American Journal of Scientific Research
ISSN 1450-223X Issue 33(2011), pp. 64-75

http://www.eurojournals.com/ajsr.htm

ICA-based Allocation of DGs in a Distribution System

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Abstract

This paper shows the results obtained in the analysis of the impact of Distributed Generation (DG) on distribution losses and presents a new algorithm to the optimal allocation of distributed generation resources in distribution networks. The optimization is based on a Imperialist Competitive Algorithm (ICA) aiming to optimal DG allocation in distribution network. Imperialist Competitive Algorithm (ICA) is a new meta-heuristic algorithm with efficient mathematical function and global search capability. Through this algorithm a significant improvement in the optimization goal is achieved. The objective function is tested on the IEEE 34-bus and 69-bus system. With a numerical example the superiority of the proposed algorithm is demonstrated in comparison with the simple genetic algorithm.

Keywords: Distributed Generation, Distribution Networks, Imperialist Competitive Algorithm (ICA), Genetic Algorithm.

Introduction

Nowadays the Distributed Generation (DG) is taking more relevance and it is anticipated that in the future it will have an important role in electric power systems. DG includes the application of small generators, scattered throughout a power system, to provide the electricity service required by the customers. DG can be powered by both conventional and renewable energy sources (H.L ,Willis, *et al*. 2000). Several DG options are fast becoming economically viable (R. C. Dugan, *et al*. 2002). Technologies of the DG allocation can be obtained by a complete enumeration of all feasible combinations of sites and sizes of DGs in the network. The artificial intelligence techniques are the most widely employed tool for solving most of the optimization problems. These methods (e.g. genetic algorithm, simulated annealing and tabu search) seem to be promising and are still evolving. The publications are on the DG allocation by application of genetic algorithm (GA) (G.Celli, & F. Pillo. 2001). Tabu Search (TS) algorithm is used for the DG allocation in distribution systems (K.Nara, *et al*. 2001). Analytical approaches minimizing line losses were also utilized for the DG allocation as provided in (C. Wang , *et al*. 2004). In (A. Keane, *et al*. 2005), the authors have integrated DG in distribution systems using power systems studies coupled with linear programming method. Analyzing these studies, the consideration of uncertainty in the DG allocation in distribution systems is neglected. Papers (L. F. Ochoa, *et al*. 2005)-(G. Celli, *et al*. 2005) utilized evolutionary programming for identifying the placement of DG in distribution systems. Imperialist Competitive Algorithm (ICA) for evaluation of the DG site and size in MV networks is proposed. The ICA is employed for the DG allocation. The results showed that the proposed method is better than the simple GA in terms of the solution quality and number of iteration.

Distributed Generation

Distributed generation is expected to become more important in the future generation system. In general, DG can be defined as electric power generation within the distribution networks or on the customer side of the network. A wide variety of DG technologies and types exists: renewable energy source such as wind turbines, photovoltaic, micro-turbines, fuel cells, and storage energy devices such as batteries. The importance of the DG is now being increasingly accepted and realized by power engineers. From the distribution system planning point of view, DG is a feasible alternative for new capacity, especially in the competitive electricity market environment and has immense benefit such as (N. Hadisaid, *et al*. 1999):

- Short lead-time and low investment risk since it is built in modules.
- Small-capacity modules that can track load variation more closely.
- Small physical size that can be installed at load centers and does not need government approval or search for utility territory and land availability.
- Existence of a vast range of the DG technologies for these reasons, the first signs of a possible technological change are beginning to arise on the international scene, which could involve in the future the presence of a consistently generation produced with small and medium size plants directly connected to the distribution network (LV and MV) and characterized by good efficiencies and low emissions. This will create new problems and probably the need of new tools and managing these systems.

Problem Formulation

Objective Function

The problem is to determine allocation and size of the DGs which minimizes the distribution power losses for a fixed number of DGs and specific total capacity of the DGs. Therefore, the following assumptions are employed in this formulation (J.O. Kim, *et al*. 1997)::

- The maximum number of installable DGs is given (D) .
- The total installation capacity of the DGs is given (Q) .
- The possible locations for the DG installation are given for each feeder.
- The upper and lower limits of node voltages are given.
- The current capacities of the conductors are given.

