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Minimization of Power Loss and Improvement of Voltage Profile in a Distribution System Using Harmony Search Algorithm

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Abstract: ***As Distribution Systems are growing large and being stretched too far, electric utilities and end users of electric power are becoming increasingly concerned about meeting the growing electric demand. Hence efforts have been made by electric utilities to reduce the losses in the distribution system. In this dissertation work, Network Reconfiguration and Optimal Distributed Generation placement are investigated for power loss reduction and to improve voltage profile of radial distribution system. Here a Meta-heuristic Harmony Search Algorithm was proposed in the literature to solve the Network Reconfiguration and to place Distributed Generation at optimal locations in network which results in minimum loss of the system. The Harmony Search Algorithm (HSA) uses a stochastic random search instead of a gradient search which eliminates the need for derivative information. This dissertation undertakes a work, first to validate the said methodologies and then extend beyond it. In undertaking this validation, it is observed that the HSA method performed well compared to the other methods in terms of the quality of solution. The experimental studies have been carried out on IEEE 33 and IEEE 69 Bus Radial Distribution Systems. From the results obtained, analysis has been done and it is found that Optimal Distribution Generation placement gives better reduction in power loss and improves voltage profile compared to Network Reconfiguration. The combined method of Network Reconfiguration and optimal Distributed Generation placement gives still better result than individual method of Network Reconfiguration and optimal Distributed Generation placement. The following case studies are performed. a) The same systems, i.e, IEEE 33 Bus and IEEE-69 Bus systems are considered for optimal no. of DG's so that the losses are minimal. The placement of DG's is based on the Loss Sensitivity Analysis. b) The same systems (without DG's) are investigated with reactive compensation for reduction of losses. The same locations are considered for placing the compensation. Simulations are carried out with the help of MATLAB 9.0 version programming***

Keywords: Distribution System, Network Reconfiguration, Distributed Generation, Power Loss Reduction, Harmony Search Algorithm

1. Introduction

Distribution systems deliver power to the customers from a set of distribution sub-stations which are normally radial in nature. In an automated distribution system the configuration is changed from time to time to supply the loads at minimum cost. Network Reconfiguration is one of the flexible methods to reduce the distribution network losses through altering the power flow in the distribution system by opening or closing the appropriate switches on the feeders. Hence the reconfiguration of a distribution system is a process of altering topological structure of the feeder by changing the status (open/close) of the sectionalizing switches (normally closed) and the tie switches (normally open) in the system. However, loads are dynamic in nature, and hence total system load is more than its generation capacity that makes relieving of load on the feeders not possible and hence voltage profile of the system will not be improved to the required level. In order to meet required load demand, DG units are integrated in distribution network to improve voltage profile, to provide reliable and uninterrupted power supply and also to achieve economic benefits such as minimum power loss, energy efficiency and load leveling. Distributed generation (DG) is small-scale power generation that is usually connected to or embedded in the distribution system.

Merlin and Back first proposed the network reconfiguration problem using branch and bound technique. Civanlar et al. Suggested heuristic algorithm. Nara et al. presented a solution using genetic algorithm. Zhu presented a refined genetic algorithm. In this paper, HSA has been proposed to solve the distribution system network reconfiguration problem in the presence of distributed generation. The algorithm is tested on 33 bus system and has been coded in MATLAB language.

2. Problem Formulation

The main aim of network reconfiguration in a distribution system is to find a best configuration of radial network which minimizes power losses by satisfying the required operating constraints such as voltage profile of the system, current capacity of the feeder, and radial structure of the distribution system. Thus the objective function for the minimization of power loss is described as

Minimize f= min.(PT, Loss)
Subjected to V min ≤/ Vi / ≤V max
and /I j /≤ /Ij, max /
det(A)=1 or -1 (radial system)

Where

PT, Loss= total real power loss of the system;
/ Vi /= voltage magnitude of bus;
V min, V max = bus minimum and maximum voltage limits, respectively;
(*V min* =0.9 p.u . and *V max*= 1.0 p.u.);

