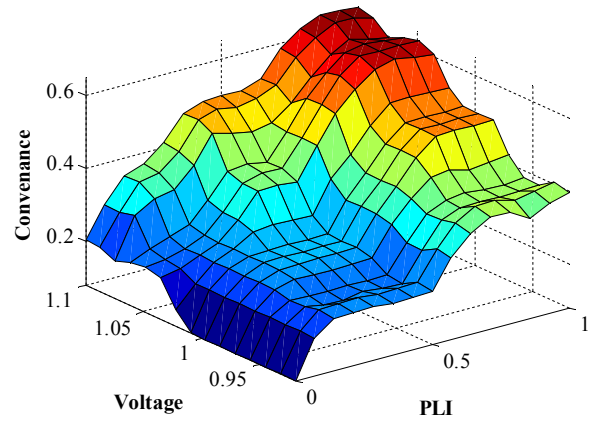| CSI		V				
		L	LM	M	HM	H
PLI	L	L	L	L	LM	LM
	LM	L	L	LM	LM	M
	M	L	L	LM	M	HM
	HM	L	LM	M	HM	HM
	H	LM	LM	M	HM	H

Fig. 6. View plot surface of fuzzy controller.

3.2 Algorithm (FLC) for identification of busses identification

Following algorithm explain the methodologies to identify critical busses, witches are more suitable for capacitor placement [6,10].

Step1: Read line and load data of power system.

Step2: Calculate power flow by Newton Raphson methods

Step: Determine total active power loss.

Step: By compensation the self –reactive power at each node and conduct the load flow to determinate the total active power losses in each case.

Step5: Calculate the power loss reduction and power flow loss indices.

Step6: The PLI and the per-unit voltage are the inputs to the fuzzy Controller.

Step7: The outputs of Fuzzy controller are defuzzified. This gives the ranking of CSI. The nodes having the highest value of CSI are the most suitable for capacitor placement.

Step8: Stop.

4. Particle Swarm Optimization (PSO)

PSO is a population-based optimization method first proposed by Eberhart and Colleagues [8, 13, 15, 16, 17]. Some of the attractive features of PSO include the ease of implementation and the fact that no gradient information is required. It can be used to solve a wide array of different optimization problems. Like evolutionary algorithms, PSO technique conducts search using a population of particles, corresponding to individuals. Each particle represents a candidate solution to the problem at hand. In a PSO system, particles change their positions by flying around in a multidimensional search space until computational limitations are exceeded. Concept of modification of a searching point by PSO is shown in Fig. 7.
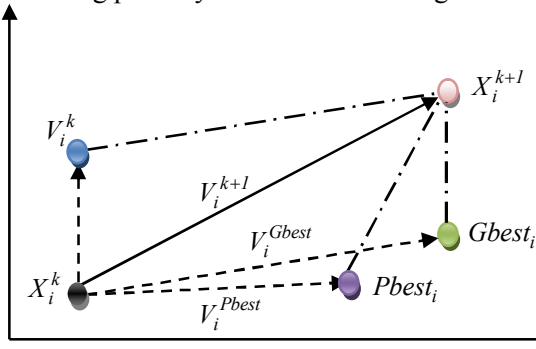

Fig. 7. Concept of modification of a searching point by PSO.

The PSO technique is an evolutionary computation technique, but it differs from other well-known evolutionary computation algorithms such as the genetic algorithms. Although a population is used for searching the search space, there are no operators inspired by the human DNA procedures applied on the population. Instead, in PSO, the population dynamics simulates a 'bird flock's' behavior, where social sharing of information takes place and individuals can profit from the discoveries and previous experience of all the other companions during the search for food. Thus, each companion, called particle, in the population, which is called swarm, is assumed to 'fly' over the search space in order to find promising regions of the landscape. For example, in the minimization case, such regions possess lower function values than other, visited previously. In this context, each particle is treated as a point in a d-dimensional space, which adjusts its own 'flying' according to its flying experience as well as the flying experience of other particles (companions). In PSO, a particle is defined as a moving point in hyperspace. For each particle, at the current time step, a record is kept of the position, velocity, and the best position found in the search space so far.