The objective function in this optimization problem is:

$$OF = \sum_{i=1}^{n} P_i \tag{1}$$

Where, P_i is the nodal injected power at bus i , and n is the total number of buses.

If the total injected power of distributed generation was constant as C MW, this equality constraint should be expressed in form of a penalty function as shown (J.O. Kim, *et al*. 1997):

$$OF = \sum_{i=1}^{n} P_i + \alpha(\sum_{K=1}^{L} P_k - C) \tag{2}$$

Constraints

1. Maximum number of DGs:
$$V_i \le V_n \pm \Delta V$$
$$I_i \le I_i^{\max} \quad (3)$$
$$(k=1,2,...,L, l=1,2,...,M, g=1,2,...,N)$$
2. Total capacity of DGs:
$$\sum_{l=1}^{M}\sum_{g=1}^{N} G_g n_{gl} \le Q \quad (4)$$
3. One DG per installation position:
$$\sum_{g=1}^{N} n_{gl} \le 1 \sum_{g=1}^{N} n_{gl} \le 1 \quad (5)$$
4. Upper and lower voltage limits:
$$V_i \le V_n \pm \Delta V \quad (6)$$
5. Current capacity limits:
$$I_i \le I_i^{\max} \quad (7)$$
$$(k=1,2,...,L, l=1,2,...,M, g=1,2,...,N)$$

Where,

P_i : Nodal injection of power at bus *i*,

P_k : Load power of bus *k*,

V_i : Magnitude of voltage of bus *i*,

V_n : Nominal magnitude of voltage in the network,

G_g : Capacity of g^{th} DG,

n_{gl} : 0-1 variable for determining whether one DG with g^{th} capacity is allocated at l^{th} location (1: allocated, 0: not allocated), (8)

L : Total number of load buses ,

M : Total number of DG location candidates,

N : Total number of capacity types of DGs,

Q : Total installation capacity of DGs,

D : Maximum number of installable DGs ,

α : Penalty weight of equality constraint,

C : Total injected dispersed generation for network,

ΔV : Maximum permissible voltage deviation,

I_i : Current of section i ,

$I_i^{\max}$: Maximum current capacity of section *i*.

ICA Algorithm Introduction

Fig 1 shows ICA algorithm flowchart. This algorithm, such as other evolutionary algorithms begins with some accidental primary crowds that each of them has been called a "country". Some of best elements of crowds are selected as imperialist (equal with elites in genetic algorithms) .the remaining crowds have been considered as colony. Imperialist, with their power, absorb these colonies to themselves with special trend that will be discussed at future. Power of each empire depends on its two constitutive part namely imperialist country (as central nucleus) and its colonies. In mathematics this dependence models with empire power definition in the form of power sum of imperialist country plus percents of average power of its colonies. The imperialist competition between them begins with forming early empires. Each empire that cannot be successful in imperialist competition and increases its power, will be removed from imperialist competition scene .therefore the survival of each empire depends on its power in absorption of revival empire's colonies and ruling over them. As a result, in imperialist competition streams, the power of greater empires will be increased and weak empires will be removed. Empire will be obliged improve their colonies for increasing their power. Colonies gradually near the empires and we can observe some sort of convergence. Final extent of imperial extent is when we have had unit empire in the world, with colonies which are close to the imperialist country accordance with their position.For starting the algorithm , we create N numbers of early countries .we select N imp of the best members of this crowd as imperialist (the countries including minimum amount of cost function) , the remains forms N col of colonies countries in which each of them belongs to one empire. We give some of these colonies to each imperialist for dividing the early colonies among the imperialist accordance with their power. consider their normalized cost as follow:

$$C_n = \max\{c_i\} - c_n \tag{9}$$

Where C_n imperialist cost max (C_i) is highest cost among imperialist and C_n is normalized cost of this imperialist.