I j, Ij, max= current magnitude and maximum current limit of branch , respectively;
A= bus incidence matrix;

To solve the optimal Distributed Generation placement and sizing problem for radial distribution networks, a simpler power flow method called as the backward/forward sweep power flow is used for computing the power loss. In this power flow method, the relationship between the bus current injections and the branch currents is represented by the matrix [BIBC] which is given as:

[B] = [BIBC][I] (1)

Where, [I] is the bus current injection vector and [B] is the branch current vector as shown in a simple radial distribution network of Fig.1. The relationship between the branch currents, [B] and bus voltages, [ΔV] is represented by the matrix [BCBV]. The matrices [BIBC] and [BCBV] are then multiplied to obtain the relationship between the voltage deviation, [ΔV] and the bus current injections [I], which is represented by the matrix [DLF] and given as:

[ΔV] = [BCBV] [B] = [BCBV] [BIBC] [I] = [DLF] [I] (2)

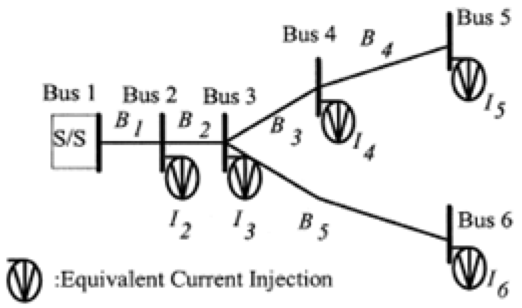
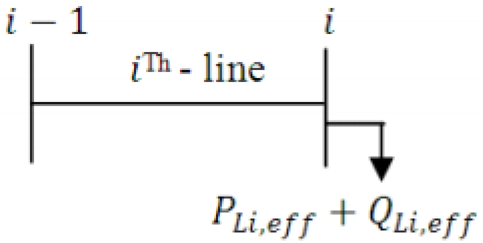


Figure 1: A Simple radial Distribution System

3. Sensitivity Analysis for Optimal DG Placement

Sensitivity analysis is used to compute the sensitivity factors [6] of candidate bus locations to install DG units in the test systems. Let us consider a line section consisting an impedance of Ri+jXi, and a load of PL, eff+QL, eff connected between i− 1 and i buses as given below.



Active power loss in the ith branch between the lines i-1 and I is given by

$$P_{lineloss} = R_i . \frac{(P_{Li,eff}^2 + Q_{Li,eff}^2)}{V_i^2}$$

Thus the Loss sensitivity factor is given as:

$$LSF = \frac{\partial P_{lineloss}}{\partial P_{Li,eff}} = \frac{2 * P_{Li,eff} * R_i}{V_i^2}$$

Thus from the above equation Loss Sensitivity Factors can be calculated and arranged in the descending order for finding the optimal locations to place DG units. Sizes of the DG units can be obtained by using Harmony Search Algorithm.

4. Overview of Harmony Search Algorithm

Recently, a meta- heuristic optimization algorithm inspired by playing music has been developed and it is called harmony search algorithm. It is based on meta-heuristic process which combines rules and randomness to imitate natural phenomena. Harmony search algorithm is inspired by the operation of orchestra music to find the best harmony between components which are involved in the operation process, for optimal solution. As musical instruments can be played with some discrete musical notes based on player experience or based on random processes in improvisation, optimization design variables can be considered certain discrete values based on computational intelligence and random processes. Music players improve their experience based on aesthetic standards while design variables in computer memory can be improves based on objective function

