ACTIVE POWER LOSS MINIMIZATION IN RADIAL DISTRIBUTION SYSTEM USING NETWORK RECONFIGURATION IN THE PRESENCE OF DISTRIBUTED GENERATION

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Abstract: This paper presents a new approach has been proposed to solve network reconfiguration in the presence of distributed generation (DG) in distribution system with an objective of minimization real power loss and improving voltage profile of the consumers connected to radial distribution network. The utilization of Distributed Generation (DG) sources in Distribution Power system is indeed vital as it is capable of solving problems especially pertaining to power losses due to an increasing demand for electrical energy. In order to reduce unnecessary power losses, in this paper proposes a Harmony Search Algorithm (HSA) was used as the solving tool, which referring two determined aim; the problem of network reconfiguration, and calculate the size of DG. Sensitivity analysis for identifying the optimal locations of distribution generation units, which in turn reduces the real power loss and improves the voltage profile in the distribution systems. The proposed method was examined on distribution network consisting of 33- bus radial distribution systems at different load levels to verify efficacy of the proposed method, the result shows that the proposed method is fast and effective.

Keywords: Power loss, Distributed Generation, reconfiguration, Harmony Search Algorithm, Sensitivity Analysis, complex combinatorial.

I.INTRODUCTION

The performance of distribution system becomes inefficient due to the reduction in voltage magnitude and increase in distribution losses. Thus, many researchers have been focusing on power loss minimization in the network reconfiguration of the distribution system by using various methods. And among the most effective
and recent method used is reconfiguration and DG. Since network reconfiguration and distribution generation placement are complex combinatorial, non-differentiable constrained optimization problem. The operation and control with this case, the power loss will not be minimum for a fixed network configuration. So, there is a need for network reconfiguration n from time to time. The major effect of DG units on the feeder reconfiguration problem lies on the fact that power flows in the distribution system, which is normally radially operated. The change in network configuration is performed by opening sectionalizing and closing tie switches of the network under normal and abnormal operating conditions. Reconfiguration also relieves the over loading of the network components but voltage profile will not be improved to the required level. In order to meet energy demand distributed generation devices can be strategically placed in power systems. Distributed generation is the practice of locating small electrical power generation units close to the point of locating small electrical power generation units close to the point of end use. DG technologies include diesel engines, heat combustion engines, small wind turbines, fuel cells and photovoltaic system. DG technologies can run on renewable energy resources, fossil fuels or waste heat. The size of DG equipment ranges from less than a KW to tens of MW. The presence of Distributed Generations (DG) in power systems may lead to several advantages such as providing sensitive load protection, reducing transmission and distribution network congestion and expansion, and improving the overall system performance by reducing power losses and enhancing voltage profiles. Depending
on the number of DGs to be installed, the optimal DG placement problem is classified as single DG or multiple DG s installation. Optimal DG placement problem is very interesting in the smart grid system, where the usage of renewable energy is expected to increase. Merlin and Back [1], first proposed network reconfiguration problem and they used a branch-and-bound-type optimization technique. The drawback with this technique is the solution proved to be very time consuming as the possible system configurations are, where line sections equipped with switches is. Based on the method of Merlin and Back [1], a heuristic algorithm has been suggested by Shirmohammadi and Hong [2]. The drawback with this algorithm is simultaneous switching of the feeder reconfiguration is not considered. A heuristic algorithm was suggested by Civanlar *et al* [3], where a simple formula was developed to determine change in power loss due to a branch exchange. The disadvantage of this method is only one pair of switching operations is considered at a time and reconfiguration of network depends on the initial switch status. Das [4] was presented an algorithm based on the heuristic rules and fuzzy multi-objective approach for optimizing network configuration. The disadvantage in this is criteria for selecting

membership Functions for objectives are not provided. A solution using a genetic algorithm (GA) [5] was presented to look for the minimum loss configuration in distribution system. A refined genetic algorithm (RGA) [6] was presented to reduce losses in the distribution system. In RGA, the conventional crossover and mutation schemes are refined by a competition mechanism. Many methods are proposed for the best placement and sizes of DG units which is also a complex combinatorial optimization problem. An analytical method [7] was introduced to determine optimal location to place a DG in distribution system for power loss minimization.