Each imperialist which have had more cost (be weaker imperialist), includes less normalized costs. Normalized respective power of each imperialist, with having normalized costs, has been calculated as follow and accordance with it, colonies countries have been divided between imperialist.

$$P_n = \frac{C_n}{\sum_{i=1}^{N_{imp}} C_i} \tag{10}$$

From other respect, normalized power of an imperialist is colonies proportion that are controlled by that imperialist.Therefore the early number of an imperialist's colonies equals with:

$$N.C.n = round\{p_n.(N_{col})\} \tag{11}$$

Where N.C.n is early number of empire 's colonies and N_{col} is the total number of existing colonies countries in the early countries crowds . Round is also function that give closest integer t a decimal number. We select accidentally some of these primary colonies countries, with considering N.C for each empire an give it to N imperialist, the imperialist competitive algorithm begins with having primary status of all empires. Evolutionary trend which located in a segment that continues till the stop condition fulfillment. Fig 2 shows the manner of early empires forming . Bigger empires have more colonies. In this Fig, imperialist number 1 creates the strongest empire and have most number of colonies.

Absorption Policy Modeling

Colonies movement toward the assimilation policy of imperialist has done with the purpose of analyzing the culture and social structure of colonies in central government culture. Imperialist countries began to creating development (building transportation substructure , university establishing ,…).

Figure 1: Flowchart of the Imperialist Competitive Algorithm

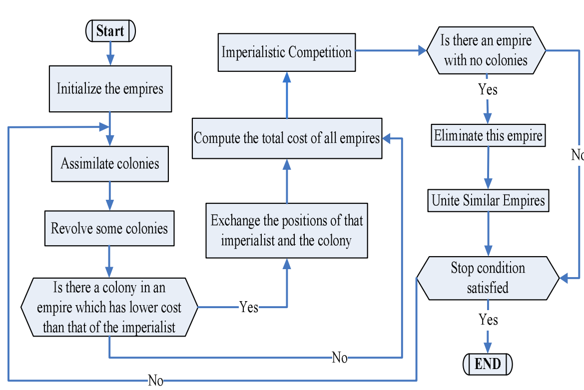
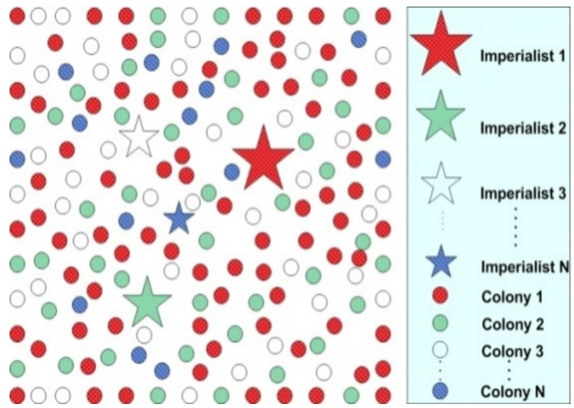


Figure 2: Manner of forming primary empire, imperialist number 1 creates strongest empire and has maximum number of colonies.



In fact this central government tries to close colony country to its self by applying attraction policy, in different political and social dimensions, with considering showing manner of country in solving optimization problem. This section of imperialistic process in optimization algorithm has been modeled in the form of colonies movement toward the imperialist country. The Fig 3 shows total image of this movement. According with this Fig, imperialist country attract to itself parallel with culture and language axis. As shown in this Fig, colony country moves in x unit size toward the attachment line of colony to the imperialist and drawn to new situation. In this Fig, distance between imperialist and colony is shown by D, and x is accidental number with steady distribution.

It means for x, we have

$$x \sim U(0, \beta \times d) \qquad (12)$$

Where β is a number bigger than 1 and nears to 2. A good selection can be β=2. The existence of coefficient β >1 causes the colony country closes to the imperialist country from different aspects while moving. With historical survey of assimilation phenomena, one clear fact in this field is in spite that imperialist countries followed seriously the attraction policy but facts did not follow totally accordance with applied policy and there were deviances in the work results. In introduced algorithm, this probable deviation has done with adding an accidental angle to the attraction path of colonies. For this purpose, in the colonies movement toward the imperialist, we add an accidental angle toward the colony movement, Fig 4 shows this state. this time we continue our path in stead of x movement toward the imperialist and in toward the vector and colony maxim to the imperialist in the same extent, but with θ deviation in the path, and consider θ accidentally and with constant distribution (but any ideal and proper distribution can be used), then. $\theta \sim U(-\gamma, \gamma)$

Figure 3: Total image of colony movement toward imperialist.