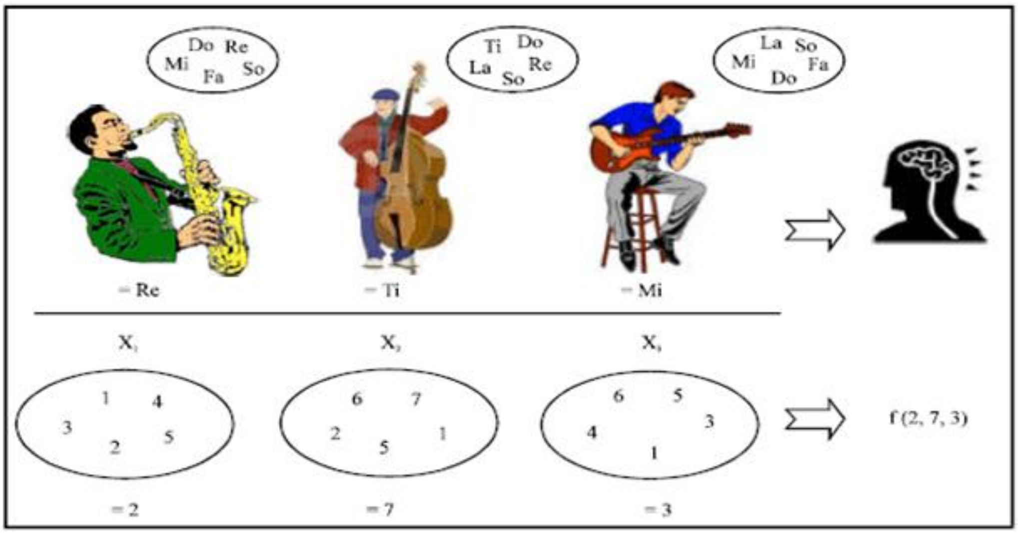


Figure 2: Harmony Search Algorithm

In music improvisation, each musician plays with in possible pitches to make a harmony vector. If all the pitches create good harmony, the musician saves them in memory and increased good or better harmony for next time (4). Similarly in the field of engineering optimization at first each decision variable value is selected within the possible range and formed a solution vector. If all the decision variables values lead to a good solution, each variable that has been experienced is saved in memory and it increases the possibility of god or better solution for next time.

The main steps of Harmony Search Algorithm are as follows.

1. Initialization of the optimization problem.
2. Initialization the Harmony Memory (HM)
3. Improvisation of New Harmony from the HM set.
4. Updating the harmony memory.
5. Repeat steps 3 and 4 until the termination criteria are satisfied.

1. Initialization of the optimization problem:

In general, optimization problem is specified as:

$$\text{Minimize } f(x)$$

$$\text{Subject to } x_i \in X_i, \qquad i = 1,2,\ldots\ldots N \quad (1)$$

Where f(x) is an objective function; x is the Set of each decision variable xi ;N is the number of decision variables; Xi is the set of the possible range of values for each decision variable. The Harmony Search parameters such as HMCR(Harmony Memory Consideration Rate), PAR (Pitch Adjusting Rate), HMS(Harmony Memory Size) that gives the number of solution vectors, HM(Harmony Memory), NI(Number of Improvisations) which is the stopping criteria. Here Harmony Memory is location where all the solution vectors are stored. HMCR and PAR are parameters that are required to improvise the new solution vector.

2. Initialization of the Harmony Memory:

In this step, HM matrix is filled with randomly generated solution vectors as that of HMS

$$HM = \begin{bmatrix} x_1^1 & x_2^1 & \cdots & x_{N-1}^1 & x_N^1 \\ x_1^2 & x_2^2 & \cdots & x_{N-1}^2 & x_N^2 \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ x_1^{HMS-1} & x_2^{HMS-1} & \cdots & x_{N-1}^{HMS-1} & x_N^{HMS-1} \\ x_1^{HMS} & x_2^{HMS} & \cdots & x_{N-1}^{HMS} & x_N^{HMS} \end{bmatrix} \quad (2)$$

3. Improvisation of new Harmony Vector

Creating New Harmony vector is called as improvisation and can be generated by considering three criteria: 1) Memory consideration, 2) Pitch adjustment, and 3) Random selection.

The, HMCR which varies between 0 and 1, HMCR is the rate of choosing one value from the historical values stored in the, while (1-HMCR) is the rate of randomly selecting one value from the possible range of values. Every component obtained with memory consideration is examined to determine if pitch is to be adjusted.

4. Updating the Harmony Memory

If the New Harmony vector has better fitness function than the worst harmony in the HM, then the New Harmony is replaced by the existing worst harmony in the HM.

