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Loss Diminution and Reliability Enhancement of Radial Distribution System by optimally placing the Distributed Generation Using Evolutionary Algorithms

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Abstract
Inclusion of Distributed Generation (DG) with Electrical Distribution System (EDS) provides prospective profit to the conservative distribution systems. Recent days, DG sources are becoming more important due to the increased electricity demand of the power sector. In any distribution network, location and ratings of DG sources will have a profound effect on the system losses. Normally an optimization of DG location and sizing is done for the reason to reduce the loss and to get better voltage profile. This paper includes the impact of DG on various aspects of distribution system operation, such as reliability indices System Average Interruption Frequency Index (SAIFI), System Average Interruption Duration Index (SAIDI), and energy loss. This work finds the solution through the optimization technique Differential Evolution Algorithm (DE) and also appraises the effectiveness of this algorithm by comparing with Gravitation Search Algorithm (GSA). The effectiveness of the suggested methodology is applied on IEEE 33 radial bus system.Results reveal the competency of the proposed DE algorithm to find the optimal location and rating of the DG units for reducing the power loss, voltage deviation and improve the reliability of radial distribution system.

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I. Introduction

The electric power distribution system is the most important part of the electrical power system, and therefore, it is mainly responsible for energy losses. Since the last few years, the installation of DG in distribution network brings the attention of researcher due to its effective role in reducing the power loss of the distribution networks. Distributed generation is a small electric power generating unit within distribution network or on the customer premises. DG technologies often consist of modular (and sometimes renewable-energy) generators, and they offer a number of potential benefits, traditionally ten mega-watts or smaller.

In [1] the most sensitive bus is identified by the performing the task of continuous power flow. Also increases the in power transfer capacity, maximum loading, and voltage stability margin. In [2] Particle Swarm Optimization (PSO) is used for placing the DG in the radial distribution systems to minimize the active power losses and to improve the voltage profile and it is followed by a two-stage methodology which is used for the optimal DG placement. Optimum size and location of distributed generation that will be placed in the radial system will be defined by an analytical method so as to minimize the total power loss for the uniformly, centrally and increasingly distributed system profile G. T.

Hocaoglu et al [3] improved the Voltage stability margin by selecting candidate buses into which to install the DG units on the system, prioritizing buses which are sensitive to voltage profile. Stability margin of the system is enhanced by

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placing and sizing of DG's via mixed-integer nonlinear programming. The constraints are the system voltage limits, feeder capacity and the DG penetration level. In [4] the addition of distributed generation (DG) in distribution systems has augmented to high incursion levels. The impact of DG units on the voltage stability margins has become significant. Optimization techniques are tools which can be used to locate and size the DG units in the system, so as to utilize these units optimally within certain limits and constraints. Thus, the impacts of DG unit's issues, such as voltage stability and voltage profile, can be analyzed effectively. The ultimate goal of this paper is to propose a method of locating and sizing DG units so as to improve the voltage stability margin. The load and renewable DG generation probabilistic nature are considered in this study.

E. Rashedi et.al [5] proposed a methodology; this method first identifies the candidate bus which has the sensitivity towards the voltage profile where the DG has to be placed, thus by increasing the voltage stability margin. The optimal reactive power dispatch (ORPD) problem is solved by the application of Gravitational Search Algorithm (GSA) by formulating this as a nonlinear constrained single-objective optimization problem where the real power loss and the bus voltage deviations are to be minimized separately

S. Duman, et.al [6], suggested the GSA algorithm to solve the optimal reactive power dispatch problem in distributed or decentralized generation units connected to local distribution systems are in general not dispatched by a central operator but they can have a significant impact on the power flow, voltage profile, stability, continuity, and quality of power supply for customers and electricity suppliers. In [7] the author discusses the impact of DG on voltage profile and voltage stability issues.For that the DG units are optimally sized by PSO Algorithm by considering the improvement of voltage stability as an objective. The placements of the DGs are done by the availability of resources and it is connected in parallel with the utility grid. The effect of DGs on the stability of transmission line is investigated in [8-9]. The transient stability and small system stability of a bulk transmission system is studied through some case studies. . As an end result, the insertion of DG to the network may influence the stability parameters of the power system, such as frequency angle, and voltage stability.

Proper location of DG's in power systems is important for obtaining their maximum potential benefits. In [10],Analytical methods are used to determine the optimal location to place a DG in radial as well as networked systems to minimize the power loss of the system.

