Optimal Sizing and Placement of Distribution Generation Using Imperialist Competitive Algorithm

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Abstract— **In this paper Imperialism Competitive Algorithm (ICA) is proposed to optimal placement of Distribution Generation (DG) in power system. The power distribution generation systems are necessary for consumers to achieve power with less price and best quality. In the other hand, they can help to the active power units in power system networks for system losses reduction, distribution lines, voltage profile improvement. Also, ICA is a global search strategy that uses the socio-political competition among empires as a source of inspiration. The effectiveness of the proposed technique is applied to mat power 30 buses and 57 bus power system. The achieved result shows the robust reaction of the system with DG.**

Keywords: DG, ICA, Losses and Prices.

I. INTRODUCTION

The design and operation of the electricity distribution networks always assumed power flows from higher voltage networks to lower voltage networks. Power injections and power demands that appear at various places in the distribution systems are assumed to be distributing equally between the phases. This assumption is valid for passive networks. However, the connection and operation of significant Distribution Generation (DG) (of varying technologies) alters many network characteristics making the existing assumptions of network design and operation less applicable to distribution networks. The power distribution generation systems are necessary for consumers to achieve power with less price and best quality. In the other hand, they can help to the active power units in power system networks for system losses reduction, distribution lines, voltage profile improvement and etc. The main goal for DG is determining of optimal size and placement of capacitors to be installed and efficient control schemes in the buses of distribution systems [1-4].

The DG sources can classified at four sets; micro DG (5KW to 1MW), small (5KW to 5MW), medium (5MW to 50MW) and large size (50MW to 300MW). Meanwhile, the source for DGs is very widespread so that they contain fuel cells, photo voltaic, hydro turbine, combustion engines, micro turbines and etc [5].

The optimal sizing and placement of DG problem is an attractive research area as publish some papers in this area such as global optimization techniques like genetic algorithms (GA), Harmony Search Algorithm (HAS), Particle Swarm Optimization (PSO) and Evolutionary Programming (EP) techniques have been applied for optimal tuning of DG based restructure schemes. These evolutionary algorithms are heuristic population-based search procedures that incorporate random variation and selection operators. Although, these methods seem to be good methods for the solution of DG parameter optimization problem, however, when the system has a highly epistatic objective function (i.e. where parameters being optimized are highly correlated), and number of parameters to be optimized is large, then they have degraded efficiency to obtain global optimum solution [6]. In order to overcome these drawbacks, in this paper, a strength heuristic algorithm has been presented to determine the optimal sizing capacitor and placement, taking into accounts fixed capacitors as well as potential harmonic interactions (losses, resonance and distortion factors) in the presence of nonlinear loads and DG using ICA. Therefore, for this reasons, ICA algorithm is used to solve DG problem in order to efficiently control the local search and convergence to the global optimum and solution quality. This proposed method has been tested on distorted 34-bus and 57-bus IEEE systems. The

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objectives on this method were to minimize power loss in the distorted distribution network having taken the cost of capacitors into account [7-10].

II. DG PROBLEM FORMULATION

The problem is formulated with a objective functions, the real power loss reduction in a distribution system is required for efficient power system operation. The loss in the system can be calculated, given the system operating condition [11].

$$SLOSS = Sij + Sji$$

$$Sloss = \sum_{j=1}^{n} Zj * Ij^2$$

$$PLOSS = real(Sloss) \qquad QLOSS = image(Sloss)$$

$$Sltotal = \sum_{j=1}^{n} Slossj$$

$$INDEX = A * Sltotal + B * \sum_{j=1}^{n} (1 - |Vj|)^2 \tag{1}$$

Where, S_{LOSS}, P_{LOSS} and Q_{LOSS} are power loss, active and reactive power loss for power system network, respectively. The A and B is penalty factor for *INDEX* objective function to voltage profit improvement and minimize total loss. This penalty factors define based operator for minimize loss or modified voltage profile [12]. Also, they are different value for test systems. This problem contains some constrains such as:

(a) Power balance constraint

$$\sum_{DG=1}^{n_{DG}} P_{DG} + \sum_{G=n_{DG}+1}^{n_G} P_G = P_D + P_L \tag{2}$$