5. Checking Termination Criteria

The Harmony Search Algorithm is terminated when the termination criterion i.e., maximum number of improvisations has been met. Or else steps 3 and 4 are repeated.

5. Applying Harmony Search Algorithm For Loss Reduction:

In this section application of HSA for network reconfiguration and DG installation problems has been specified for real power loss minimization and voltage profile improvement. Applying HSA for loss reduction with reconfiguration and DG installation is demonstrated with the help of standard 33-bus radial distribution system. For 33-bus system, 33, 34, 35, 36, and 37, are open tie-switches respectively, which forms five loops to L1 to L5. As shown in Fig. 3.

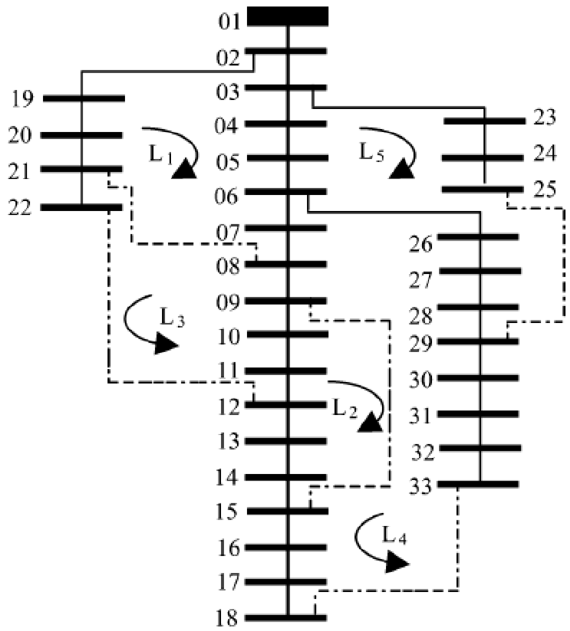


Figure 3: 33-bus radial system

In the simulation of network, four scenarios are considered to analyze the superiority of the proposed method.

Case I: The system is without reconfiguration and distributed generation (Base case);

Case II: same as Case I except that system is reconfigured by the available sectionalizing and tie switches;

Case III: same as Case I except that DG units are installed at candidate buses in the system;

Case IV: DG units are installed after reconfiguration of network;