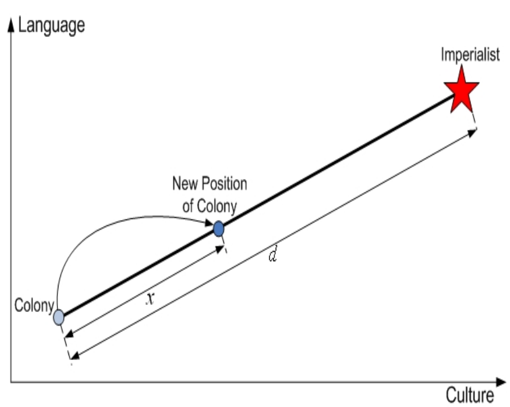
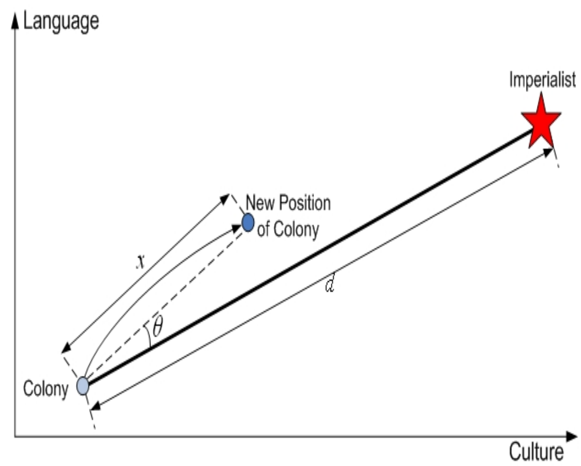


Figure 4: Real movement of colonies toward the imperialist.



In this relation y is ideal parameter that its increasing causes increasing searching around imperialist and its decreasing causes colonies close possibly to the vector of connecting colony to the imperialist. With considering the radian unit for θ, a number close to $\pi / 4$ was proper selection in the most depletion .

Position Displacement of Colony and Imperialist

In some cases attraction policy has had possitive result for them, in spite of destroying political-economical structures of colony countries . some of countries with appling this policy accessed to general self confidence and after awhile it was the educated people who combat with the nation leadership for escaping from imperialist . We can find various cases of these in enland and france' s colonies . from other perspective , looking at up and downs of power circulation in the countries shows truly that the countries in which were at the peak of politic military power , after awhile declined and contrary the countries reached to the power that before were not into the power. This historical movement in the modelling in the algorithm has been applied in the way of colony movement toward the imperialist country , some of these colonies may reach to a better condition than imperialist (reaching to the points in cost function that generate less costs than cost function extent) . In this state , the imperialist country and colony change their position and algorithm continues with imperialist counry in new situation and this time it is the new imperialist country in which begin to applying assimilation policy for its colonies. The colony and imperialist displacement is shown in the Fig 5. In this Fig the best empire's colony in which has less costs than imperialist, is shown with dark colour. Fig 6 shows the whole empire after position changing.

Figure 5: Displacement of colony and imperialist

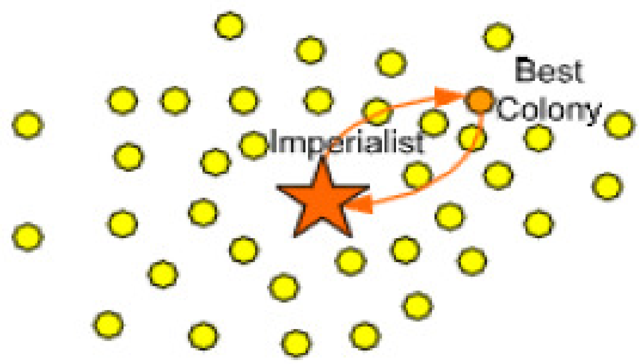
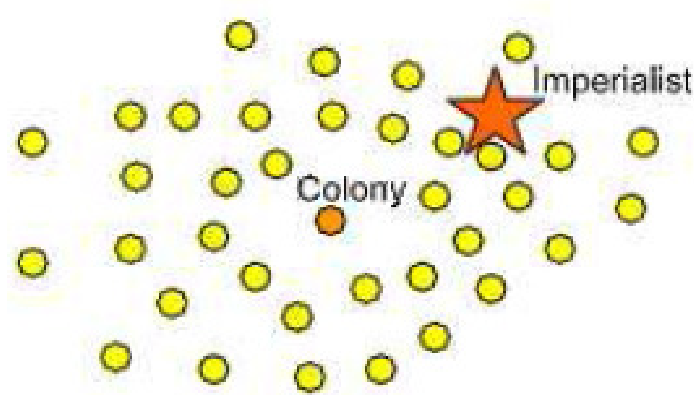