In [11], Methodology for employing fuel cell generators throughout a power system to allow for more efficient operation is used. In this wok an algorithm is used to find out the near optimal, by considering the system losses and the location of the units on the power grid is presented. In [12]A new software based Genetic Algorithm is suggested to find the optimal location of DG inMega Volt range distribution system with the constraints, such as feeder voltage profile,capacity limits and three-phase short circuit current.

Duong Quoc Hung et.al [13] proposed analytical expressionsto obtain the optimal size and power factor of different kind of distributed generation (DG) units. DG units are optimally sized for the highest better loss reduction in distribution networks. The proposed analytical expressions are more suitable for the DG type which deliver the real power. The same expressions extended for other three types of DG. The proposed method requires less computation leading to the optimal solution as verified by the exhaustive load flow method.

R.A. Jabrand and B.C. Pal[14] suggested an ordinal optimization (OO) method to identify the optimal location and rating of distributed generation (DG). This method reveals that the maximization of the DG capacity leads to loss minimization.In [15]. a multi-objective approach for optimal sizing and placing of multiple DG units in distribution systems with different load conditions is proposed. It inferred that the optimal placement and size depends on the load models.M.M. Aman, et.al[16] recommended a new algorithm for DGlocation and sizing for distribution network.In this paper an index is obtained by considering stable node voltages. In[17] Optimal DG placement is proposed to provide the best locations and sizes of DGs to optimize the distribution network planning and operation. In this problemcapacity of DGis taken as a constraint. In this work [18], Harmony Search Algorithm (HSA) is used for the simultaneous re-configuration and the optimal locations for of DG units in a distribution network. Here the author used the sensitivity analysis method to determine the optimal locations of DG units.

In [19], the author presents a method to study r the impact of the DG on electrical distribution system whether it is positive or negative. As a result the improper placement of DG leads to sudden transient voltages, reduction of power quality, and

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increases of power loss and make the system unreliable.

To overcome these problems during the placement of DG in Electrical Distribution network different methodologies and techniques are practiced by various authors.In this paper the exact placement of DGs is achieved by taking into consideration all possible combinations of sites and sizes of DGs in the system.The problem was converted to an optimization program and the real power loss of the system was the only aspect considered in this study in order to determine optimally the location and size of the DG unit. Gravitational Search Algorithm(GSA) and Differential evaluation algorithm (DE) are used in this paper in order to find solution to optimization problems, optimal size and site of DG in IEEE33- bus \ system. The aim of this paper reduction in real power losses, improving the voltage profileand the reliability indices like Energy Not supplied (ENS), SAIDI and SAIFI.

II. Problem Formulation

The objective of this work is to minimize the real power loss in the radial distribution system as well as to improve the voltage profile of the system by solving the distributed Generator placement and sizing problem. Problem formulation is nothing but the formulation objective function. It is mathematically formulated as,

$$Minf1 = \sum_{l=1}^{nl} P_L^l \qquad (1)$$

$$Minf2 = \sum_{i=1}^{nb} ENS_i \qquad (2)$$

$$Minf3 = \sum_{i=1}^{nb-g} V_{D_i} \qquad (3)$$

$$Minf4 = \frac{\sum_{i=1}^{nb} \lambda_i N_i}{\sum_{i=1}^{nb} N_i} \qquad (4)$$

$$Minf5 = \frac{\sum_{i=1}^{nb} U_i N_i}{\sum_{i=1}^{nb} N_i} \qquad (5)$$

In which,

P_L^l - Real power loss in l[th] branch
nl - No of branches in a network
nb - No of buses in a network
λ_i - Failure rate of bus i
N_i - No of customers at bus i
U_i - Annual outage time of bus i
g - No of generator buses in a network
ENS_i - ENS of node i which is given by,

$$ENS_i = P_i \sum_{i,j\in V, i\neq j} \left(U_{j,i} + U'_{j,i}\right) \qquad (6)$$

Where,

$V = \{1,2 \ldots.. nb\}$, nb - No of nodes in a network

P_i- Real power at bus I

$U_{j,i} and U'_{j,i}$ - Service unavailability associated with the reconstruction time of all the branches connecting the node.

