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AN INVESTIGATION ON PARTICLE SWARM OPTIMIZATION ALGORITHM FOR DISTRIBUTION SYSTEM PLANNING WITH DISTRIBUTED GENERATION

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Abstract—**Nowadays, technology advancement, the drive to reduce environmental pollution and power system restructuring have caused the increase in the utilization of Distributed Generations (DGs). One of the important aspects of the power system is the optimal operation of distribution networks. Therefore, the main objective of this paper is to investigate and to find the best solution for optimal operation of distribution networks which takes into account the impact of DG. Since optimal operation of distribution networks is an optimization problem with discrete and continuous variables, so it can be introduced as an integer problem that can be formulated by metaheuristic. In this regards, this paper presents the Particle Swarm Optimization (PSO) algorithm to solve the distribution planning problem with DG. In addition, case study on IEEE 34 buses system have been carried out to demonstrate the effectiveness of the PSO algorithm. And finally the performance of PSO algorithm is compared with Genetic Algorithm (GA).**

Keywords—DG, Distribution System Planning, PSO.

I. INTRODUCTION

The power system management has faced with the major changes during the past decades. The desire to create a competitive environment has caused the separation of various sectors such as generation, transmission and distribution. These developments and the other issues such as the environmental pollution, construction problems of the new transmission lines, and technology development to the construction of small generation units has caused the increase in the utilization of Distributed Generation (DG). Most of DGs can be connected to distribution network directly without the needs to install any new transmission lines. Researches that carried out by reputable research centers such as the Electric Power Research Institute (EPRI) has shown that more than 25 percent capacity of new installed DGs were installed until 2010. According to the above explanations about DGs that connected to distribution networks, thus obviously, the most of plans and studies related to the grids should be reviewed again which one of the importance of them is optimal management of distribution networks [1, 2].

Generally, optimal operation of distribution networks applies to optimum use of resources and control equipment's such as transformers with tap changing ability under the loads, automatic voltage regulators and capacitors. This optimization is applied with two conditions; firstly, the objective function has a minimum value, secondly, the technical constraint of the problem should be applied. The distribution networks before connecting to DG were not involved with distributed electrical resources, thus the problem formulation of optimal management utilization just was included active power resources control pattern aims to reduce grid losses [3, 4]. But nowadays, first and foremost important factor in distribution network planning that should be considered is objective function and provide the appropriate solutions to control their impacts and effects. The purpose of this paper is to present the optimized utilization algorithm for distribution networks considering DGs connected to the grid. Section II will discuss the PSO algorithm.

II. PARTICLE SWARM OPTIMIZATION

The swarm intelligent algorithm is one of the evolutionary computation methods that produced by Eberhart and Kennedy to solve the optimization problems and since, their ability to be used in optimization problems has been demonstrated [5]. In this method, the movement towards the optimal point that obtained from the best information of each particle included in the initial population (Best Personal Position) and optimal position that is found by neighbor's points (Best Global Position). According to Fig1 the basis of PSO can be explained as following:

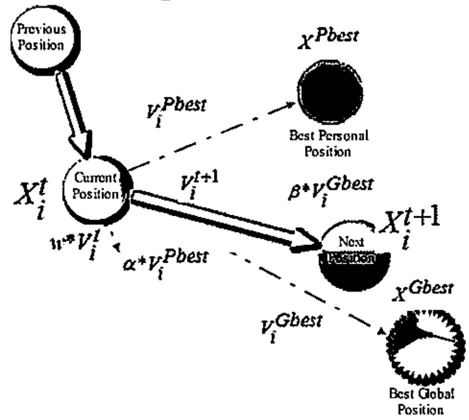

Fig 1: Principle of PSO particle movement

In PSO algorithm at first some candidate point assume in intended search space as initial population. All points are based on Euclidean distance in a various categories. The instance, in Fig 1 X_i is consisting of three factors tracer. The function of each particle in the search space is calculated and in each category is determined the value of particle depending on the target function is minimized or maximized. Thus, the best member of each category is determined. On the other hand, with regard to previous information of each particle the best point can be identified that it's already discovered. Therefore the optimal point of each category and each particle is determined. The first recognition is in each category corresponding to the global optimum and the second recognition is corresponding to the personal or local optimum point. According to Fig 1 and with this information, the particle can move in the direction of the following vector equation [6]:

$$V_i^{t+1} = (w * V_i^t) + \alpha(X^{Pbest} - X_i^t) + \beta(X^{Gbest} - X_i^t) \qquad (1)$$

$$X_i^{t+1} = X_i^t + V_i^{t+1} \qquad (2)$$

Where,

X_i^t Current position of Particle

X^{Pbest} Best personal position of Particle

$$X^{Pbest} = \begin{cases} X^{Pbest(J)} & if\ OF^{J+1} \geq OF^J \\ X_i^t & if\ OF^{J+1} \leq OF^J \end{cases} \qquad (3)$$

X^{Gbest} Best global position of Particle

$$X^{Gbest} = \begin{cases} X^{Gbest(J)} & if\ OF^{J+1} \geq OF^J \\ X^{Pbest(J+1)} & if\ OF^{J+1} \leq OF^J \end{cases} \qquad (4)$$

V_i^t Velocity of particle i towards previous vector

V_i^{t+1} Velocity of particle i towards next position

w Inertia weight factor

α&β Acceleration coefficient

OF Objective Function

So, PSO algorithm is able to achieve the best optimal global point with sequence iteration.

A. Methodology

The main target of distribution network planning is to minimize an objective function equation that the variables of this equation have a non-linear relation; therefore the objective function of the optimal operation problem is non-linear and discrete. The PSO is a heuristic method based on creating an initial random solution that Fig 2 shows the flowchart of PSO.

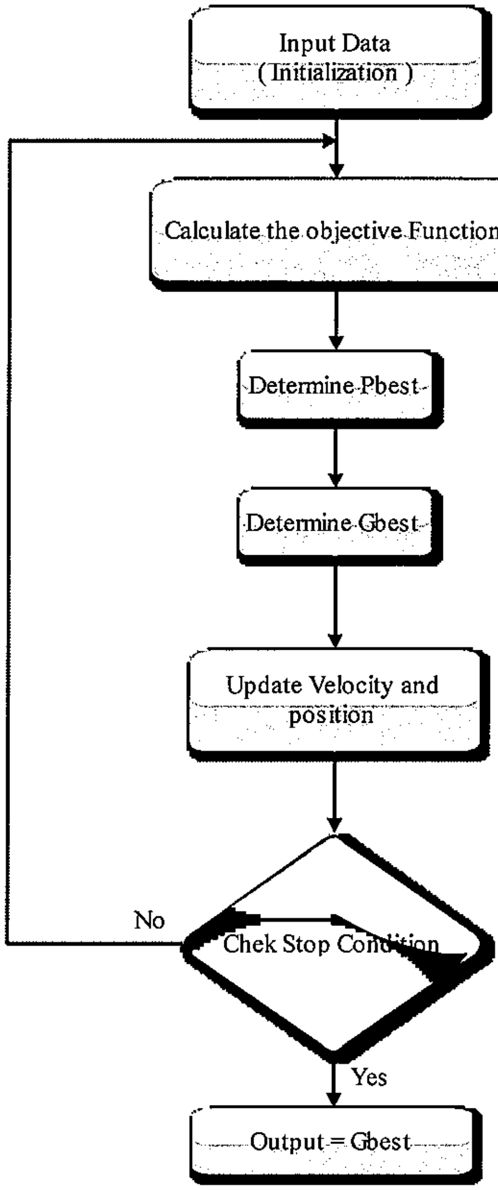

Fig 2: PSO algorithm

a) Input data initialize

The configuration of the distribution network and candidate DG sizing and locating are given in this step. Produce the function model by setting random initial population and iteration number, random initial selection of particles weight and velocity into the search space.

b) Calculate the objective function

The network solution program will set up with initial data that objective function will calculate for summation of each particle.

c) Determine Pbest

The parameters of objective function values related to the position of each particle is compared with the corresponding value in previous position with lower objective function is listed as Pbest for the current iteration as equation (3)[7].

d) Determined Gbest

In this step, the lowest objective function among the Pbests related to all particles in the current iteration is compared with it in the previous iteration and the lower one is recorded as Gbest as equation (4)[7].

e) Update velocity and position

The position and velocity of particles can be calculated for next iteration with using equations (1) and (2). It should be noted which α&β are acceleration coefficients that can be calculated as following:

$$\alpha = C_1 r_1 \quad (5)$$

$$\beta = C_2 r_2 \quad (6)$$

Where,

C_1	Personal learning coefficient
C_2	Global Learning coefficient
$r_1 \& r_2 \sim U(0,1)$	Uniformly distributed random numbers

f) Check stop condition

Depends on objective function there are different modes of finalization of the algorithm. Fig 3 shows some condition that can be stopping the algorithm.

