A Modified PSO Technique for the Coordination Problem in Presence of DG

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***Abstract*— Classic optimization methods are slow and have low performance. Also it does not give global solution for the problem. Using a new technique like PSO is promise technique, but this evolutionary technique sometime do not converge faster because setting initial values of that technique depend on every domain of application. Choose suitable initial setting to that technique which makes it converge faster is a hard task. In this paper, the author used PSO with prediction technique to solve coordination problem. Author used prediction technique to choose suitable initial setting for PSO in the coordination domain. Optimum initial setting of PSO is done which make PSO faster in converging. And the other after prediction of optimal initial setting values is used. Results show the second method is valid and conversion is done faster than the first one which proves the validity of prediction technique. The Modified PSO technique cares about the determination of the PSO initial values and number of particles. The new proposed PSO technique is applied to a 10-bus system and a real feeder to calculate the maximum allowable DG penetration level for maintaining the coordination of distribution system's protection devices. A comparison between the results with the classic PSO technique and the proposed modified PSO technique shows that the new technique provides better results in terms of the speed of convergence.**

***Keywords*— Distributed Generation, Particle Swarm Optimization (PSO), Coordination.**

I. INTRODUCTION

PSO is a population-based optimization technique that is originally inspired by the sociological behavior associated with bird flocking and fish schooling [1]. PSO has many advantages over other optimization techniques like [1]:

- It is easy to implement and program with basic mathematical and logic operations.
- It does not require a good initial solution to start its iteration process.
- It is a free algorithm unlike many conventional techniques.
- It has less parameters to adjust unlike many other competing evolutionary techniques.

Research in power system has its share in applying PSO to various optimization problems. Reference [2] introduced a survey of PSO applications in power system operations such as economic dispatch, power system restoration, reactive power control, power losses reduction, optimal power flow, and power system controller design. According to reference [3], most DG studies use the PSO technique such as; DG optimal sizing &sitting for different objective functions and constraints. The application of protection studies needs fast responses. PSO technique acts faster than any other EA. In most published literature, the classic PSO technique is used for constrained optimization protection tasks. In this paper, a new approach to make the classic PSO technique faster. A modified PSO technique cares about the determination of the PSO initial values and number of particles. The modified technique is used to calculate the maximum allowable DG penetration level keeping the same protection system before DGs integration. In the present work a comprehensive optimization function that can address the maximum size of the DG is formulated. The optimization problem is formulated considering some constraints such as; *coordination criteria*, *system losses and voltage limits*.

II. CLASSIC PSO TECHNIQUE

PSO is initialized with a population of random solutions, called particles. The main idea of the PSO algorithm is to maintain a population of particles, referred to as "*swarm*" where each particle represents a potential solution to the objective function under consideration. Each particle in the swarm can memorize its current position that is determined by evaluation of the objective function, velocity, and the best position visited during its flying tour in the problem search space referred to as "*personal best position*" (P_{best}) [1]. *The personal best position* is the one that yields the highest fitness value for that particle. For a minimization task, the position having a smaller function value is regarded to as having a higher fitness. Also the best position visited by all the particle is memorized, i.e., the best position among all P_{best} positions referred to as "*global best position*" (g_{best}) [1]. The particles of the swarm are assumed to travel the problem search space in a discrete rather than continuous time steps. At each time step (iteration) the velocity of each particle is updated using its current velocity and its position from P_{best} *and* g_{best} according to the following equations:

$$\mathbf{V_i(t+1) = \omega V_i(t) + r_1 C_1 \left(P_i(t) - X_i(t)\right) + r_2 C_2 (G_i(t) - X_i(t))} \quad (1)$$

$$\mathbf{X_i(t+1) = X_i(t) + V_i(t+1)} \quad (2)$$

Where:

$\mathbf{V_i(t)}$: represents the particles vector initial velocity
$\boldsymbol{\omega}$: inertia weight factor

$\mathbf{r_1}$ & $\mathbf{r_2}$: random values in the range [0:1]
$\mathbf{C_1}$&$\mathbf{C_2}$: positive constants
$\mathbf{P_i(t)}$: represents the best particles initial position gives the best objective function
$\mathbf{X_i(t)}$: represents the particles vector initial position
$\mathbf{G_i(t)}$: represents the best initial position gives the best objective function among all particles
$\mathbf{V_i(t+1)}$: represents the particles vector updated velocity