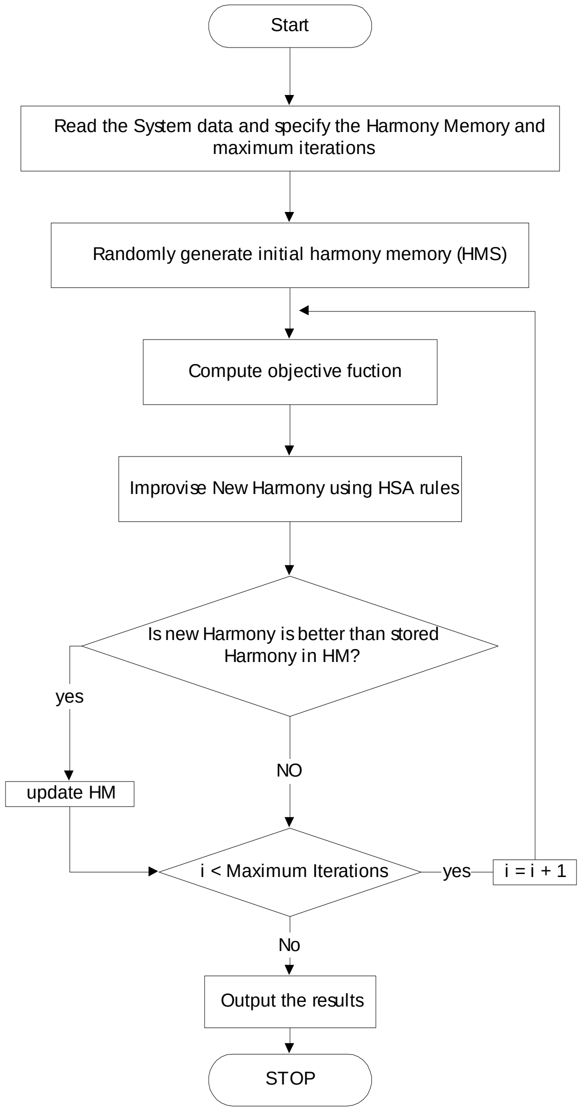


Figure 4: Flow chart for HSA method

6. Test Results and Analysis:

The test system is 33- bus radial distribution System (5) with 32 sectionalizing switches that are numbered from 1 to 32 which are normally closed and 5 tie-switches which are normally opened that are numbered from 33 to 37 respectively. The total real and reactive powers on the system are considered as 3715kW and 2300kVAR.By using sensitivity analysis; loss sensitivity factors are computed in order to install the DG units at optimal bus locations.. After computing sensitivity factors at all buses, they are sorted and ranked depending on the descending order of the sensitivity factors. Only top three locations are selected to install DG units in the given distribution system. The limits of DG unit sizes that are chosen for installation at selected optimal candidate buses are taken from 0 to 2 MW.

Table 1: "Loss sensitivity coefficients" of proposed algorithm

Bus Number	Loss Sensitivity Factor (LSF)	Normalization Factor Norm[i]= V[i]/0.95
18	**0.0986**	**0.9611**
17	**0.289**	**0.9618**
33	**0.0304**	**0.9648**
32	0.1244	0.9651
15	0.2367	0.9654
31	0.6063	0.9661
14	0.3124	0.9668
16	0.2332	0.969
13	0.9723	0.9692
30	0.4619	0.9705
29	0.867	0.9742
12	0.2773	0.9757
11	0.158	0.9772
10	0.9279	0.9782
28	1.2126	0.9829
9	0.9923	09843
8	0.8766	0.9909
27	0.3414	0.9949
7	0.2805	0.996
26	0.2595	0.9976
6	2.3288	0.9996

The result of sensitivity factor method for the required test system is tabulated above. Now for the buses whose Norm [i] value is less than 1.01 are considered as the optimal candidate bus locations requiring for the DG Placement. Amongst the buses first three.

Table 2: Results of 33-bus system:

Cases		Load Level		
		Light Load(0.5)	Nominal Load(1.0)	Heavy Load(1.6)
Base case (Case I)	Tie Switches	33,34,35,36,37	33,34,35,36,37	33,34,35,36,37
	Power Loss (kW)	47.07	202.68	575.36
	Minimum Voltage in p.u	0.9583	0.9131	0.8528
Only Reconfiguration (Case II)	Tie Switches	7,9,14,32,37	7,9,14,32,37	7,9,14,32,37
	Power Loss (kW)	32.96	138.36	377.64
	Minimum Voltage in p.u	0.9693	0.9369	0.8950
	Percentage of loss Reduction (%)	29.97	31.73	34.36
Only DG without Network Reconfiguration (Case III)	Tie Switches	33,34,35,36,	33,34,35,36,	33,34,35,36,37
	Sizes of DG in MW & Bus Number	0.509(17)	0.209(17)	0.683(17)
	Power Loss(kW)	24.20	97.28	261.73
	Minimum Voltage in p.u	0.9871	0.9392	0.9465
	Percentage of Loss Reduction (%)	48.58	52.00	54.51
Placing DG after Network Reconfiguration (Case IV)	Tie switches	7,9,14,32,37	7,9,14,32,37	7,9,14,32,37
	Sizes of DG in MW & Bus Number	0.405(17)	0.456(17)	0.810(17)
	Power Loss(kW)	22.59	96.68	254.60
	Minimum Voltage in p.u	0.9988	0.9601	0.9477
	Percentage of Loss Reduction (%)	52	52.29	55.74

Buses which are having less normalization factor are selected for optimal DG placement. Those are 17, 18, and 33 respectively.