A multiobjective algorithm using GA [8] was presented for sitting and sizing of DG in distribution system. Placement and penetration level of the DGs under the SMD framework was discussed by Agalgaonkar [9].The authors R.Srinivasa Rao,S.V.L.Narasimham, M.R.Raju, and A.Srinivasa Rao presents a Harmony Search algorithm (HSA) was proposed to solve the network reconfiguration problem to get optimal switching combinations simultaneously in the network to minimize real power losses in the distribution network[10]. The proposed algorithm converges to optimum solution quickly with high accuracy. The size of the solution vector is equal to the total number of switches in the system. As the size of the system increases, the size of the solution vector in the other methods is large compared to the proposed method and computation time is also better than other methods.

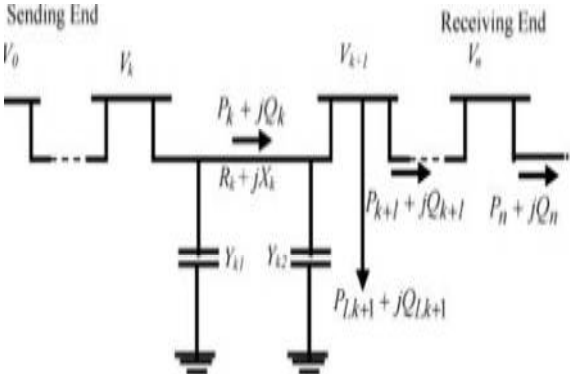


Fig. 1. Single-line diagram of a main feeder.

II. FORMULATION OF OPTIMIZATION PROBLEM

a) Power Flow Equations

By applying efficient method [11], the load flow solutionsin a distribution system are computed by the following set of simplified recursive equations derived from the single-line diagram shown in Fig.1:

$$P_{k+1} = P_k - P_{Loss,k} - P_{Lk+1}$$
$$= P_k - \frac{R_k}{|V_k|^2}\{P_k^2 + (Q_k + Y_k|V_k|^2)^2\} - P_{Lk+1} \quad (1)$$
$$Q_{k+1} = Q_k - Q_{Loss,k} - Q_{Lk+1}$$
$$= Q_k - \frac{X_k}{|V_k|^2}\{P_k^2 + (Q_k + Y_{k1}|V_k|^2)^2\} - Y_{k1}|V_k|^2 - Y_{k2}|V_{k+1}|^2 - Q_{Lk+1} \quad (2)$$
$$|V_{k+1}|^2 = |V_k|^2 + \frac{R_k^2 + X_k^2}{|V_k|^2}(P_k^2 + (Q_k + Y_k|V_k|^2)^2) - 2\big(R_k P_k + X_k(Q_k + Y_k|V_k|^2)\big). \quad (3)$$

The power loss in the line section connecting buses k and k+1 may be calculated as,

$$P_{Loss}(k, k+1) = R_k \cdot \frac{(P_k^2 + Q_k^2)}{|V_k|^2}. \quad (4)$$

By summing up the losses of all line sections of the feeder, the total power loss is given by,

$$P_{T,Loss} = \sum_{k=1}^{n} P_{Loss}(k, k+1). \quad (5)$$

B. Power Loss Using Network Reconfiguration

The network reconfiguration plays a vital role in finding the radial operating structure in order to minimize the system power losses and at the same time maintaining operating constraints, such as voltage profile of the system, current carrying capacity of the feeder and radial structure of distribution system.After reconfiguration, the power loss in the line section with buses k and k+1 is calculated as follows

$$P'_{Loss}(k, k+1) = R_k \cdot \frac{(P_k'^2 + Q_k'^2)}{|V_k'|^2}. \quad (6)$$

The total real power loss of the all lines sections in n bus system ($P_{T,Loss}$) is calculated by adding up the losses of all line sections of the feeder, which is described as,

$$P'_{T,Loss} = \sum_{k=1}^{n} P'_{Loss}(k, k+1). \quad (7)$$

C. Loss Reduction Using Network Reconfiguration

Net power loss reduction in the system is the variance of power loss before and after reconfiguration, that is equations (5) – (7)and is given by

$$\Delta P_{Loss}^{R} = \sum_{k=1}^{n} P_{T,Loss}(k, k+1) - \sum_{k=1}^{n} P'_{T,Loss}(k, k+1). \quad (8)$$