V_{D_i}- Voltage deviation of load bus i, which is given by,

$$V_{D_i} = (1 - V_i)^2 \qquad (7)$$

Where,

V_i- Voltage at bus i

2.1. Real power and bus voltage constraints

Real power limit of distribution feeders for the network should not be exceeded.

$$P_{pq} \leq P_{pq}^{max} \qquad (8)$$

Where,

P_{pq} - Actual Real power flow of the feeder between buses p and q

P_{pq}^{max} - Maximum thermal limit for the feeder between buses p and q

Voltage magnitude at each bus must lie within their permissible ranges and it is given by,

$$V_b^{min} \leq V_b \leq V_b^{max} \qquad (9)$$

Where,

V_b- Voltage at bus b

V_b^{max} - Maximum voltage at bus b

P_b^{min} - Minimum voltage at bus b

2.2 DG rating constraints

The ratings of DG units must be constrained between its maximum and the minimum levels as given as follows,

$$P_{DG,i}^{min} \leq P_{DG,i} \leq P_{DG,i}^{max} \qquad (10)$$

In which,

$P_{DG,i}$- DG capacity at bus i

$P_{DG,i}^{max}$ - Maximum DG capacity that can be placed at bus i

$P_{DG,i}^{min}$ - Minimum DG capacity that can be placed at bus i

III. GSA Algorithm for DG Placement

Gravitational search algorithm (GSA) was introduced by Rashedi E et al. in 2009 based gravitational kinematics. This algorithm is based on the Newtonian gravity: "Every particle in the universe attracts every other particle with a force that is directly proportional to the product of their masses and inversely proportional to the square of the distance between them [19]. The superiority of GSA over other conventional optimization techniques are as follows [19]:

(i)The agent direction is calculated based on the overall force obtained by all other agents.

(ii) The force is proportional to the fitness value and so the agents see the search space around themselves in the influence of force.

(iii). GSA is memory-less and only the current position of the agents plays a role in the updating procedure.

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(iv) Balance between exploitation (heavier mass have higher attractions and move slowly) & exploration (lighter mass for fast moving and avoid trapping in a local optimum).
(v) The force is reversely proportional to the distance between solutions.

IV. DE Algorithm for DG Placement

DE uses some evolutionary operators like selection recombination and mutation operators. Different from genetic algorithm, DE uses distance and direction information from current population to guide the search process. DE strategies differ based on the selection of target vector and the usage of a number of difference vectors. Compared with other optimization algorithm DE finds a better solution without trapping in local maximum, and to achieve faster convergence rate. These algorithms are more reliable in giving better quality solutions with reasonable computational time since it avoids premature convergence of the search process to local optima and provides better exploration of the search process. The step by step procedure of DE algorithm for the proposed problem is given as below:

(i) Input the bus data
(ii) Calculate the Active power loss, ENS, SAIDI, SAFI and voltage deviation of the base case (without inserting the DG) using Backward/Forward algorithm
(iii) Identify the optimal placement and size of DG using the equations (1) to (5)
(iv) Find out the active power loss for each bus by locating the DG at particular location has been obtained from the previous step
(v) Check the constrain violation
(vi) Identify the bus in which the minimum loss is obtained after locating the DG
(vii) Stop.

V. Results and Discussion

IEEE 33 Bus Radial distribution is considered as test System. The test system has 5 tie line and 32 sectionalizing switches, with total load of 3.7 MW and 2.3 MVar.

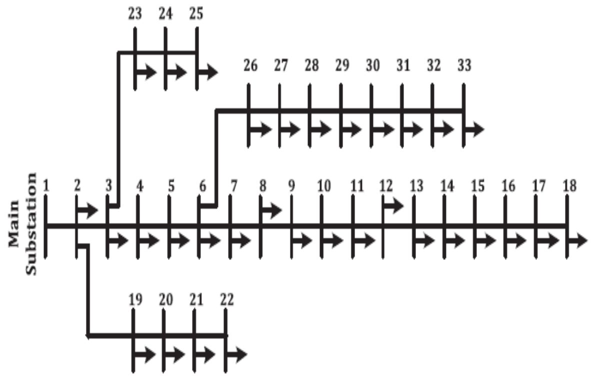

Figure 1. IEEE 33 Bus Test Systems

5.1 Case- I Base Case

In this case, Back /forward algorithm is applied to find out the power losses in the IEEE 33 bus system. As a result, the active power loss obtained is 210.0594kW and the voltage deviation as 0.1328. The reliability indices ENS, SAIDI and SAIFI are calculated as 11.8406 X 10^4 kWhr/yr, 0.3639 hrs/customer in a year, 0.0727 int/customer in a year respectively. These values are tabulated as shown in Table I