(b) Generation and voltage limits constraints

$$P_i^{\min} \le P_i \le P_i^{\max} \qquad i \in 1,2,...,\alpha$$

$$V_i^{\min} \le V_i \le V_i^{\max} \qquad i \in 1,2,...,\alpha \tag{3}$$

The active power transmission loss P_L can be calculated by the network loss formula:

$$P_L = \sum_{i=1}^{n}\sum_{j=1}^{n} A_{ij}(P_iP_j + Q_iQ_j) + B_{ij}(Q_iP_j - P_iQ_j) \tag{4}$$

Where,

$$A_{ij} = \frac{R_{ij}\cos(\delta_i - \delta_j)}{V_iV_j}$$

$$B_{ij} = \frac{R_{ij}\sin(\delta_i - \delta_j)}{V_iV_j} \tag{5}$$

Where, *Pi* and *Qi* are net real and reactive power injection in bus *'i'* respectively, *Rij* is the line resistance between bus *'i'* and *'j'*, *Vi* and *δi* are the voltage and angle at bus *'i'* respectively.

III. IMPERIALIST COMPETITIVE ALGORITHM

Imperialism is the policy of extending the power and rule of a government beyond its own boundaries. A country may attempt to dominate others by direct rule or by less obvious means such as a control of markets for goods or raw materials. The latter is often called neo-colonialism [13]. ICA is a novel global search heuristic that uses imperialism and imperialistic competition process as a source of inspiration. This algorithm starts with some initial countries. Some of the best countries are selected to be the imperialist states and all the other countries form the colonies of these imperialists. The colonies are divided among the mentioned imperialists based on their power. After dividing all colonies among imperialists and creating the initial empires, these colonies start moving toward their relevant imperialist state. This movement is a simple model of assimilation policy that was pursued by some imperialist states [14]. Figure 1 shows the initial empires. Accordingly, bigger empires have greater number of colonies where weaker ones have less. In this figure, Imperialist 1 has formed the most powerful empire and consequently has the greatest number of colonies.

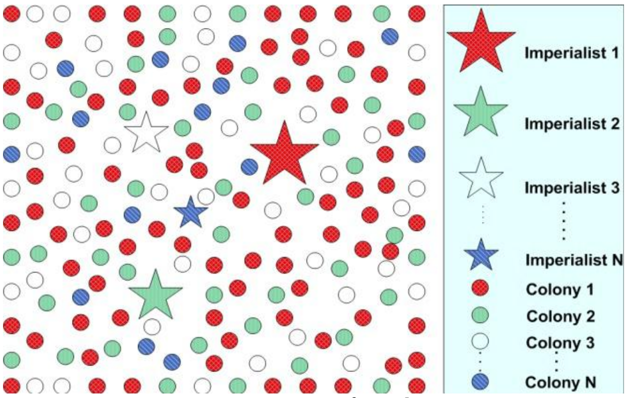


Figure 1. Generation of initial empires

A. *Movement of Colonies toward the Imperialist*

It is clear that, imperialist countries start to improve their colonies. We have modeled this fact by moving all the colonies toward the imperialist. Figure 2 shows a colony moving toward the imperialist by units. The direction of the movement is shown by the arrow extending from a colony to an imperialist [15]. In this figure x is a random variable with uniform (or any proper) distribution. Then for x we have:

$$x \approx U(0, \beta \times d)$$

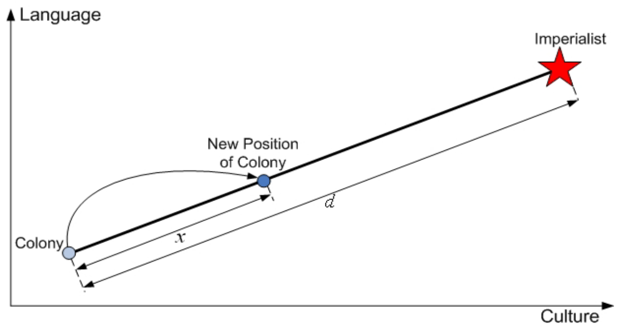


Figure 2. Movement of colonies toward their relevant imperialist

Where d is the distance between the colony and the imperialist state. The condition β >1 causes the colonies to get closer to the imperialist state from both sides.