The assumption is a basic concept of PSO [13]. In the PSO algorithm, instead of using evolutionary operators such as mutation and crossover, to manipulate algorithms, for a d-variable optimization problem, a flock of particles are put into the d-dimensional search space with randomly chosen velocities and positions knowing their best values so far (Pbest) and the position in the d-dimensional space. The velocity of each particle, adjusted according to its own flying experience and the other particle's flying experience. For example, the i-th particle is represented as $x_i = (x_i,1, x_i,2,....., x_i,d)$ in the d-dimensional space. The best previous position of the i-th particle is recorded and represented as:

$$Pbest_i = (Pbest_i,1, Pbest_i,2,....., Pbest_i,d) \qquad (6)$$

The index of best particle among all of the particles in the group is gbestd. The velocity for particle i is represented as $v_i = (v_i,1, v_i,2,....., v_i,d)$ The modified velocity and position of each particle can be calculated using the current velocity and the distance from Pbesti,d to gbestd as shown in the following formulas [4]:

$$v_{i,m}^{(t+1)} = w.v_{i,m}^{(t)} + c_1 * rand() * (Pbest_{i,m} - x_{i,m}^{(t)}) + c_2 * Rand() * (gbest_m - x_{i,m}^{(t)}) \qquad (7)$$

$$x_{i,m}^{(t+1)} = x_{i,m}^{(t)} + v_{i,m}^{(t+1)} \qquad (8)$$

$$i = 1,2,....,n; m = 1,2,....,d$$

Where:

X_k	: Current position,
X_{k+}	: Modified position
V_k	: Current velocity,
V_{k+1}	: Modified velocity,
$VPbest$	:Velocity based on Pbest,
$VGbest$	:Velocity based on Gbest
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,
	$: V_d^{min} \le v_{i,d}^{(t)} \le V_d^{max}$
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

The evolution procedure of PSO Algorithms is shown in Fig. 5. Producing initial populations is the first step of PSO. The population is composed of the particle. The corresponding evaluation of a population is called the "fitness function". It is the performance index of a population. The fitness value is bigger, and the performance is better. The fitness function is defined in (1).After the fitness function has been calculated, and check the constraint voltage the fitness value and the number of the generation determine whether or not the evolution procedure is stopped (Maximum iteration number reached?). In the following, calculate the Pbest of each particle and Gbest of population (the best movement of all particles). The update the velocity, position, gbest and pbest of particles give a new best position (best chromosome in our proposition).

The principal idea is to form a matrix of which the number of line is equal to the number of critical busses and the number of column is equal to the capacitor size. The problem becomes entirely mathematical. Follows called the algorithm illustrate in fig8.

5. Results

The FLC-PSO is coded in MATLAB environment version7.6 (R2008a), and run using an Intel Pentium 4, core duo 1.87 GHz PC with 2 Go DDRAM-II- and 2 Mo cache memory. All computations use real float point precision without rounding or truncating values. More than 6 small-sized test cases were used to demonstrate the performance of the proposed algorithm. Consistently acceptable results were observed.

The FLC-PSO method has been applied on the network test IEEE 57 buses that represent a portion of the American electric power system (the Midwestern, USA) for December 1961. This electric network is constituted of 57 buses and 7 generators (at the buses Nº: 1, 2, 3, 6, 8, 9 and 12) injecting their powers for a system nourishing 42 loads through 80 lines of transportation (Show in Fig 1). The base voltage for every bus is of 135 kV. The proposed method is illustrated with a system, consisting of standard IEEE 57-bus test System. The location for placement of

capacitors is determined by fuzzy controller and the capacitor sizes are evaluated using particle swarm optimization.

FLC-PSO approach is applied for IEEE 57-approach given above is shows at table 1.

In primary case we applied the first algorithm (FLC) based fuzzy logic controller logic which gives the critical busses show in table 1, follows in makes call the particle swarm optimization conceived for difficult combinative optimization to optimize the objective function (1) all respect limit constraints voltage (2) .finally we obtained the optimal cost function and the value of optimal capacitor for each critical buses all that are illustrated in table 2.
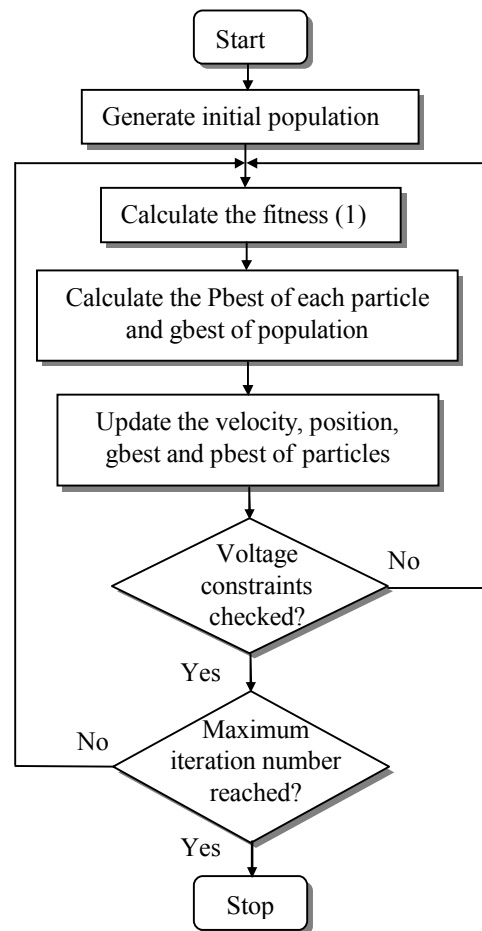