$\mathbf{X_i(t+1)}$: represents the particles vector updated position

There are some attempts made to modify or develop the classic PSO technique in order to obtain best results convergence in less time. Most of researchers modified the PSO technique to solve general optimization problems such as references [4-7]. References [4-5] proposed the selection for the inertia weights according to the objective function nature. They proposed some equations to calculate the inertia weights based on the particles fitness variance. The authors in [6] proposed a combination between genetic algorithm and PSO to perform a local search. This local search modifies the particles position according to the particles fitness values. The authors in [7] propose a combining attractive and repulsive operator with function stretching technique. This algorithm utilizes adequately the characters that the attractive and repulsive operator can efficiently ensure diversity of swarm, and the characters that function stretching technique can decrease efficiently the complexity of objective function. The other researchers made special modifications to solve a specific problem such as references [8-15]. Reference [8] proposed a Tabu Search with multi-objective PSO algorithm for optimal reactive power problem. This algorithm combines table search algorithm and mutation operator to select particle's global optimal solution. The authors in [9] used PSO to solve the optimal network reconfiguration problem for power loss reduction. They proposed decreasing the inertia weight linearly during the simulation. References [10-11] modified the PSO technique to solve the optimal power flow problem. The idea of this modification is based on this social behavior that each particle tries to leave its previous worst position and its group's previous worst position. The authors in [12] presented a global convergent PSO algorithm to solve the economic dispatch problem of power systems. They added some operators such as; mutation operator to ensure the algorithm search globally in theory; the neighborhood searching operator to improve the precision of convergence; and the disturbance operator makes it possible that the particle can jump out from local minima. For the optimal protective devices coordination problem, references [13-15] modified the PSO technique. The authors in [13] reported that instead of updating the entire particle's position in all *D*-dimensions at the same time, the positions are updated one after the other.

Reference [14] proposed using the used the interior point method to obtain initial feasible solutions. This is done by initializing the pickup currents randomly, thus the problem becomes linear and the TDS values are calculated using the interior point method. The initial feasible solutions are then applied to the PSO algorithm. The authors in [15] determined the number of particles. They reported that five particles need 200 iterations for results convergence.

III. Modified PSO Technique

The classic PSO technique needs some vectors to be initialized randomly. The PSO variables are determined according to the solved problem nature. This paper proposed a modified PSO technique includes the determination the limits of the initial vector for DG current and the number of particles. This development provides better results in terms of the speed of convergence. The paper assumed that the normal range for the DG current limits can be taken as (0:0.5). The proposed development is based on some computation trials in the DG current range (0:0.5) and changing the numbers of particles (5, 10, 15,……..). In every computation trial, the number of iterations is determined. After 41 computation trial, the results convergence fast with the limits of the initial vector for DG current is [0.01:0.25] at 50 particle. The maximum iteration number during the 41 computation trial is 58 iteration. The best selection for the initial vector limits reduces the maximum number of iterations to 24. So, the computation process more fast and accurate. Figure 1 shows the result for determination of DG current initial vector limits.

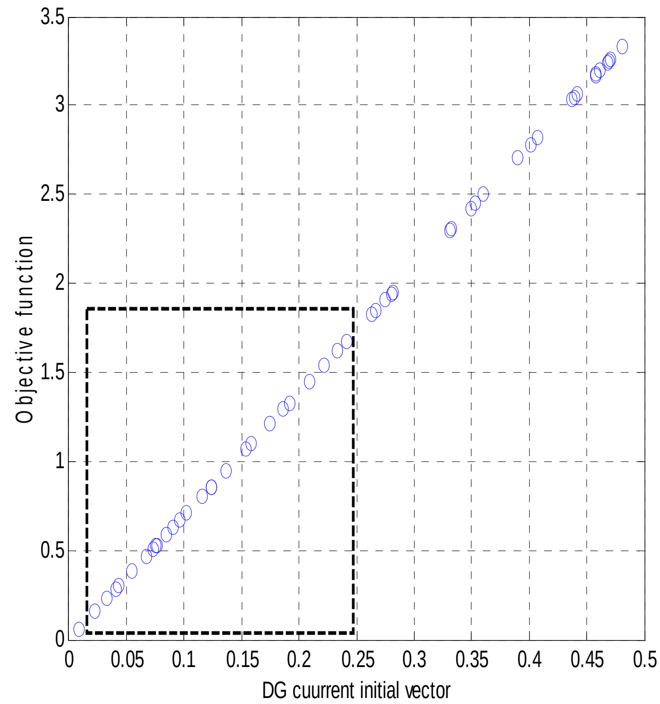

Fig.1, Determination of DG current initial vector limits

IV. Problem Formulation

The problem can be mathematically formulated as follows:

Objective function:

Max. (P_{DG}) (3)

$$P_{DG} = \sqrt{3} V_i I_{DG} \quad (4)$$

Where: P_{DG}: Output of DG

V_i: The bus (i) voltage

I_{DG}: The DG current

Constraints:

- ***Coordination constraint:***

For traditional coordination scheme, the operating time for the main protective device is less than the operating time of the backup protective device. This time relation must be held in case of maintaining coordination after adding DG.

$$T_{main\ device} - T_{backup\ device} < 0 \quad (5)$$

- ***Voltage constraint:***

$$V_{i\ min} < V_i < V_{i\ max} \quad (6)$$

V. CASE STUDIES

- **10-bus system**

The proposed algorithm is applied to a radial 10 bus distribution feeder [16] shown in Figure 2. The test system is composed of a 3-phase 2.5 MVA, 11 KV source supplying through a primary feeder, a 3-phase 2.5 MVA, 11000/400 V distribution transformer connected to two secondaries ended with 7 loads. The length of the primary feeder is 10 Km and the length of the two secondaries is 6.5 Km with the following parameters: R= 0.125 Ω/Km, L= 0.293 mH/Km and C=0.286 µF/Km. Table 1 gives the fuses and load data.

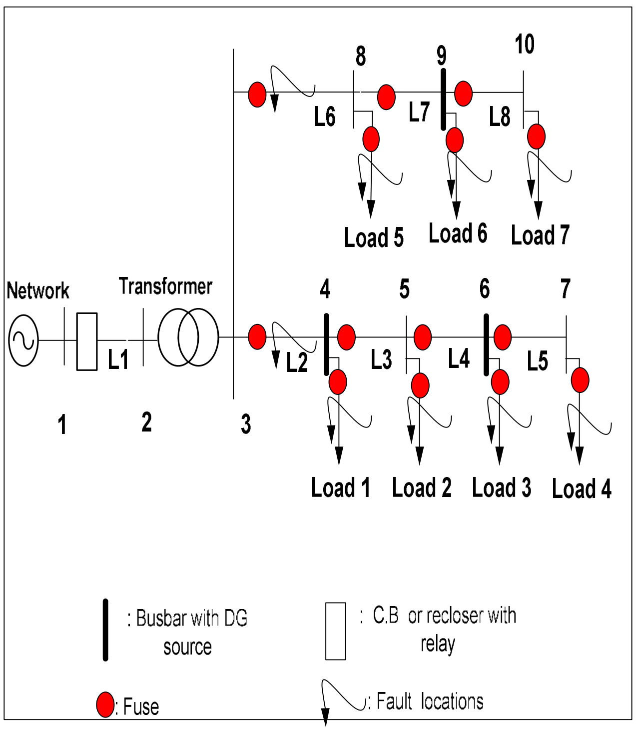

Fig.2, Schematic diagram for the 10 bus system

TABLE 1: TEST SYSTEM DATA

Fuse	Rated Current (Amps)	Load	KVA
3-4	200	Load 1	30.88
4-5	125	Load 2	38.12
5-6	80	Load 3	24.56
6-7	50	Load 4	15.12
3-8	125	Load 5	43.86
8-9	50	Load 6	14.70
9-10	25	Load 7	10.08

- Results

The classic PSO is applied to this system before applying the modified PSO technique. Table 2 shows the results comparison between the classic PSO technique and the proposed modified PSO technique. From the table; the maximum DG penetration level that maintains the traditional protective devices coordination unchanged occurs at bus 3. The classic PSO calculates this value as 0.4305 MW (17.22 % penetration level) in 47 iteration. But the proposed modified PSO gives this value as 0.4123 MW (16.491 % penetration level) in 18 iteration. The obtained value using the modified PSO technique is more accurate in less time.

In [16], a simulation method based on Simulink is used to calculate the maximum DG penetration level for the 10 bus system. The simulation method gives that maximum allowable DG penetration level 0.5 MW (20% penetration level).

TABLE 2: RESULTS COMPARISON BETWEEN CLASSIC PSO AND MODIFIED PSO FOR 10-BUS FEEDER

	Classic PSO technique			Modified PSO technique		
Bus Number	Minimum DG Size (MW)	Penetration level (%)	Number of Iterations	Minimum DG Size (MW)	Penetration level (%)	Number of Iterations
3	0.4305	17.22	47	0.4123	16.491	18
4	0.4216	16.864	21	0.3925	15.700	11
5	0.4290	17.16	41	0.3947	15.788	16
6	0.4138	16.552	33	0.4000	16.000	21
7	0.4220	16.88	31	0.4106	16.424	20
8	0.4153	16.612	28	0.4118	16.472	17
9	0.3709	14.836	47	0.3690	14.760	20
10	0.3453	13.812	26	0.3400	13.600	13

- **Real feeder**

The proposed method is applied to a real feeder: a part of AL-Mokhtalat feeder in North Delta Electricity Distribution Company in Egypt. The feeder supplies eight 3-phase distribution transformers (11KV/400V) connected to 8 loads as shown in Figure 5. The lines have the following parameters: R= 0.125 Ω/Km, X= 0.092Ω/Km. Table 3 gives the fuses and load data.