D. Power Loss Reduction Using DG Installation

Distributed generation units' installation in optimal location of a distribution system results in various benefits. These contain Supplying peaking power to reduce the cost of electricity, reduce environmental emissions through clean and renewable technologies (Green Power), combined heat and power (CHP), high level of reliability and quality of supplied power

and deferral of the transmission and distribution line investment through improved load ability are the major applications of the DG. Other than these applications, the major application of DG in the deregulated environment lies in the form of ancillary services. The power loss when a DG is installed at an arbitrary location, the power loss is given by,

$$P_{DG,Loss} = \frac{R_k}{V_k^2}(P_k^2 + Q_k^2) + \frac{R_k}{V_k^2}(P_G^2 + Q_G^2 - 2P_kP_G - 2Q_kQ_G)\left(\frac{G}{L}\right). \quad (9)$$

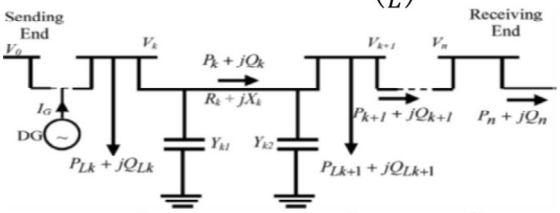


Fig. 2. Distribution system with DG installation at an arbitrary location.

Net power loss reduction is the variance of equations (9) and (16) is given by,

$$\Delta P_{Loss}^{DG} = P_{DG,Loss} - P_{lineloss}$$

$$\Delta P_{Loss}^{DG} = \frac{R_k}{V_k^2}(P_G^2 + Q_G^2 - 2P_kP_G - 2Q_kQ_G)\left(\frac{G}{L}\right). \quad (10)$$

The positive sign of ΔP_{Loss}^{DG} indicates that the system loss reduces with installation of DG. In difference the negative sign of ΔP_{Loss}^{DG} denotes that DG origins the higher system loss.

E. *Objective Function of the Problem*

The objective function of the problem is expressed to maximize the power loss reduction in distribution system while subjected to power balance constraints and power generation limit.Which is given by

Maximize the$f = \max\cdot(\Delta P_{Loss}^{R} + \Delta P_{Loss}^{DG})$ (11)

The bus voltage magnitudes are to be kept within acceptable operating limits throughout the optimization process, as follows, that means voltage constraints should be satisfied, as given below,subjected to

$$V_{min} \le V_k \le V_{max}$$

Andfeeder capability limits

$|I_{k,k+1}| \le |I_{k,k+1,max}|\}$(12)

Generator operator constraints

$$\sum_{k=1}^{n} P_{Gk} \le \sum_{k=1}^{n}(P_k + P_{Loss,k})$$

Radial structure of the system

$$\det(A) = 1\ or - 1\ (radialsystem)$$
$$\det(A) = 0(\ notradial)\} \quad (13)$$

Where the lower bound of bus voltage limits is V_{min} andV_{max} is the upper bound of bus voltage limits.

III. SENSITIVITY ANALYSIS FOR DG INSTALLATION

Sensitivity factor method is based on the principle of linearization of original nonlinear equation around the initial operating point, which helps to reduce the number of solution space. Loss sensitivity factor method has been widely used to solve the capacitor allocation problem [12].Sensitivity factors [13] are evaluated at each bus to install DG units, firstly using the values obtained from the base case power flow. The fig.3 shows a line impedance of $R_K + jX_K$ between k-1 and k buses connected to the load of$P_{LK,eff} + jQ_{LK,eff}$. The active power loss in k[th]line as shown in equation [1].

$$P_{Loss} = [I_k^2] \times R_k (14)$$

Wherethe branch current is I_k and R is the resistance of line. In addition,

$$I_k = \left[\frac{P_{Lk,eff} + jQ_{Lk,eff}}{V_{Lk,eff}}\right]^* \quad (15)$$



Fig.3: connected line between bus k-1 and k

Where P, Q, V are the real power load and reactive power load, voltage at the receiving end.By substituting equation (15) in (14) as given follows, Active power loss in the k^{th}-line between k-1 and k buses is given by,

$$P_{lineloss} = \frac{(P_{Lk,eff}^2 + Q_{Lk,eff}^2)R_k}{V_k^2} (16)$$

The sensitivity factor of real power loss is obtained by differentiating equation (16) with respect to real power injection from DG at bus k which is given by as follows,

$$\frac{\partial P_{lineloss}}{\partial P_{LK,eff}} = \frac{2 * P_{LK,eff} * R_K}{V_K^2}. \quad (17)$$

Using above equation (17), LSFs are computed from load flows and values of the buses are ranked in descending order of the values of their sensitivity factors to form a priority list. The top-ranked buses in the priority list are most sensitive to DG placement in order to have the best effect on loss reduction.