Table 1.Effects of Single and Multiple DGs Using GSA

Case	DG location	DG size	Real power loss (kW)	Voltage Deviation	ENS × 10^4kWh/yr	SAIDI hrs/customer in a year	SAIFI int/customer in a year
Base case	-	-	210.0594	0.1328	11.8406	0.3639	0.0727
With 1 DG	[23]	[149.97]	192.1160	0.1035	3.3842	0.3452	0.0685
With 2 DG	[32 18]	[149.99 109.21]	166.4732	0.0857	3.3536	0.3196	0.0573
With 3 DG	[17 32 12]	[124.34 139.99 132.40]	156.3369	0.0749	3.3210	0.2910	0.0466

5.2

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Case II System with DGs

First GSA algorithm is applied to find the optimal location and size of the DG to reduce the active power loss, reliability indices and voltage deviation. The identified location for placing single DG is 23. The active power loss is reduced to 192.1150 kW. At the same time, the voltage profile is improved by the value of 0.1035, the reliability indices also reduced as shown in table I. Similarly the same procedure is followed to place two and three DGs. The optimal placement and other obtained values are shown in Table 1. From these it evident that the increasing the number of DGs gives better power loss reduction and voltage profile improvement. The ENS, SAIDI and SAIFI values also improved in better way when the number of DGs is increased.The fitness curve for single and multiple DG using GSA algorithms is shown in Figure 2.

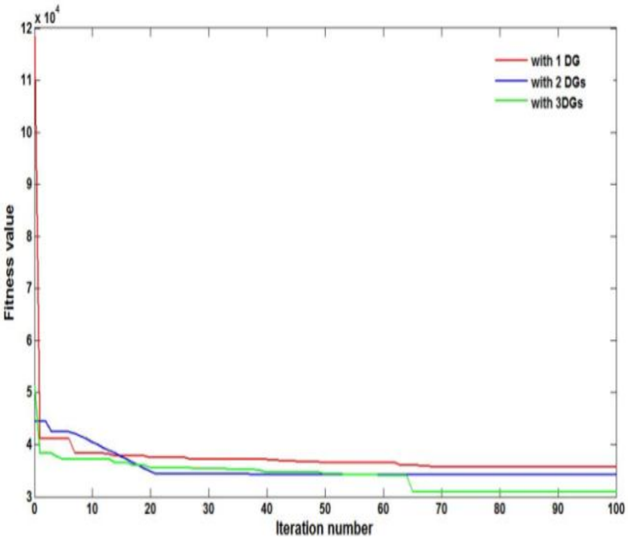

Figure 2.Fitness curves obtained with single and multiple DGs using GSA

Then, The DE algorithm is applied in the same test system to obtain the optimal sitting and sizing of DG. The obtained results for single and multiple DG is tabulated in Table 2. The evaluated fitness for placing single and multiple DG is shown in Figure 3.

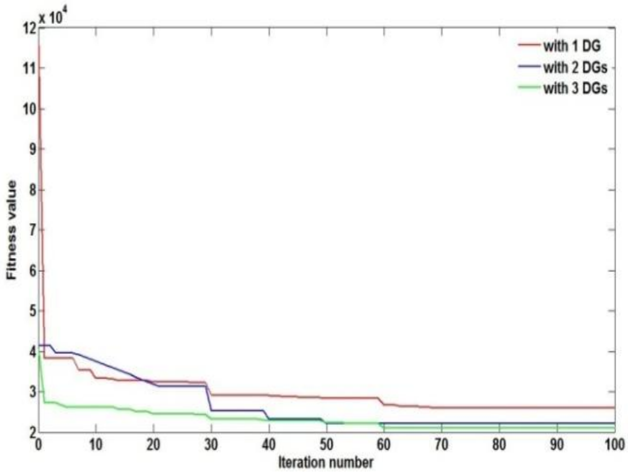

Figure 3.Fitness curves obtained with single and multiple DGs using DE

Table 2.Effects of Single and Multiple DGs Using DE

Case	DG location	DG size	Real power loss (kW)	Voltage Deviation	ENS× 10^4kWh/yr	SAIDI hrs/customer in a year	SAIFI int/customer in a year
Base case	-	-	210.0594	0.1328	11.8406	0.3639	0.0727
With 1 DG	[22]	[155.15]	186.2089	0.1001	3.1000	0.3111	0.0556
With 2 DG	[23,22]	[123.47, 102.55]	140.5430	0.0713	3.0274	0.3024	0.0498
With 3 DG	[22, 18,15]	[115.89, 142.20, 149.36]	122.1344	0.0549	3.0048	0.2018	0.0359