Figure 6: The whole empire after displacement



Total Power of an Empire

The power of an empire equals with the power of imperialist country in addtion to some perceptage of total power of whole colonies , in this case the total cost of an empire calculate as follow:

$$T.C. = Cost(imprialist_n) + \xi mean\{Cost(colonies\ of\ empire_n)\} \quad (13)$$

Where T.C.n is the empire's total cost and ζ is possitive number that is usually between zero and one and near to zero.This low considering of ζ cause total cost of empire be nearry equal with its central government and inreasing ζ causes increasing the colonies's costs measure infulunce of an empire in determining the its total costs. In generic state ζ =0/ 05 in the most cases reulted to proper answers.

Imperial Competition

Each empire which cannot increase its power and looses its competition power, will be removed from imperialistic competitions. This removing forms gradually . it means that with passing the time , weak empire give up their colonies and the strong empire take possession of these colonies and increase their power. For modeling this fact, we assume the empire at the time of deleting, is the weakest existing empire. So in the algorithm repetition, we take some of weakest colonies of the empire and create a competition between the whole empires. Mentioned colonies will not necessarily be possessed the strongest empire. But this is the stronger empire which has more chance for its ownership. Fig 9 shows total image of this part of algorithm.

Figure 7: Exchanging the positions of a colony and the imperialist

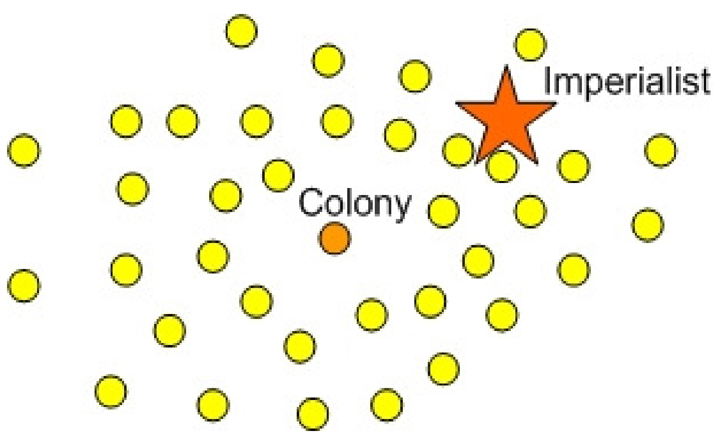
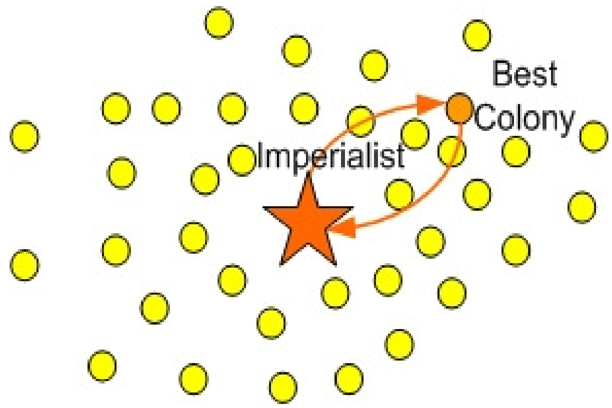


Figure 8: The entire empire after position exchange

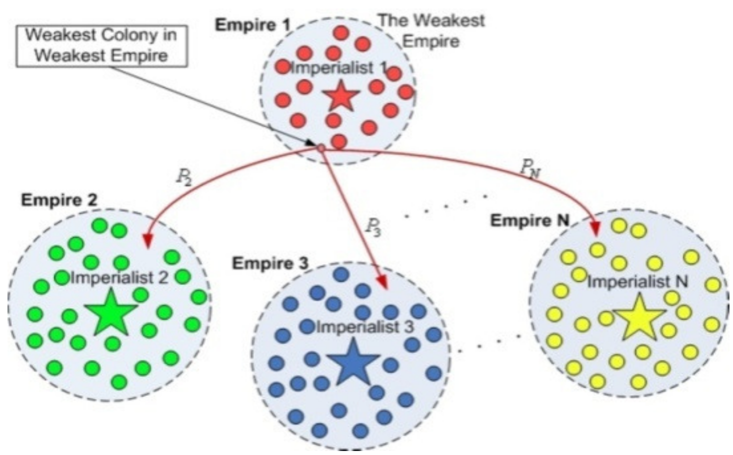


For modeling the competition between the empires for possessing these colonies , first of all we calculate the ownership probability of each empire(that be fit with the power of that empire) with considering total cost of each empire , as follow: first we determine total costs of empire based on its nnormalized costs:

$$N.T.C._n = T.C._n - \max_i \{T.C._i\} \tag{14}$$

Where T.C.N is n total cost of empire and N.T.C.n is normalized costof that empire. Each emire which have had less T.C.N ,has more n.t.cn . infact T.C .n equals total cost of an empire and N.T.C. N equalsits total power.

Figure 9: Total image of imperialistic competition : bigger empire take the possession oof the other emire's colonies with more likelihood.



The probability of colony ownership in competition by each empire calculates as follow:

$$p_{p_n} = \left| \frac{N.T.C._n}{\sum_{i=1}^{N_{imp}} N.T.C._i} \right| \tag{15}$$

With ownership probability of each empire, we divide the mentioned colonies accidentally between the empires, but with related probability to ownership probability of each empire. Then we form vector P based on above probability extents as follow:

$$\mathbf{P} = \left[p_{p_1}, p_{p_2}, p_{p_3}, \ldots, p_{p_{N_{imp}}} \right] \tag{16}$$

vector P' s size is 1×nimp and is constituted based on probability amounts of empires ownership. Then we form the accidental vector R as equal as vector P , the arrays of this vector are accidental number with the same distribution in [0,1].

$$R=\left[r_1, r_2, r_3, \ldots, r_{N_{imp}}\right]$$

$$r_1, r_2, r_3, \ldots, r_{N_{imp}} \sim U(0,1) \tag{17}$$

Then we form vector D as follow:

$$\mathbf{D=P\text{-}R}=\left[D_1, D_2, D_3, \ldots, D_{N_{imp}}\right]$$

$$=\left[p_{p_1}-r_1,\ p_{p_2}-r_2,\ p_{p_3}-r_3, \ldots, p_{p_{N_{imp}}}-r_{N_{imp}}\right] \tag{18}$$

We give the mentioned colonies to the empires with having cector D so that related andis in vector D be bigger than others. The empire which has more ownership probability , has the highest extent ,with more chances in related andis in vector D.

Declining the Weak Empires

Weak empires gradually decline in imperialistic competition and strong empires take the possession of their colonies. There are different conditions for declining an empire. In suggested empire , when an empire loose its colonies ,it assumped deleted.

Convergency

The mentioned algorithm continues till fulfillment of one convergence condition or finishing the number of whole repetition. After awhile all the empires will decline and we have only one empire and other countries are under the control of this united empire. In this new ideal world all the colonies are controled bye an united empire and the colonies 's cost and situations equals with the empirilaist 's cost and situation . in this new world, there are no difference not only between colonies but also between colonies and imperialist country . in other words, all the countries are both colony and imperialist at the same time. In such situation the imperialistic competition have been finished and stops as one stop codition of algorithm.

ICA alghorithm

Assimilation: this function applies assimilation part or in other word attraction policy . Primary empires : it forms primary empires with proper dividing of colonies among them , with considering situation and cost of primary countries. Imperialistic competition: The imperialistic competition between the empires in order to attract each other colonies is done by this function . removing the weak empires is also in this function. Imperialist and colony displacement: Displacement of imperialist and colony is done in this function. If a colony reach to a better position than imperialist ,it immediately take the control of emperor and continues the work with applying the attraction policy on them. The colonies revolution: Revelation , that is main counterweight of discovery balance and exploitation and is useful for discovery, applies in this function . sudden changes happens in some countries and in some cases leads to discovery of minimum indiscernible point in function.

ICA Algorithm's Similar Code

1. Select some accidental point on the function and form the primarily empires. We mean the powerhouses power that are considered as primary guess.
2. Move the colonies toward the imperialist country (assimilation policy).
3. If there are an empire that has less costs than imperialist, change the position of colony and imperialist .