IV. HARMONY SEARCH ALGORITHM

The harmony search algorithm (HSA) is a new meta-heuristic population algorithm. The harmony search algorithm (HSA) is simple in conceptfrom natural musical performance processes [14], few in parameters and easy in implementation. In music improvisation, each musician plays within possible pitches to make a harmony vector. If all the pitches create good harmony, the musician saved them in memory and increases good or better harmony for next time. 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 decision variable values lead to a good solution, each variable that has been experienced is saved in memory and it increases the possibility of good or better solutions for next time. Both processes intend to produce the best or optimum. It has been successfully applied to various computational optimization [15] problems such as structural design, water network design, dam scheduling, and variousbenchmark and real-world problems like traveling salesman problem [16].

The main steps of HS are as follows [14]:

Step 1) Initialize the problem and algorithm parameters.

Step 2) Initialize the harmony memory.

Step 3) Improvise a new harmony.

Step 4) Update the harmony memory.

Step 5) Check the stopping criteria.

These steps are explained in below as follows,

Step 1. Initialize the Problem and Algorithm Parameters

The general optimization problem is specified as follows:

$$minimize f(x) subject to x_i \in X_i, \quad i = 1,2,\dots N$$

where $f(x)$ is an objective function; x is the set of each decision variable x_i; N is the number of decision variables; X_i is the set of the possible range of values for each decision variable, that is $Lx_i \le X_i \le Ux_i$;and Lx_i and Ux_i are the lower and upper bounds for each decision variable. The HS algorithm parameters are also specified in this step. These parameters are harmony memory size (HMS), harmony memory considering rate (HMCR), pitchadjusting rate (PAR), number of improvisation (NI), andharmony memory (HM), which are defined in further steps.

Step 2.Initialize the Harmony Memory

In this step, the harmony memory (HM matrix) is filled with as many randomly generated solution vectors as HMS and sorted by the values of the objective function.

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

Step 3. Improvise a New Harmony

A New Harmony vector $x^{\rightarrow'} = (x_1', x_2', \cdots\cdots\cdots x_N')$ is generated from the HM based on memory considerations, pitch adjustments, and randomization. For instance, the value of the first decision variable for the new vector can be chosen from any value in the specified HM range Values of the other decision variables can be chosen in the same manner known as improvisation. There is a possibilitythat the new value can be chosen using the HMCR parameter, which varies between 0 and 1 as follows:

$$x_i' = \begin{cases} x_i' \in \{x_i^1, x_i^2, \cdots\cdots x_i^{HMS}\} \text{with probability HMCR} \\ x_i' \in X_i \text{with probability}(1 - \text{HMCR}) \end{cases}$$

The HMCR sets the rate of choosing one value from the historic values stored in the HM and (1-HMCR) sets the rate of randomly choosing one feasible value not limited to those stored in the HM. For example, a HMCR of 0.9 indicates that the HS algorithm will choose the decision variable value from historically stored values in the HM with the 90% probability or from the entire possible range with the 10% probability. Each component of the New Harmony vector is examined to determine whether it should be pitch adjusted. This procedure uses the PAR parameter that sets the rate of adjustment for the pitch chosen from the HM as follows: Pitch adjusting decision for

$$x_i' = \begin{cases} \text{with probability HMCR} \\ \text{with probability}(1 - \text{HMCR}) \end{cases}$$

A PAR of 0.3 indicates that the algorithm will choose a neighboring value with $30\% \times \text{HMCR}$ probability.

$$if\ (rand() < HMCR)$$
$$x_i' \leftarrow x_i' \in \{x_i^1, x_i^2, \cdots\cdots\cdots x_1^{HMS}\}$$
$$elseif (rand < PAR)$$
$$x_i' = x_i' \pm rand() b\omega$$

Where $b\omega$ is an arbitrary distance bandwidth for the continuous design variable and $rand()$ is uniform distribution between 0 and 1. Since the problem is discrete in nature, is taken as 1.

Step 4. Update Harmony Memory

In this stage, if the New Harmony vector $x^{\rightarrow'} = (x_1', x_2', \cdots\cdots\cdots x_N')$ is better than the worst harmony vector in the HM in terms of the objective function value, the existing worst harmony is replaced by the New Harmony.

