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FIREFLY OPTIMIZATION BASED DG PLACEMENT FOR IMPROVING VOLTAGE PROFILE OF DISTRIBUTION NETWORKS

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ABSTRACT

This paper presents a Firefly Optimization (FFO) based solution methodology for optimally placing DG units with a view of improving the voltage profile. FFO, inspired by social flashing behaviour of fireflies, is one of the evolutionary computing models for solving multimodal optimization problems. The DG placement problem is formulated as an optimization problem and the FFO based solution methodology is tailored to optimize the node locations and DG ratings with a view to obtain the global best solution. The developed methodology is tested on a 33 node distribution networks and the results are presented with a view of exhibiting the superiority of the developed algorithm.

Keywords: induction motor, firefly optimization.

1. INTRODUCTION

Distributed generation (DG) in the range of 1 KW to 50 MW plays a significant role in reducing real power loss, lowering the operating cost and improving the voltage profile of distribution networks (DNs). The performances of DNs can be improved by placing of DGs at best possible locations with appropriate ratings. Several methods such as mixed integer linear programming [1], mixed integer nonlinear programming [2], dynamic programming [3] and methods involving simulated annealing [4], genetic algorithm (GA) [5], particle swarm optimization (PSO) [6], ant colony optimization [7], invasive weed optimization [8] and biogeography based optimization [9] have been suggested for solving DG placement problems.

Recently, firefly optimization (FFO) has been suggested for solving optimization problems [10, 11]. It is inspired by the light attenuation over the distance and fireflies' mutual attraction rather than the phenomenon of the fireflies' light flashing. In this approach, each problem solution is represented by a firefly, which tries to move to a greater light source, than its own. It has been applied to a variety of power system problems [12-15] and found to yield satisfactory results.

A FFO based methodology for optimally placing DGs with a view of improving voltage profile has been presented in this paper. The results on 33 node DN are presented to illustrate the effectiveness of the proposed method (PM).

2. PROPOSED METHOD

The proposed FFO based solution method for DG placement problem involves formulation of the problem, representation of fireflies through the problem variables and construction of a light intensity function, LI .

2.1 Problem formulation

The DG placement problem is formulated as a optimization problem with an objective minimizing the net voltage deviations (NVD) of the network with respect to nominal node voltage of 1.0 per unit, while satisfying several equality and inequality constraints as

$$\text{Minimize} \quad NVD = \sum_{j=1}^{nn} \left| V_j - 1.0 \right| \tag{1}$$

Subject to

$$P_{DG,j}^{\min} \le P_{DG,j} \le P_{DG,j}^{\max} \tag{2}$$

$$1 \le L_j \le nn \tag{3}$$

$$\left| i_{km} \right| \le i_{km}^{\max} \tag{4}$$

$$\sum_{j=1}^{Ndg} P_{DG,j} \le \sum_{m=1}^{nn} P_{load,m} \tag{5}$$

2.2 Representation of problem variables

The firefly f is represented to denote the problem variables, defined by Equations (2) and (3), in vector form as:

$$f_i = \left[L_1, L_2, \cdots\cdots L_{Ndg}, \; P_{DG,1}, P_{DG,2}, \cdots\cdots, P_{DG,Ndg} \right] \tag{6}$$

2.3 Fitness function

The algorithm searches for optimal solution by maximizing a light intensity function LI , which is formulated from the objective function of Eq. (1) and the penalty terms representing the limit violation of the explicit constraints of Equations (4) and (5). The LI function is written as

$$\text{Maximize} \quad LI = \frac{1}{1+\Psi} \tag{7}$$

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Where

$$\Psi = \begin{cases} \Phi + \lambda_b \sum_{i \in \Re} \left(|i_{km}| - i_{km}^{\max} \right)^2 & \leftarrow \text{ if } \sum_{j=1}^{Ndg} P_{DG,j} \le \sum_{m=1}^{nn} P_{load,m} \\ \Phi + \lambda_b \sum_{i \in \Re} \left(|i_{km}| - i_{km}^{\max} \right)^2 + \lambda_g \left| \sum_{j=1}^{Ndg} P_{DG,j} - \sum_{k=1}^{nn} P_{load,j} \right| & \leftarrow \text{ otherwise} \end{cases} \quad (8)$$

2.4 Solution process

An initial population of fireflies is obtained by generating random values within their respective limits through Equations (4) and (5). The LI is calculated by considering the values of each firefly and the movements of all fireflies are performed with a view of maximizing the LI till the number of iterations reaches a specified maximum number of iterations. The pseudo code of FFO is available in [15].