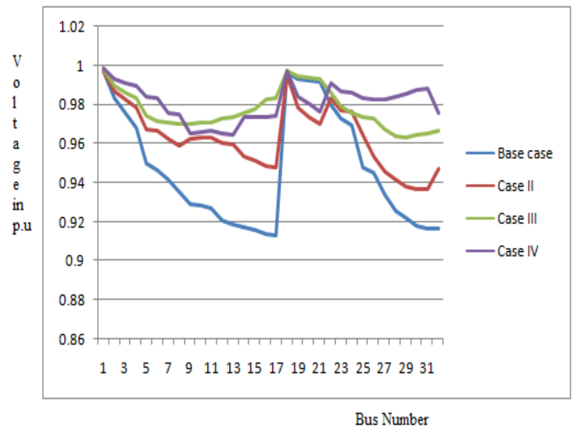


Figure 4: Voltage Profile for light load

Why only 3 DG's placed?

Table 3: DG Placement Results for 33 Bus System

No.of DG's	Light Load Conditions (0.5)	Nominal Load Conditions (1.0)	Heavy Load Conditions (1.6)
1 DG	34.10	144.27	400.16
2 DG	33.51	141.11	390.60
3 DG	23.49	97.83	261.42
4 DG	22.98	94.74	255.94
5 DG	24.01	91.01	246.30

Power Loss in KW

Thus from the above we can observe that placing 3DG's is more economical than placing 4DG's as there is less power loss reduction by placing 3DG's to 4DG's.

Table 4: Comparison of simulation Results with other Methods

Method	Item	Case II	Case III	Case IV
HSA	Tie Switches	7,9,14,32,37	-----------	7,9,14,32,37
	Power Loss in kW	138.36	97.28	96.28
	% Loss Reduction	31.73	52	52.29
	Minimum Voltage in p.u	0.9369	0.9392	0.96011
GA	Tie Switches	9,33,34,28,36	---------	9,33,34,28,36
	Power Loss in kW	141.60	100.1	98.36
	% Loss Reduction	30.15	50.60	51.46
	Minimum Voltage in p.u	0.9310	0.9605	0.9506

From Table II, we can determine that for a given 33- bus test system under the light load conditions the losses have been reduced from 47.07kW to 29.97kW, 24.2kW, 22.29 kW respectively for scenarios II, Scenario III, Scenario IV .For the nominal load conditions the losses have been reduced from 202.68 to 138.36kW, 97.28kW and 96. 68kW respectively. For the heavy load conditions losses have been reduced from 575. 36kW to 377.64kW, 261.73kW, and 254.60kW respectively. Hence we can observe that the percentage of loss reduction is more in the case IV. From the Table III, we can con conclude that proposed Harmony Search Algorithm gives better results than Genetic Algorithm(3) as per literature survey.

Table 5: Results of 69-bus system:

Cases		Load Level		
		Light Load(0.5)	Nominal Load(1.0)	Heavy Load(1.6)
Base case (Case I)	Tie Switches	69,70,71, 72,73	69,70,71, 72,73	69,70,71, 72,73
	Power Loss (kW)	51.59	224.95	652.35
	Minimum Voltage in p.u	0.9567	0.9092	0.8445
Only Reconfig uration (Case II)	Tie Switches	13,18,58, 61,69	13,18,58, 61,69	13,18,58, 61,69
	Power Loss (kW)	24.05	100.25	270.83
	Minimum Voltage in p.u	0.9762	0.9369	0.9194
	% of loss Reduction	53.38	55.43	58.48
Only DG without Network Reconfig uration (Case III)	Tie Switches	69,70,71, 72,73	69,70,71, 72,73	69,70,71, 72,73
	Sizes of DG in MW & Bus Number	0.546(63) 0.253(64) 0.332(65)	1.227(63) 0.127(64) 1.040(65)	1.872(63) 0.656(64) 1.462(65)
	Power Loss(kW)	21.35	86.39	228.62
	Minimum Voltage in p.u	0.9877	0.9697	0.9607
	% of Loss Reduction	58.61	61.59	64.93
Placing DG after Network Reconfig uration (Case IV)	Tie switches	13,18,58, 61,69	13,18,58, 61,69	13,18,58, 61,69
	Sizes of DG in MW & Bus Number	0.091(63) 0.979(64) 0.153(65)	0.498(63) 1.809(64) 0.641(65)	0.626(63) 1.934(64) 1.677(65)
	Power Loss(kW)	12.98	52.20	137.35
	Minimum Voltage in p.u	0.9892	0.9620	0.9598
	% of Loss Reduction	74.48	76.79	78.94

From which we can conclude that in Case IV percentage of Loss reduction is more compared to Case II and III and in Case III percentage of loss reduction is more compared to Case II.