Step 5. Check stopping criterion

Repeat steps 3 and 4 until the termination criterion is satisfied Termination criterion: The computations are terminated when the termination criterion (maximum number of improvisations) is satisfied. Otherwise, steps 3 (improvising New Harmony from the HM) and 4 (updating the HM) are repeated.

V. CASE STUDY

Getting the optimal solution for combined network reconfiguration and DG allocation using conventional methods is difficult because they are complex combinatorial optimization problems. So, a nature inspired evolutionary algorithm, HSA, that is based on the improvisation process of music players is applied.

The main idea is to get best combinations of open/closed switches and place an optimal size of DGs at sensitive buses so that the combined network must give minimum real power loss and improve the voltage profile in the system.

In general, the structure of solution vector for reconfiguration of a radial distribution system is expressed by Arc No. (i) and SW. No. (i) for each switch i. Arc No. (i) Identifies the arc (branch) number that contains the ith open switch, and SW. No. (i) identifies the switch that is normally open on Arc No. (i). For large distribution networks, it is not efficient to represent every arc in the string, since its length will be very long. To memorize the radial configuration, it is enough to number only the open switch positions. The solution vector must contain the open switch numbers and DG values. Hence the first part of variables in the solution vector is open switch numbers and second part of variables is sizes of the DG settings. The second part of the solution vector is DG values required to be placed at different nodes in the system. If a network has n buses and s is number of available DG sizes, then there are +1possible combinations of solution are possible. This requires a lot of computational burden. In order to reduce the computational efficiency and dimension of the solution vector, voltage stability indices are used to select most sensitive nodes which require reactive power compensation. The format of the solution vector in Harmonic Memory(HM) is

$$\text{HMS}=\underbrace{\left[os_1^1 \quad os_2^1 \quad os_3^1 \quad os_4^1\right.}_{\text{Reconfiguration}}\underbrace{\left.os_5^1 \quad S_1^1 \quad S_2^1 \quad S_3^1\right]}_{\text{DG sizes}}$$

In order to explain the proposed method, a standard IEEE 33-bus distribution system is considered. It consists of 32 normally closed switches and 5 normally opened switches as shown in Fig. 4. This network contains one tie switch in each loop and these are designated as 33, 34, 35, 36, and 37. In the solution process only tie switches are used to form solution vectors of the HMS.

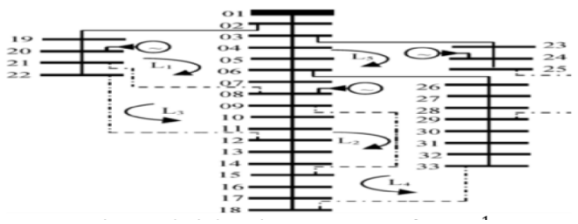


Fig. 4. 33-bus radial distribution system for 1 The computation of voltage stability indices help to select optimal locations (most sensitive nodes) for DG placement in the system. For this network optimal locations are computed as 6, 28, 29, 30 and 9 which require reactive power compensation to minimize power loss and improve voltage profile. Thus the second part contains three variables and these are DG sizes. Throughout the optimization process the dimension of second part of the solution vector is constant and only optimal size of the capacitor at a node will vary. The solution vector 1 for this configuration is represented as:

$$HMS^1 = \underbrace{\left[33 \quad 34 \quad 35 \quad 36 \quad 37\right.}_{\text{Reconfiguration}}\underbrace{\left.S_1 \quad S_2 \quad S_3\right]}_{\text{DG Sizes}}$$

The DG sizes are chosen randomly from 0 to maximum size of the capacitors available. For other solution vector(HMS^2), a radial network, shown in Fig. 5, is randomly generated with open tie switches 19, 13, 21, 30, and 24 without violating the radiality constraint.