After dividing all colonies among imperialists and creating the initial empires, these colonies start moving toward their relevant imperialist state which is based on assimilation policy [16]. Fig.3 shows the movement of a colony towards the imperialist. In this movement, θ and x are random numbers with uniform distribution as illustrated and d is the distance between colony and the imperialist.

$$x \approx U(0, \beta \times d), \theta \approx U(-\gamma, \gamma) \tag{6}$$

Where,

β, γ = parameters that modify the area that colonies randomly search around the imperialist.

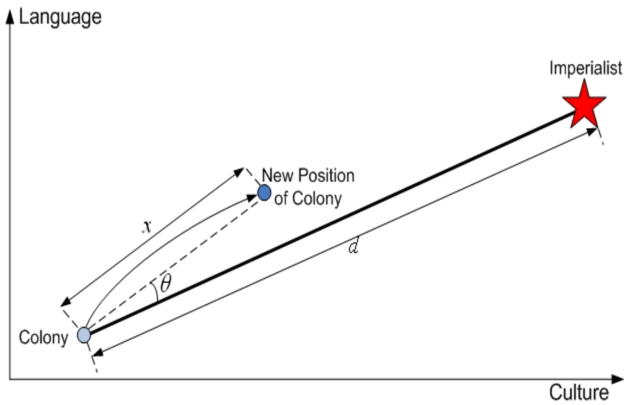


Figure 3. Movement of colonies toward their relevant imperialist in a randomly deviated direction

The total power of an empire depends on both the power of the imperialist country and the power of its colonies. In this algorithm, this fact is modeled by defining the total power of an empire by the power of imperialist state plus a percentage of the mean power of its colonies. Any empire that is not able to succeed in imperialist competition and can not increase its power (or at least prevent decreasing its power) will be eliminated.

The imperialistic competition will gradually result in an increase in the power of great empires and a decrease in the power of weaker ones. Weak empires will lose their power gradually and ultimately they will collapse [15]. The movement of colonies toward their relevant imperialists along with competition among empires and also collapse mechanism will hopefully cause all the countries to converge to a state in which there exist just one empire in the world and all the other countries are its colonies. In this ideal new world colonies have the same position and power as the imperialist. Fig.4 shows a big picture of the modeled imperialistic competition. Based on their total power, in this competition, each of the empires will have a likelihood of taking possession of the mentioned colonies.

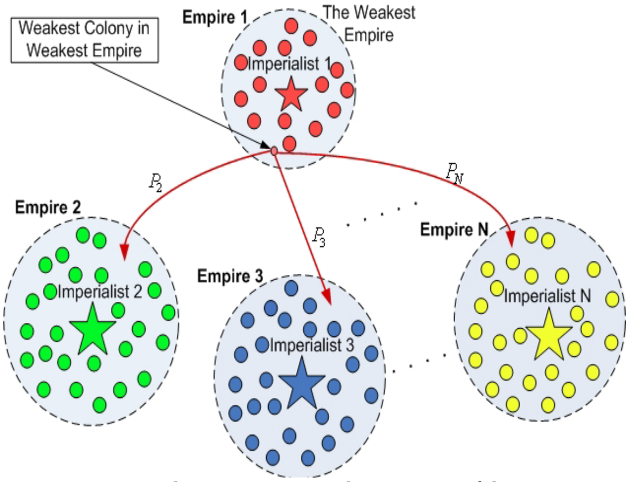


Figure 4. Imperialistic competition: The more powerful an empire is, the more likely it will possess the weakest colony of weakest empire

IV. ICA BASED DG PROBLEM

The ICA technique for solving the optimal placement and capacitor sizing DG problem to minimize the loss may be constructed with the following main stages:

Set power system: Input line and bus data, and bus voltage limits.

Calculate fitness based load flow: Calculate the loss using distribution load flow based on backward-forward sweep.