TABLE 3: PRACTICAL FEEDER DATA

Fuse	Rated Current (Amps)	Load	KVA
1	150	Load 1	67.20
2	125	Load 2	55.22
3	100	Load 3	50.00
4	50	Load 4	22.47
5	100	Load 5	50.00
6	100	Load 6	46.40
7	65	Load 7	33.29
8	80	Load 8	40.22

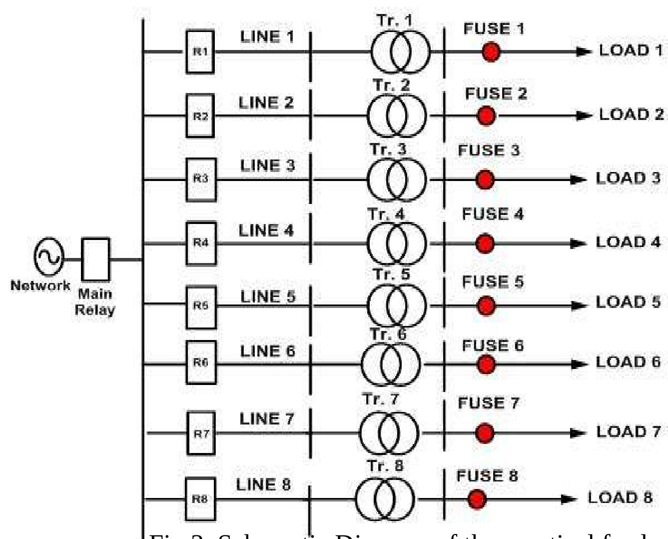

Fig.3, Schematic Diagram of the practical feeder

- **Results**

The classic PSO is applied to this system before applying the modified PSO technique. Table 4 shows the results comparison between the classic PSO technique and the proposed modified PSO technique. From the table; the maximum DG penetration level that maintains the traditional protective devices coordination unchanged occurs at the main bus. The classic PSO calculates this value as 0.7738 MW (16.121 % penetration level) in 32 iteration. But the proposed modified PSO gives this value as 0.7520 MW (15.667 % penetration level) in 24 iteration. The obtained value using the modified PSO technique is more accurate in less time. The simulation method gives the maximum allowable DG penetration level of 0.816 MW (17% penetration level).

TABLE 4: RESULTS COMPARISON BETWEEN CLASSIC PSO AND MODIFIED PSO FOR AL-MOKHTALAT FEEDER

	Classic PSO technique			Modified PSO technique		
Bus Number	Minimum DG Size (MW)	Penetration level (%)	Number of Iterations	Minimum DG Size (MW)	Penetration level (%)	Number of Iterations
Main Bus	0.7738	16.121	32	0.7520	15.667	24
1	0.7405	15.427	41	0.7113	14.818	37
2	0.7500	15.625	21	0.7381	15.377	16
3	0.7313	15.235	28	0.7258	15.121	19
4	0.7586	15.804	31	0.7511	15.647	22
5	0.7408	15.433	58	0.7439	15.497	17
6	0.7414	15.445	44	0.7277	15.160	31
7	0.7621	15.877	32	0.7410	15.437	25
8	0.7507	15.639	26	0.7358	15.329	11

VI. Conclusion

This paper presented a new approach to make the classic PSO technique faster and gives more accurate results for the coordination problem in presence of DGs. The new problem formulation takes into account maintaining the old coordination scheme before DGs integration. A proposed modified PSO technique is used to calculate the maximum allowable DG penetration level keeping the same protection system before DGs integration. The modified PSO technique cares about the determination of the PSO initial values and number of particles. As seen from the simulation results, the proposed modified PSO technique succeeds to converge to the same optimal setting found by the Simulink method. Regarding the computational speed, the proposed modified PSO technique is able to reach a very good result in small time. In spite of most of previously published PSO literature recommended the use of a population size of about 5-20 agents. This population size needs 200 iterations or 500 iteration to reach a satisfactory result. Consequently, the proposed modified PSO technique outperforms the classic PSO in terms of computational speed and memory requirements, as it requires only 10% of the number of iterations recommended by most of the previously published PSO literature (50 instead of 500).

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