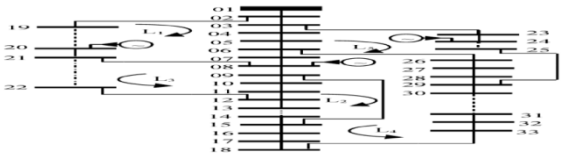


Fig.5. 33-bus radial distribution system for HV^2

For the above configuration the solution vector is represented as:

$$HMS^2 = \underbrace{\left[19 \quad 13 \quad 21 \quad 30 \quad 37\right.}_{\text{Reconfiguration}}\underbrace{\left.S_1 \quad S_2 \quad S_3\right]}_{\text{DG sizes}}$$

In the fashion, all the other possible solution vectors randomly are generated without violating the radial structure or islanding any load in the network. For this network, total number of solution vectors made are less than or equal to maximum numbers of switches in any individual loop. The total Harmony Matrix (HM) generated randomly with objective function values is shown below.

$$\begin{bmatrix} 19,13,21,30,37,S_1^1,S_2^1,S_3^1 & | & f_1 \\ 6,34,14,30,37,S_1^2,S_2^2,S_3^2 & | & f_2 \\ \cdots \quad \cdots\cdots \quad \cdots \quad \cdots \quad \cdots \quad \cdots \quad \cdots & & \cdots \\ 33,34,35,36,37,S_1^N,S_2^N,S_3^N & | & f_n \end{bmatrix}$$

The objective function values$(f_1, f_2, \cdots\cdots f_n)$ shown in the last column of the HM matrix are arranged in ascending order to eliminate the worst solution vectors in the next iteration. The new solution vectors are updated. Using the new solution vectors, the worst vectors of previous iteration will be eliminated with new random vectors selected from the population that has less objective function value. This procedure is repeated until termination criteria are satisfied.

VI. SIMULATION RESULTS

To demonstrate the application of the proposed method, test system comprising of 33 buses are

considered. The substation voltage is considered as 1p.u. The algorithm was developed in MATLAB and simulations are carried out. The test system is a 33 bus, 12.66 kV, radial distribution system [17]. It consists of five tie lines and 32 sectionalize switches. The normally open switches are 33 to 37 and the normally closed switches are 1 to 32. The line and load data of the network is obtained and the total real and reactive power loads on the system are 3715 kW and 2300 kVAR. The parameters of HSA algorithm used in the simulation of network are HMS=20, MCR=0.85, PAR=0.9, maximum iterations = 20.Using sensitivity analysis [13] sensitivity factors are computed to install the DG units at candidate bus locations for scenarios III, IV, and V. After computing sensitivity factors at all buses, they are sorted and ranked. Only top three locations are selected to install DG units in the system. The limits of DG unit sizes chosen for installation at candidate bus locations are 0 to 2 MW. The optimal structure of network after simultaneous reconfiguration and DG installation for scenario V is shown in Figure 6.

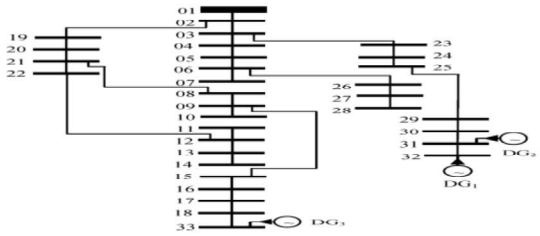


Fig.6.Optimal network structure after simultaneous reconfiguration and DG installation.

TABLE I

RESULTS OF 33-BUS SYSTEM

Case		Load Level		
		Light (0.5)	Nominal (1.0)	Heavy (1.6)
Base Case (Case I)	Switches Opened	33,34,35,36,37	33,34,35,36,37	33,34,35,36,37
	Power Loss (kW)	47.06	202.67	575.27
	Minimum Voltage (p.u)	0.9583	0.9131	0.8529
Only Reconfiguration (Case II)	Switches Opened	7,14,9,32,37	7,14,9,32,37	7,14,9,32,37
	Power Loss	33.27	138.06	380.43
	%Loss Reduction	29.3	31.88	33.86
	Minimum Voltage (p.u)	0.9698	0.9342	0.8967
Only DG Installation (Case III)	Switches Opened	33,34,35,36,37	33,34,35,36,37	33,34,35,36,37
	Size of DG in MW (Bus Number)	0.1303 (18) 0.1777 (17) 0.5029 (33)	0.1070 (18) 0.5724 (17) 1.0462 (33)	0.1939 (18) 0.9108 (17) 1.6115 (33)
	Power Loss (kW)	23.29	96.76	260.97
	%Loss Reduction	50.5	52.26	54.63
	Minimum Voltage (p.u)	0.9831	0.9670	0.9437
DG Installation After Reconfiguration (Case IV)	Switches Opened	7,14,9,32,37	7,14,10,32,28	7,14,10,28,32
	Size of DG in MW (Bus Number)	0.1015 (32) 0.1843 (31) 0.2568 (30)	0.2686 (32) 0.1611 (31) 0.6612 (30)	0.2443 (32) 0.3068 (31) 1.2185 (30)
	Power Loss (kW)	23.54	97.13	259.63
	%Loss Redductio n	49.98	52.07	54.87
	Minimum Voltage (p.u)	0.9745	0.9479	0.9140
Reconfiguration With Simultaneous DG Installation (Case V)	Switches Opened	7,14,11,32,27	7,14,10,32,28	7,14,10,28,32
	Size of DG in MW (Bus Number)	0.1954 (32) 0.4195 (31) 0.2749 (33)	0.5258 (32) 0.5586 (31) 0.5840 (33)	0.5724 (32) 1.2548 (31) 0.9257 (33)
	Power Loss (kW)	17.78	73.05	194.22
	%Loss Reduction	62.22	63.95	66.23
	Minimum Voltage (p.u)	0.9859	0.9700	0.9516