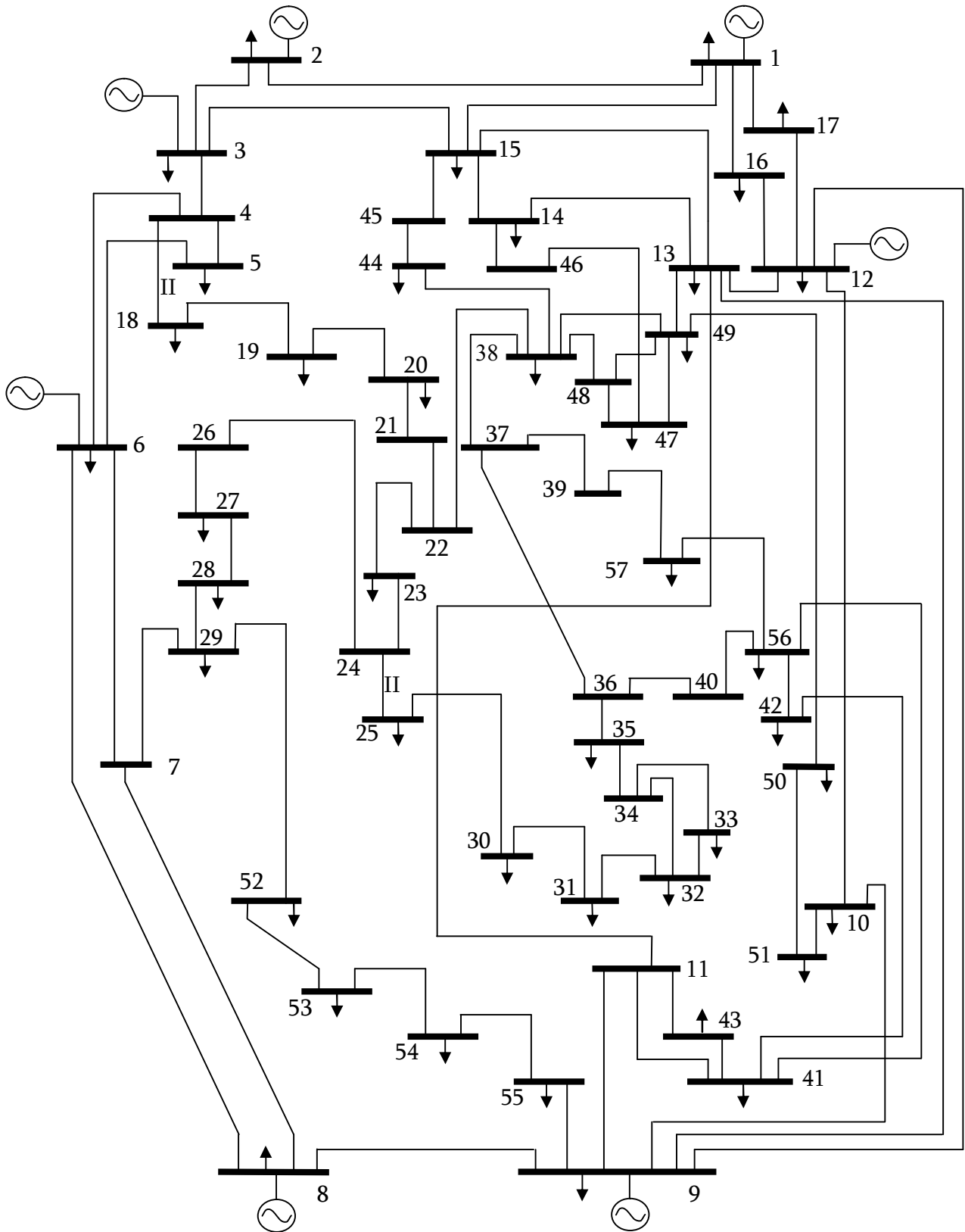Fig. 8. The evolution procedure of PSO Algorithms

Fig. 9. Topology of the IEEE 57-bus.