3. NUMERICAL RESULTS

The PM has been applied on 33 node DN [16] operating at 12.66 kV with net loads of 3715 kW and 2300 kVar. The DG placement problem has been solved by GA and PSO based approaches in addition to solving by the PM. The results in terms of node locations, DG ratings, NVD and lowest voltage magnitude (LVM) seen in the network, are presented in Table 1. It is clear from the table that the PM reduces the initial NVD of 1.8046 to 0.0971 by placing DG units with ratings of 1611.255, 1386.148 and 530.613 kW at nodes of 30, 8 and 16 respectively, while the existing GA and PSO cause higher NVD than that of the PM, thereby offering better solution.

Table-1. Comparison of results.

	Method	DG Loc	DG rating	NVD	LVM
Before DG Placement	**---**	---	---	1.8046	0.9038
After DG Placement	PM	30 8 16	1611.255 1386.148 530.613	0.0971	0.9829
	GA	5 32 10	811.718 1464.918 1560.435	0.1336	0.9840
	PSO	32 12 27	925.383 1190.610 1627.930	0.1146	0.9837

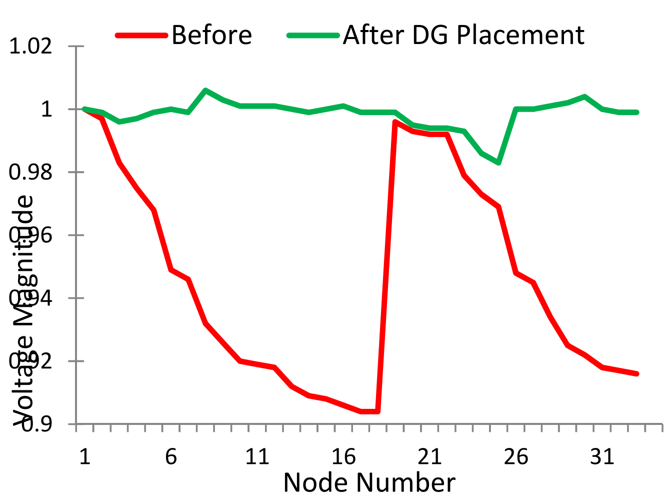

Figure-1. Comparison of % efficiency enhancement.

The VMs at all nodes of the DN before and after placing DGs of the PM are shown in Figure-1. It is observed from the figure that there is noteworthy improvement in the VP after DG placement.

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It is very clear from these results that the PM offers better results that improve the VP of the DN.

4. CONCLUSIONS

The FFO is a powerful population based metaheuristic method for solving complex optimization problems. A new methodology involving FFO for solving DG placement problem has been developed and applied on 33 node DN. It determines the optimal node locations and DG ratings with a view of improving the VP. The ability of the PM to produce the global best solution has been projected. It has been chartered that the new approach fosters the continued use of FFO and will go a long way in serving as a useful tool in DG placement problems.

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Nomenclature

DG	distributed generation
DN	distribution network
FFO	firefly optimization
f_i	i -th firefly
GA	genetic algorithm
i_{km}	current through the branch connected between nodes-k and -m
$i_{km}^{\max}$	maximum permissible current limit for i_{km}
LVM	lowest voltage magnitude seen in the network
L_j	node location for j-th DG unit
LI	light intensity function
NVD	net voltage deviations
Ndg	number of DG units for placement
nn	number of nodes
PM	proposed method
$P_{DG,j}$	real power generation of j-th DG unit
$P_{load,m}$	real power load at node-m
PSO	particle swarm optimization
$P_{DG,j}^{\min}$	lower limit for real power generation of j-th DG unit respectively
$P_{DG,j}^{\max}$	upper limit for real power generation of j-th DG unit respectively
VP	voltage profile
V_j	voltage at node-j
Ψ	augmented cost function
λ_g	penalty factor for handling violation of DG power constraint
λ_b	penalty factor for handling violation of branch current flow constraint
$\Re$	a set of branches, whose current flow exceed the respective thermal limit