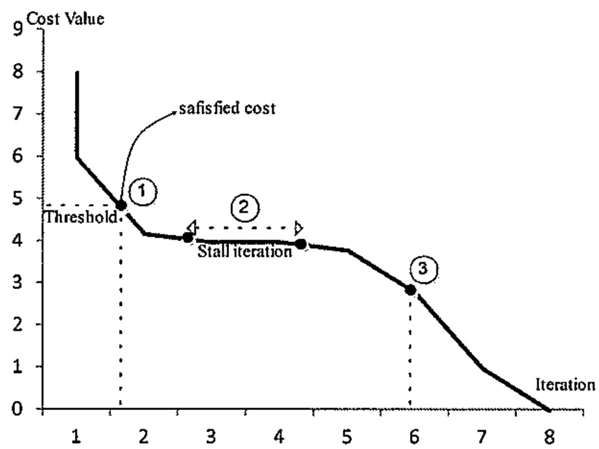

Figure 3: Stop Conditions

There are a few methods for stopping the iteration loop that in the following is expressed in three modes:

1) The algorithm can be finalized after satisfying the cost and the desired value of the objective function.

2) After achieving some stall iteration. It means after the specified time has elapsed or number of iterations without any improvement in outcome

3) After the specified time has elapsed or number of state iterations has obtained.

Finally, after calling each of the above cases, the algorithm will end and the result will print in the output.

III. THE IMPACTS OF DGS ON DISTRIBUTION NETWORK VOLTAGE DROP

Due to the small ratio of X to R in distribution networks and the radial network topology, the impact of DGs on distribution network voltage is much higher than the other power reactive resources. For this purpose the following two buses network has been considered to derive the voltage control relationship [8].

Fig 4: Two bus network

Voltage drop for the network is calculated as follows:

$$\Delta V = V_1 - V_2 = (R + jX)I \quad (7)$$

$$I = \frac{P - jQ}{V_2^*} \quad (8)$$

$$|\Delta V|^2 = \frac{(RP+XQ)^2 + (RP-XQ)^2}{V_2^2} \approx \frac{(RP+XQ)^2}{V_2^2} \quad (9)$$

Where,

ΔV	Line voltage drop
$R + jX$	Line impedance
Q	Reactive power
P	Active power
$V_1 \& V_2$	Bus 1 and 2 voltage amplitude, respectively
I	Current flow through the line

As is observed from the above equation, because of the greater resistance value of distribution networks towards their reactance, the voltage change affiliation to active power is not negligible. Therefore observe this case in optimization problem constraints is essential and more important for consideration in the objective function as one of the sections of penalty factor.

IV. OBJECTIVE FUNCTION AND PROBLEM FORMULATION

In this section, the objective function as well as constraints are formulated. Allocating and sizing of DG resources has significant impact on the distribution networks system losses. Therefore, the following objective function will be used to minimize the power losses and improve voltage profiling in the radial distribution network [9, 10].

A. Power losses formulation

$$L_{real\,power} = \sum_{i=2}^{n} (APO_i - APD_i - (Vs_i * Vr_i * Ysr_i * cos(\delta r_i - \delta s_i + \theta y_i))) \quad (10)$$

Where,

$L_{real\ power}$	Real Power Losses
APO_i	Active power from output bus i
APD_i	Active power on demand bus i
Vs_i	Voltage from sending bus i
Vr_i	Volatge on receiving bus i
Ysr_i	Admittance between sending bus I and receiving bus i
δs_i	Phase angle of sending bus i
δr_i	Phase angle of receiving bus i
θy_i	Phase angle of $Y_i \angle \theta_i$

B. Improve the voltage profile

$$V_P = \sum_{i=1}^{n}(Vr_i - V_{rate})^2 \qquad (11)$$

Where,

V_P Voltage profile objective function

V_{rate} Rated voltage (1 pu)

Thus, from equations (10) and (11), represents the objective function in Equation(12) that must be minimized.

$$Z = Min\left[\left(L_{real\,power} + \gamma * V_P\right) + DP\right] \qquad (12)$$

Where, γ is violation coefficient, DP is penalty factor that derived from problem constraints and the Z is the cost function that should be minimized with PSO algorithm.