After application the new approach FLC-PSO the results are improved, the loss are decreased by 17.189 % as well as the reactive power injected into the electrical distribution system is diminishing by 12.33 % and the nodal voltages are improved.

Table 2
The initialized coefficients of the PSO

Coefficients	Value
Population Size	50
Number of Iteration	100
w_{max}	0.6
w_{min}	0.1
$c_1 = c_2$	1.5

Table 3
Results of FLC-PSO

Fuzzy logic controller (FLC)	
N° of critical buses	Value of capacitor [MVAR]
10	4.39
19	2.12
21	3.11
28	3.69
32	5.91
33	7.35
52	1.55
Practical swarm optimization (PSO)	

	Before placement of optimal capacitor	After placement of optimal capacitor
Power Losses [MW]	18.50	15.32
Minimal Voltage [Per Unit]	0.935	0.976
Reactive Power [MVAR]	275.23	241.27

Table 4
Comparison of the results gotten by ACO-OPF, QN-OPF, matpower and proposed method FLC-PSO on the IEEE 57-bus electrical network

Results	Power Loss [MW]	Reactive Power [MVAR]
GA-OPF [29]	18.60	-
QN-OPF	17.16	-
ACO-OPF	17.96	-
MATPOWER	16.512	270.56
FLC-PSO	15.32	241.27

In our application we have compared the FLC-PSO by another approach explained in the tables 3 and 4. Genetic algorithm based optimal power GA-OPF [8], Ant Colony Optimization (ACO) algorithm for optimal flow ACO-OPF [14], Quasi Newton based optimal power flow QN-OPF and MATPOWER. Our approach FLC-PSO was proved the satisfactory results are illustrated in table 4.

The constraints of security are also verified for the angles and the amplitudes of voltages, the levels of voltage (Per Unit) for the IEEE 57-bus Electrical Network are drawn in the Fig. 10 and Fig. 11.
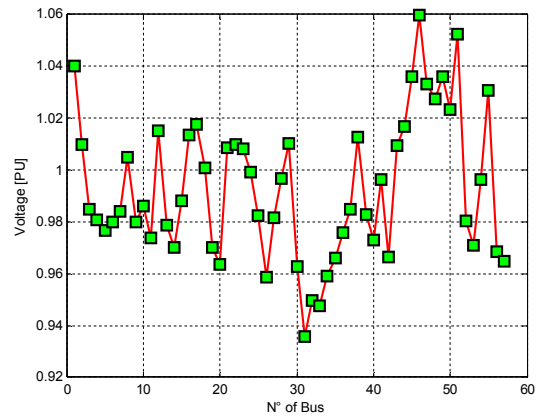

Fig. 10. The levels of voltage (Per Unit) for the IEEE 57-bus Electrical Network Before placement of optimal capacitor.
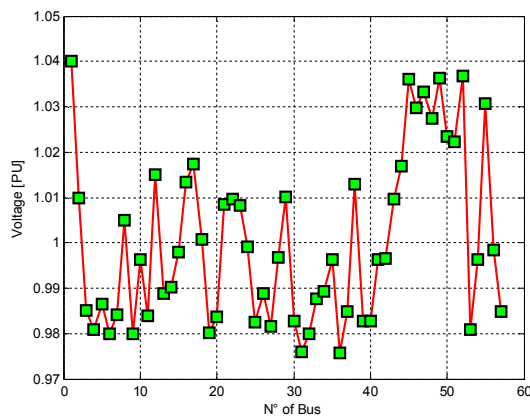
Fig. 11. The levels of voltage (Per Unit) for the IEEE 57-bus Electrical Network After placement of optimal capacitor.

6. Conclusions

In this paper, a novel approach FLC-PSO based particle swarm optimization and fuzzy logic controller to OPF problem has been presented. The proposed approach FLC-PSO utilizes the fuzzy logic controller for identification the critical bus and the update velocity and position for each particle capabilities of PSO to search the optimal seizing capacitor banks. Different objective functions have been considered to minimize losses and, to improve the voltage profile, and to enhance voltage stability. The proposed approach has been tested and examined with different objectives to demonstrate its effectiveness and robustness. The results using the proposed approach were compared to those reported in the literature. The results confirm the potential of the proposed approach and show its effectiveness and superiority over the classical techniques and genetic algorithms

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