Initial population: Randomly generates an initial population (array) of particles with random positions and velocities on dimensions in the solution space. Set the iteration counter k = 0. In the other hand, in this step, an initial population based on state variable is generated, randomly. That is formulated as:

$$D = [D_1, D_2, D_3, ..., D_n] \qquad D_i = (d_i^1, d_i^2, ..., d_i^m) \tag{7}$$

Calculate fitness: For each particle if the bus voltage is within the limits, calculate the total loss. Otherwise, that particle is infeasible. That is formulated as:

min *INDEX*

Updating: update population with ICA explore engine.

Finish: If the iteration number reaches the maximum limit, go to next Step. Otherwise, set iteration index $k = k + 1$, and go back to Step 4.

Results: Print out the optimal solution to the target problem. The best position includes the optimal locations and size of DG or multi-DGs, and the corresponding fitness value representing the minimum total real power loss.

The flowchart of the proposed ICA algorithm is shows in Fig .5.

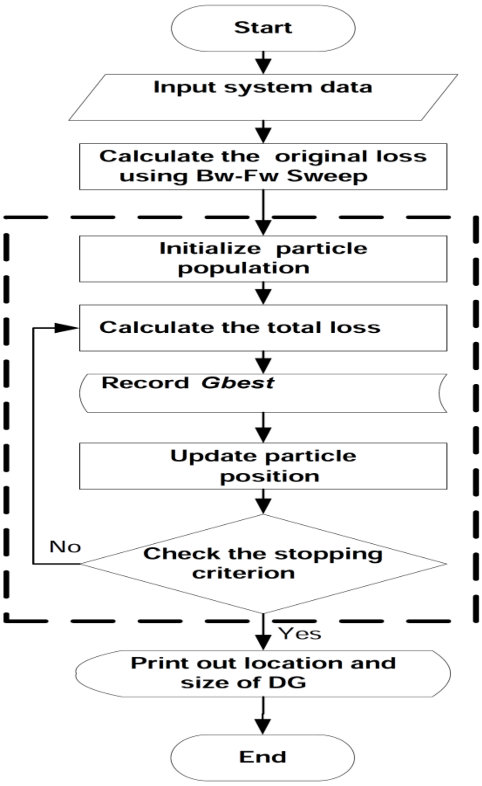


Figure 5. ICADG computational procedure

V. SIMULATION RESULTS

A. 30 and 57 bus Power System

For the testing of proposed technique two case studies are considered as; mat power 30 and 57 bus power system. For both of the case studies, the DGs are considered with 5-50 MW and 1-10 Mvar. Also the proposed technique considered 5 source of DGs to power systems. Table. 1-2, shows the numerical results of DGs in system.

In the mentioned tables, the active and reactive powers are presented for 5 optimized buses. Fig. 6-7, shows the system response with 5 sources and without sources. It is clear that by increasing the number of DGs in power system, the stability, losses decreasing and improving of voltage profile will be appropriate.

The presented figures show the losses and voltage of active and reactive power in proposed case studies.