V. THE PROBLEM CONSTRAINTS

The problem constraints and limitation of optimal management distribution system planning are as follows:

Bus voltage	$V_i^{min} \leq V_i^t \leq V_i^{max}$
Current feeders	$I_{fi} \leq I_{fi}^{rated}$
Reactive power of capacitors	$Q_{ci}^{min} \leq Q_{gi}^t \leq Q_{ci}^{max}$
Maximum power line transaction	$\left\|P_{ij}^{line}\right\|^t \leq P_{ij\,max}^{line}$

VI. RESULT

This section compares the results of the application of PSO algorithm with other evolutionary methods such as GA that is proposed to solve the problem of distribution system planning. The IEEE_34 buses system have been tested and shown in Figure 4. It has three (3) DG units with the features as listed in Table 1.

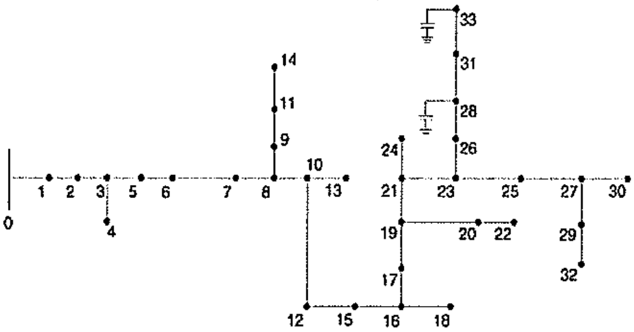

Figure 5: IEEE 34 buses diagram

Table 1:Distributed Generation features

	G1	G2	G3
Max Active power (KW)	100	400	600
Max reactive power (Kvar)	80	320	480
Min Reactive power (Kvar)	-60	-240	-360
Position in Buses	5	15	33
Type of DG	Micro-turbine with CHP	Wind Turbine	Gas Turbine with CHP

Table 2 is shown for comparison between the results of PSO and GA after solving the objective function.

Solution	Convergence time(Sec)		Objective function	
	Best	Worst	Best	Worst
GA	1200	1300	102646	126824
PSO	450	600	102043	127056

Figure 6 and Figure 7 show the convergence of both PSO and GA methods.

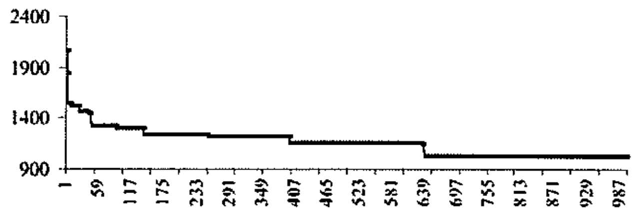

Figure 6: Minimize the cost according to Number of Function Evaluation in GA

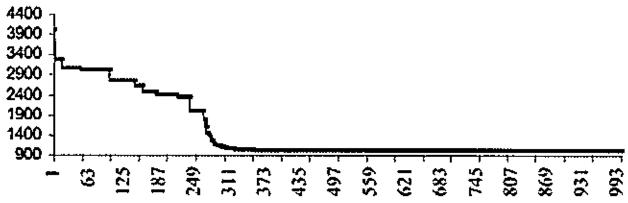

Figure 7: Minimize the cost according to Number of Function Evaluation in PSO

VII. CONCLUSIONS

Particle Swarm Optimization (PSO) algorithm has been considered in this paper due to the robustness of the evolutionary computation methods. This method has been applied to solve the problem of distribution system planning in order to to obtain the optimal operation of distribution networks with DGs. And finally the performance of PSO algorithm is compared with Genetic Algorithm (GA).

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