REFERENCES

[1] Rueda-Medina AC, Franco JF, Rider MJ, Padilha-Feltrin A and Romero R. 2013. A mixed integer linear programming approach for optimal type, size and allocation of distributed generation in radial distribution system. Electr Power Syst Res. 97: 133-43.

[2] Kaur, Sandeep, Ganesh Kumbhar and Jaydev Sharma. 2014. A MINLP technique for optimal placement of multiple DG units in distribution systems. Electrical Power and Energy Systems. 63: 609-17.

[3] Khalesi N, Rezaei N, Haghifam M-R. 2011. DG allocation with application of dynamic programming for loss reduction and reliability improvement. International Journal of Electrical Power & Energy Systems. 33(2): 288-95.

[4] Injeti, Satish Kumar, Prema Kumar N. 2013. A novel approach to identify optimal access point and capacity of multiple DGs in small, medium and large scale radial distribution systems, Electrical Power and Energy Systems. 45(1): 142-51.

[5] López-Lezama, JesúsMaría, Javier Contreras and Antonio Padilha-Feltrin. 2012. Location and contract pricing of distributed generation using a genetic algorithm. International Journal of Electrical Power & Energy Systems. 36(1): 117-26.

[6] Soroudi, Alireza, and Mozhgan Afrasiab. 2012. Binary PSO-based dynamic multi-objective model for distributed generation planning under uncertainty. IET renewable power generation. 6(2): 67-78.

[7] Nayak and Manas Ranjan. 2014. Optimal feeder reconfiguration of distributed system with distributed generation units using Hypercube-Ant Colony optimization algorithm. Int. J. Electr. Eng. Inform. 6(1): 107-28.

[8] Rama Prabha D and Jayabarathi T. 2015. Optimal placement and sizing of multiple distributed generating units in distribution networks by invasive weed optimization algorithm, Ain Shams Engineering Journal. http://dx.doi.org/10.1016/j.asej.2015.05.014.

[9] Aruul Vizhiy S and Santhi RK. 2016. Biogeography Based Optimal Placement of Distributed Generation Units in Distribution Networks. IEEE Sponsored International Conference on Electrical, Electronics and Optimization Techniques. 3-5 March. India.

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[10] Yang X S. 2008. Nature-Inspired Meta-Heuristic Algorithms. Luniver Press, Beckington, UK.

[11] Yang X S. 2009. Firefly algorithms for multimodal optimization, in Proceedings of the Stochastic Algorithms. Foundations and Applications (SAGA '09), Vol. 5792 of Lecture Notes in Computing Sciences. Springer, Sapporo, Japan. p. 178.

[12] Chandrasekaran K and Sishaj P Simon. 2012. Tuned Fuzzy Adapted Firefly Lambda Algorithm for Solving Unit Commitment Problem, J. Electrical Systems. 8(2): 132-150.

[13] Kuldeep Kumar Swarnkar. 2012. Economic load dispatch problem with reduce power loss using firefly algorithm, Journal of Advanced Computer Science and Technology. 1(2): 42-56.

[14] Sulaiman M H, Mustafa M W, Zakaria Z N, Aliman O and Abdul Rahim S R. 2012. Firefly Algorithm Technique for Solving Economic Dispatch Problem. IEEE International Power Engineering and Optimization Conference (PEOCO2012). Melaka, Malaysia. 6-7 June 2012.

[15] Prakash PS and Aravindhababu P. 2015. Firefly Optimization based Design for Improving Efficiency of Induction Motor. ARPN Journal of Engineering and Applied Sciences. 10(4): 1711-1716.

[16] Baran M. and Wu F. 1989. Network reconfiguration in distribution systems for loss reduction and load balancing. (IEEE Trans on Power Delivery). 4(2): 1401-1407.