Table 6: DG Placement Results for 33 Bus System

No.of DG's	Light Load Conditions	Nominal Load Conditions (1.0)	Heavy Load Conditions
	-0.5		-1.6
1 DG	34.1	144.27	400.16
2 DG	33.51	141.11	390.6
3 DG	23.49	97.83	261.42
4 DG	22.98	94.74	255.94
5 DG	24.01	91.01	246.3

Table 7: Comparison of simulation Results with other Methods:

Method	*Item*	*Case II*	*Case III*	*Case IV*
HSA	Power Loss in kW	100.25	86.4	52.2
	% Loss Reduction	55.43	61.59	76.79
GA	Power Loss in kW	103.29	88.5	54.53
	% Loss Reduction	54.08	60.66	75.76

7. Conclusion

In this paper, Heuristic optimization technique is used for Network Reconfiguration and Distributed Generation (DG) installation to minimize the real power loss and to improve the voltage profile in the radial distribution system. The proposed method has been tested on in 33-bus and 69-bus radial distribution systems at three different load conditions i.e. Light load condition, Normal Load condition, Heavy Load condition. The Results shows that DG installation after Network Reconfiguration method is more efficient in reducing power losses and improves voltage profile than implementing DG installation and Network Reconfiguration individually.

References

[1] J. S. Savier and D. Das, "Impact of network reconfiguration on loss allocation of radial distribution systems," IEEE Trans. Power Del., vol.2, no. 4, pp. 2473–2480, Oct. 2007.

[2] K. Prakash and M. Sydulu, "Particle swarm optimization based capacitor placement on radial distribution systems," in Proc. IEEE Power Engineering Society General Meeting, 2007, pp. 15.

[3] K. Nara, A. Shiose, M. Kitagawoa, and T. Ishihara, "Implementation of genetic algorithm for distribution systems loss minimum reconfiguration," IEEE Trans. Power Syst., vol. 7, no. 3, pp. 1044–1051, Aug.1992.

[4] Merlin and H. Back, "Search for a minimal-loss operating spanning tree configuration in an urban power distribution system," in Proc. 5th Power System Computation Conf. (PSCC), Cambridge, U.K., 1975, pp. 1–18.

[5] M. E. Baran and F. Wu, "Network reconfiguration in distribution system for loss reduction and load balancing," IEEE Trans. Power Del., vol.4, no. 2, pp. 1401–1407, Apr. 1989.

[6] P. Agalgaonkar, S. V. Kulkarni, S. A. Khaparde, and S. A. Soman, "Placement and penetration of distributed generation under standard market design," Int. J. Emerg. Elect. Power Syst., vol. 1, no. 1, p. 2004.

[7] R. Srinivasa Rao, S. V. L. Narasimham, M. R. Raju, and A. Srinivasa Rao, "Optimal network reconfiguration of large-scale distribution system using harmony search algorithm," IEEE Trans. Power Syst., vol. 26, no. 3, pp. 1080–1088, Aug. 2011.

[8] W. Rosehart and E. Nowicki, "Optimal placement of distributed generation," in Proc. 14th Power Systems Computation Conf., Sevillla, 2002, pp. 1–5, Section 11, paper 2.

[9] Z. W. Geem, J. H. Kim, and G.V.Loganathan, "A new heuristic optimization algorithm: Harmony search," Simulation, vol. 76, no. 2, pp.60–68, 2001.

[10] Z. W. Geem, "Novel derivative of harmony search algorithm for discrete design variables," Appl. Math. Computat., vol. 199, no. 1, pp.223–230, 2008.