From the comparison, it concludes that the DE algorithm outperformed better than the GSA in the performance improvement of the Distribution system by optimally placing the DGs. The real power reduction by GSA is obtained as 25.574% but in the case of DE, it is reduced by 41.85%. The reliability indices ENS, SAIDI and SAIFI obtained by DE, also improved better than GSA as shown in Table.3

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Table 3.Comparison between DE and GSA Algorithm

Case	DG sizekW		Realpower loss (kW)		Voltage Deviation		ENS × 10^4kWh/yr		SAIDI hrs/customer in a year		SAIFI int/customer in a year	
	DE	GSA	DE	GSA	DE	GSA	DE	GSA	DE	GSA	DE	GSA
With1 DG	[155.15]	[149.97]	186.2089	192.1160	0.1001	0.1035	3.1000	3.3842	0.3111	0.3639	0.0556	0.0685
With2 DG	[123.47 102.55]	[149.99 109.21]	140.5430	166.4732	0.0713	0.0857	3.0274	3.3536	0.3024	0.3452	0.0498	0.0573
With3 DG	[115.89 142.20 149.36]	[124.34 139.99 132.40]	122.1344	156.3369	0.0549	0.0749	3.0048	3.3210	0.2018	0.3196	0.0359	0.0466

Voltage levels of all the busses keep the standard level of voltages (±5) both with GSA and DE. However, the voltage is more improved by using DE as shown in Figure 4. Displacement of DG makes the voltage profile instability.

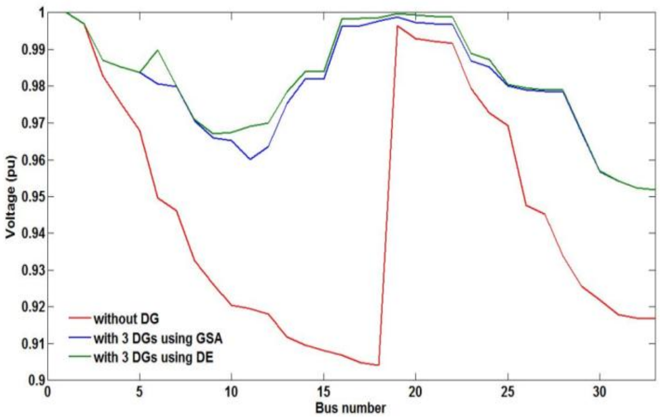

Figure4. Voltage profile of the IEEE-33 bus Radial distribution system with and without DG

VI. Conclusion

The Distributed Generations (DG) are capable of reducing real power losses in a power distribution system, however, they need to be placed at suitable locations. The GSA and DE algorithms are optimally placing the DG with the objective of reducing the total real power losses in the distribution systems. From the obtained results, the best locations corresponding to the optimum size for reducing the total real power loss in the distribution system. Especially the DE optimizes in a better way, the real power loss by 41.85% at the same time giving an improved voltage profile.Thus the optimal location of DG placement was determined by DE algorithm where the real power loss decreased, voltage profile and reliability indices were improved compared with Gravitational Search Algorithm (GSA)

References

[1] H. Hedayati, S. A. Nabaviniaki and A. Akbarimajd, "A Method for Placement of DG Units in Distribution Networks," IEEE Transactions on Power Delivery, Vol. 23, No. 3, July 2008, pp.1620-1628.

[2] Lalitha, M.P., Reddy, V.C.V., Usha, V.: “Optimal DG placement for minimum real power loss in radial distribution systems using PSO”, J. Theor. Appl. Inf. Technol., 2010, 13, (2), pp. 107–116.