4. Calculate total costs of an empire (with pay attention to imperialist and its colonist's costs).
5. Select one colony from weakest empires an give it to the empire which has more chance for ownership.
6. Delete weak empires.
7. Stop if there are only one remained empire , otherwise go to 2.

Case Study

In order to test the proposed algorithm, the 33 and 69 node distribution test feeder has been considered.

Figure 10 and Figure 11 shows the convergence process of the GA and ICA when employed to solve the Optimization problem of 33 and 69 node test network, respectively.

Conclusion

In this paper the results of application of SFL algorithm to the optimal allocation of DGs in Distribution Network is presented. The effectiveness of the proposed algorithm to solve the DG allocation problem is Demonstrated through a numerical example. The IEEE 33 and 69 node distribution test feeders have been solved with the proposed algorithm and, the simple genetic algorithm. The results in table 1 and table 2 demonstrated the better characteristics of the ICA in comparison with the GA specially in terms of solution quality and number of iterations.

Figure 10: Power losses reduction with generation number for IEEE 33-node system

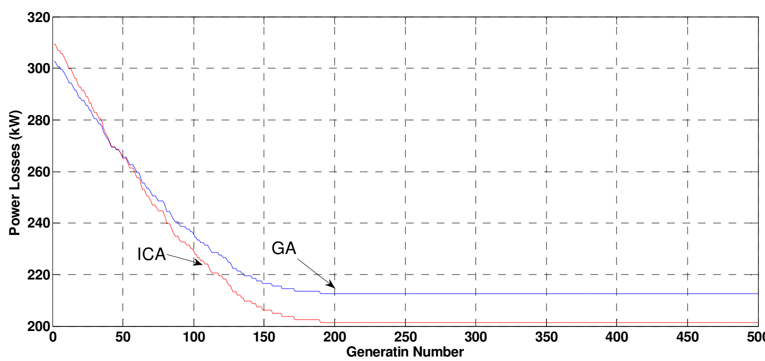


Figure 11: Power losses reduction with generation number for IEEE 69-node system

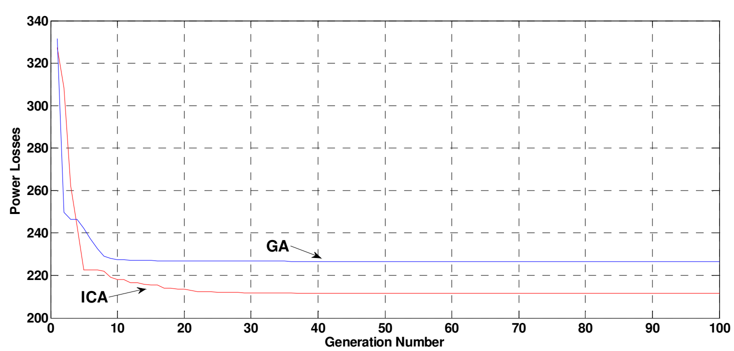


Table 1: Comparison of GA & ICA results for IEEE 33-node Algorithms

Algorithms	Total Capacity of Installed DGs (kW)	Power Losses (kW) with DG
GA	200	212.52
ICA	200	201.38

Table 2: Comparison of GA & ICA results for IEEE 69-node

Algorithms	Total Capacity of Installed DGs (kW)	Power Losses (kW) with DG
GA	200	226.52
ICA	200	211.45

References

[1] Amiri, M., Fathian, A. Maroosi, 2007. Application of Shuffled frog-leaping algorithm on clustering," Applied Mathematics and Computation.

[2] Celli, G. and F. Pillo, 2001. "Optimal distributed Generation allocation in MV distribution networks," Proceedings of the IEEE International Conference on Power Engineering Society, pp: 81-86.

[3] Celli, G., E. Ghiani, S. Mocci and F. Pilo, 2005. "A multiobjective evolutionary algorithm for the sizing and siting of distributed generation", IEEE Transactions on Power Systems, 20(2): 750-757.

[4] Chiradeja, P. and R. Ramakumar, 1998. "A review Of distributed generation and storage," in Proc. 31st Annual Frontiers of Power Conf., Stillwater, UK, pp: VIII 1-11.

[5] Chiradeja, P. and R. Ramakumar, 1999. "Benefits of Distributed generation-a simple case study," in Proc. 32nd Annual Frontiers of Power Conf., Stillwater, UK, pp: X 1-9.