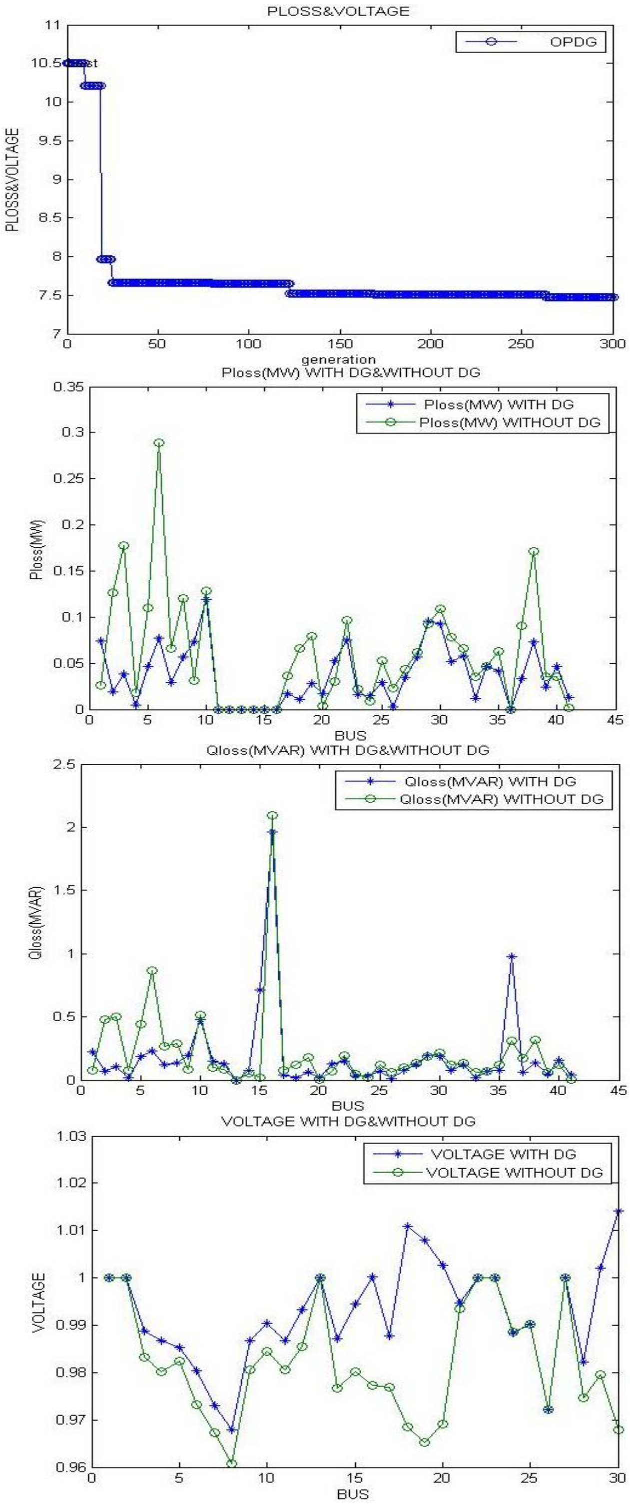
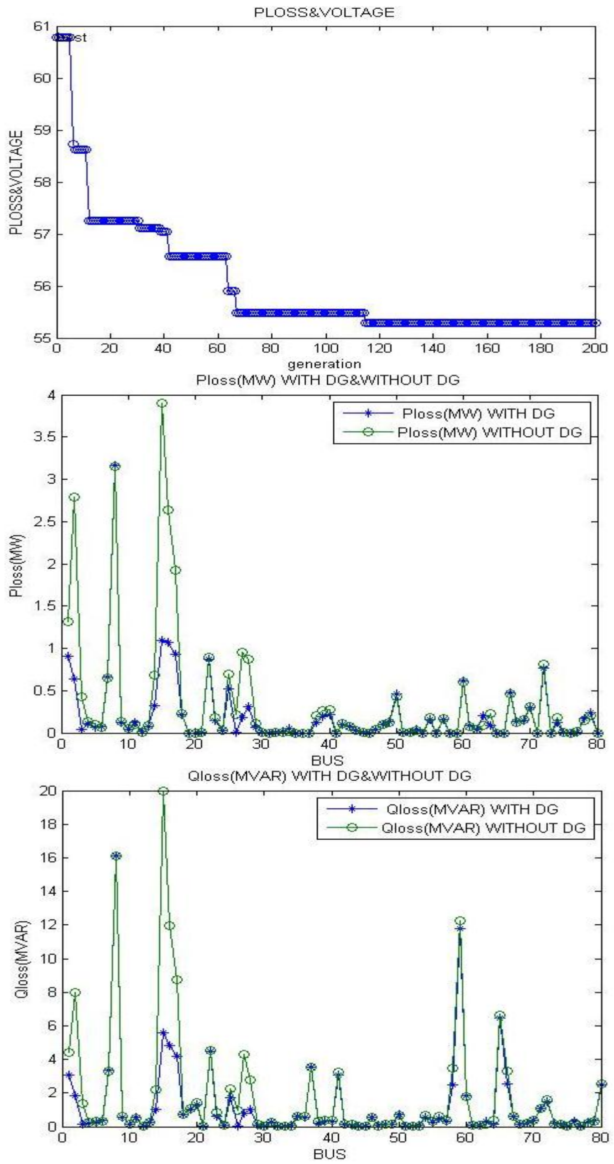


Figure 6. The losses and voltage of active and reactive power in 30-bus system.