[3] G. T. Hocaoglu, M. H. Eminoglu, and U. A. B Alikci, “Optimal placement and sizing of distributed generation on radial feeder with different static load models,” IEEE Trans. Future Power Systems, 2005 International Conference on, pp. 02-06, Nov.2005

[4] R. S. Al Abri, E. F. El-Saadany, and Y. M. Atwa, “Optimal placement and sizing method to improve the voltage stability margin in a distribution system using distributed generation,” IEEE Transactions on Power Systems, vol. 28, no. 1, pp. 326–334, 2013

[5] E. Rashedi, H. Nezamabadi-pour, and S. Saryazdi, “GSA: a gravitational search algorithm,” Information Sciences, vol. 179, no. 13, pp. 2232–2248, 2009

[6] S. Duman, Y. Sonmez, U. Guvenc, and N. Yorukeren, “Application of gravitational search algorithm for optimal reactive power dispatch problem,” in Proceedings of the International Symposium on Innovations in Intelligent Systems and Applications (INISTA '11), pp. 519–523, IEEE, Istanbul, Turkey, June 2011.

Published by: The Mattingley Publishing Co., Inc.

January - February 2020
ISSN: 0193 - 4120 Page No. 14244 – 14250

[7] Sriramulu, Mantyena, and M. Raji Rahul. "Optimal placing and sizing of DG in a distribution system for voltage stability improvement." *2016 International Conference on Electrical, Electronics, and Optimization Techniques (ICEEOT)*. IEEE, 2016.

[8] M. K. Donnelly, J. E. Dagle, D. J. Trudnowski, and G. J. Rogers, "Impacts of the distributed utility on transmission system stability," *IEEE Trans. Power Syst.*, vol. 11, no. 2, pp. 741–746, May. 1996

[9] M. Reza, J. G. Slootweg, P. H. Schavemaker, W. L. Kling, and L. van der Sluis, " Investigating impacts of distributed generation on transmission system stability," in *Proc. IEEE PowerTech.*, Rome, Italy, Jun.2003

[10] Caisheng Wang and M.HashemNehrir, "Analytical Approaches for Optimal Placement of Distributed Generation Sources in Power Systems", *IEEE Transactions On Power Systems*, vol. 19, no. 4, November 2004

[11] T. Griffin, K.Tomsovic, D.Secrest and A. Low, "Placement of dispersed generations systems for reduced losses," in *Proc. IEEE 33rdAnnu. Hawaii Int. Conf. Syst. Sciences (HICSS)*, Big Island, HI, 2000, pp. 1446–1454

[12] G. CELLI and F. PILO, "Optimal distributed generation allocation in MV distribution networks," in *Proc. 22nd IEEE PES Int. Conf. onPower Industry Computer Applications (PICA 2001)*, Sydney, Australia, May 2001

[13] Duong Quoc Hung, NadarajahMithulananthan and R. C. Bansal, "Analytical Expressions for DG Allocation in Primary Distribution Networks", *IEEE Transactions On Energy Conversion*, vol. 25, no. 3, September 2010

[14] R.A. Jabrand B.C. Pal, "Ordinal optimization approach for locating and sizing of distributed generation", *IET Generation, Transmission and Distribution*, vol. 3, Issue. 8, pp. 713–723, May 2009.

[15] A.M. El-Zonkoly, "Optimal placement of multi-distributed generation units including different load models using particle swarm optimization", *Swam and Evolutionary Computation, Elsevier*, vol.1, pp-50-59, March 2011.

[16] M.M. Aman, G.B. Jasmon, H. Mokhlis, A.H.A. Bakar, "Optimal placement and sizing of a DG based on a new power stability index and line losses", *SciVerseScienceDirect, Elsevier*vol 43, pp 1296-1304, May 2012

[17] Pavlos S. Georgilakis, Nikos D. Hatziargyriou, "Optimal Distributed Generation Placement in Power Distribution Networks: Models, Methods, and Future Research" *IEEE Transactions On Power Systems*, vol. 28, no.3, August 2013

[18] R. SrinivasaRao, K. Ravindra, K. Satish, and S. V. L. Narasimham, "Power Loss Minimization in Distribution System Using Network Reconfiguration in the Presence of Distributed Generation" *IEEE Transactions On Power Systems*, vol. 28, no.1, February 2013

[19] Rashedi E., Nezamabadi-pour H., Saryazdi S., GSA: A Gravitational search algorithm, Information Science, 179(2009), No. 1, 2232-2248.

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