[6] Chiradeja, P. and R. Ramakumar, 2001. "A Probabilistic approach to the analysis of voltage profile improvement with distributed wind electric generation," in Proc. 32nd Annual Frontiers of Power Conf., Stillwater, UK, pp: XII 1-10.

[7] CIGRE WG 37-23, 1998. "Impact of increasing contribution of distributed generation on the power system," Final Report, Electra.

[8] Dugan, R.C. and S.K. Price, 2002. "Issues for Distributed generations in the US," in Proc. IEEE Power Engineering Society Winter Meeting, 1: 121-126.

[9] Dugan, R.C. and T.E. Mcdermont, 2002. "Distributed generation," IEEE Industrial, Application Magazine, pp: 19-25.

[10] Eusuff, M.M., K. Lansey, F. Pasha, 2006. "Shuffled frog-leaping algorithm: a memetic meta-heuristic for discrete optimization, " Engineering Optimization, 38(2): 129-154.

[11] Eusuff, M. and K.E. Lansey, 2006. "Optimization of water leaping algorithm: a memetic meta-heuristic for discrete optimization, " Engineering Optimization, 38(2): 129-154.

[12] Gray, T., 1998. "Wind gets competitive in the US," Solar Today, 12(2): 18-21.

[13] Hadisaid, N., J.F. Canard, and F. Dumas, 1999. "Dispersed generation impact on distribution networks," IEEE Transactions on Computer Applications on Power, 12(2): 22-28.

[14] IEEE distribution test feeders; http://ewh.ieee.org /soc/pes/dsacom/testfeeders.htm.

[15] Keane, A. and M. O' Malley, 2005. "Optimal allocation of embedded generation on distribution network", IEEE Transactions on Power Systems, 20(3): 1640-1646.

[16] Kim, J.O., S.W. Nam, S.K. Park and C. Singh, 1997. "Distributed generation planning using improved hereford ranch algorithm," Electric Power System Research, 47: 47-55.

[17] Nara, K., Y. Hayashi, K. Ikeda and T. Ashizawa, 2001. "application of tabu search to optimal placement of distributed generators," Proceedings of the IEEE power engineering Society, 2: 918- 923.

[18] Ochoa, L.F. and A.P. Feltrin and G.P. Harrison, 2005. "Evaluation of a multiobjective performance index for distribution systems with distributed generation", 18th International Conference on Electricity Distribution (CIRED), Turin, Session., 4: 6-9.

[19] Raissi, T., A. Banerjee and K.G. Scheinkopf, 1997. "Current technology of fuel cell systems," in Proc. Intersociety Energy Conversion Engineering Conference, pp: 1953-1957.

[20] Rahman, S., 2001. “Fuel cell as a distributed generation technology,” in Proc. IEEE Power Engineering Society Summer Meeting, 1: 551-552.

[21] Silversti, A. and S. Buonaao, 1997. "Distributed generation planning using genetic algorithm," Proceedings of the IEEE International Conference on Power Tech, pp: 257.

[22] Wang, C. and M.H. Nehrir, 2004. “analytical Approaches for optimal placement of distributed generation sources in power systems”, IEEE Transactions on Power Systems, 18(4): 2068-2076.

[23] Esmaeil Atashpaz-Gargari, 2007. Caro Lucas systemfor “Imperialist competitive algorithm:an algorithm for optimization inspired by imperialistic competition” 2007 IEEE Congress on Evolutionary Computation, pp: 4461-4667.

[24] Rajabioun, R., Atashpaz-Gargari, E., and Lucas, C. (2008). Colonial Competitive Algorithm as a Tool for Nash Equilibrium Point Achievement. *Lecture notes in computer science,* 5073, 680-695.

[25] Sepehri Rad, H., Lucas, C. (2008). Application of Imperialistic Competition Algorithm in Recommender Systems. In: 13th Int'l CSI Computer Conference (CSICC'08), Kish Island, Iran.

[26] Biabangard-Oskouyi, A., Atashpaz-Gargari, E., Soltani, N., Lucas, C. (2008). Application of Imperialist Competitive Algorithm for materials property characterization from sharp indentation test. *To be appeared in the International Journal of Engineering Simulation*