TABLE I. THE RESULTS OF 30 BUS POWER SYSTEM

30 Bus Power System	SIZE DG	P=5-50			Q=1-10	
	NUMBER DG	1	2	3	4	5
	BUS	19	8	24	20	30
	P(MW)	31	44	6	17	7
	Q(MVAR)	10	10	10	10	9
	BUS		19	8	21	19
	P(MW)		22	34	6	7
	Q(MVAR)		10	10	9	10
	BUS			20	26	22
	P(MW)			21	3	15
	Q(MVAR)			10	10	9
	BUS				18	18
	P(MW)				9	7
	Q(MVAR)				10	9
	BUS					16
	P(MW)					8
	Q(MVAR)					10



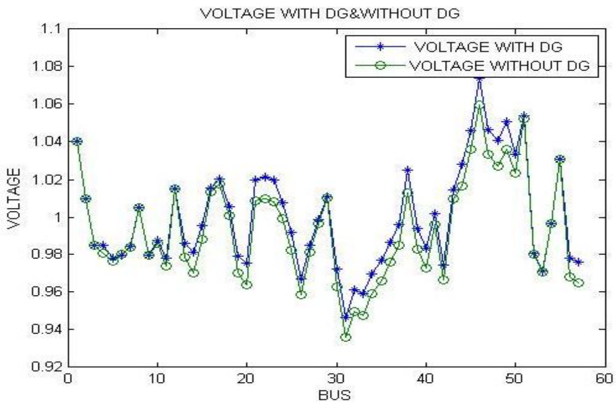


Figure 7. The losses and voltage of active and reactive power in 57-bus system.

TABLE II. THE RESULTS OF 57 BUS POWER SYSTEM

57 Bus Power System	SIZE DG	P=5-50			Q=1-10	
	NUMBER DG	1	2	3	4	5
	BUS	49	50	50	12	45
	P(MW)	50	47	47	30	38
	Q(MVAR)	1	1	2	3	1
	BUS		47	48	16	49
	P(MW)		48	48	50	29
	Q(MVAR)		1	2	2	2
	BUS			16	47	4
	P(MW)			41	47	38
	Q(MVAR)			1	4	4
	BUS				49	46
	P(MW)				40	36
	Q(MVAR)				1	3
	BUS					12
	P(MW)					37
	Q(MVAR)					3

VI. CONCLUSIONS

In this paper, we investigated the optimal placement and capacitor sizing DG power problem by employing an evolutionary algorithm based on Imperialist Competitive Algorithm. The DG optimization problem was considered and formulated as single-objective optimization problem with competing objectives of power loss and voltage profile improvement. The concept of Pareto dominance was employed to provide the selection mechanism between different objectives. The proposed algorithm applied to two standard IEEE systems to show advantages of proposed algorithm in DG problem, 34-bus IEEE test system and 57-bus IEEE test system. The numerical results demonstrate that the proposed method has better ability in finding optimal answers and possibility of particle placed in local zone. Moreover, the proposed strategy has simple structure, easy to implement and tune and therefore it is recommended to generate good quality and reliable electric energy in the restructured power systems.

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BIOGRAPHIES

Heidarali Shayanfar received the B.S. and M.S.E. degrees in Electrical Engineering in 1973 and 1979, respectively. He received his Ph. D. degree in Electrical Engineering from Michigan State University, U.S.A., in 1981. Currently, he is a Full Professor in Electrical Engineering Department of Iran University of Science and Technology, Tehran, Iran. His research interests are in the Application of Artificial Intelligence to Power System Control Design, Dynamic Load Modeling, Power System Observability Studies, Voltage Collapse, Congestion Management in a Restructured Power System, Reliability Improvement in Distribution Systems and Reactive Pricing in Deregulated Power Systems. He has published more than 405 technical papers in the International Journals and Conferences proceedings. He is a member of Iranian Association of Electrical and Electronic Engineers and IEEE.

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