The voltage profile curve of all scenarios at light load conditions is shown in Figure.7. The graph shows how the voltage varies with bus number. The bus number is taken along the x-axis since it is an independent quantity and the voltage is taken along y-axis because it is a dependent quantity. The bus number is from 1 to 33 and the voltage in per unit is taken from 0.955 to 1. It is seen that the voltage reaches 1p.u at bus number near 1 and 19.

Descriptions on five different case studies:

In the simulation of network, from the base system, five different cases are formed and shall be analyzed for their robustness and efficiency of HSA in obtaining the best configuration (To analyze the dominance of the proposed method).

The lists of cases are:

Case I: The system is without reconfiguration and DG units (base case).

Case II: The system is optimally reconfigured by the available sectionalizing and tie switches.

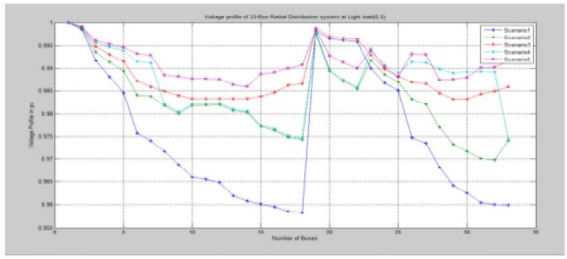
Case III: Optimal size of DG units installed at the candidate buses of the system.

Case IV: Optimal size of DG units is installed after reconfiguration of the network.

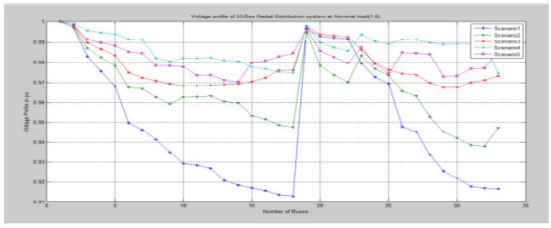
Case V: The system is optimally reconfigured in presence of DG units installed.

The voltage profile of the system for the five scenarios at different load levels as shown in above table,

(a) Volatage Profile of 33-bus Radial Distribution System at Light Load (0.5)



(b) Voltage Profile of 33-bus Radial Distribution System at Nominal Load (1.0)



(c) Voltage Profile of 33-bus Radial Distribution System at Heavy Load (1.6)

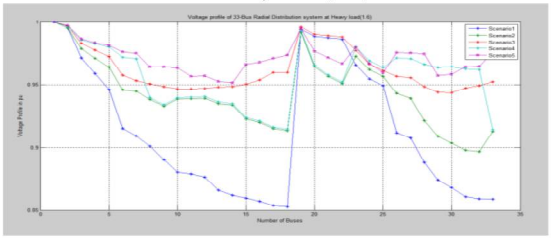


Fig.7. Voltage profiles of 33-bus system at light, nominal, and heavy load conditions.

CONCLUSION

A new algorithm has been presented to solve the network reconfiguration problem in the presence of distributed generation (DG) for minimizing the real power losses. An efficient Meta heuristic HSA is used in the optimization process of the network reconfiguration and DG installation. The proposed method is tested onanIEEE test system at different load levels, light, nominal and heavy. The results show that simultaneous network reconfiguration and DG installation method is more effective in reducing power loss and improving the voltage profile compared to other methods. The ratio of percentage loss reduction to DG size is highest when number of DG installation locations is three. In earlier approaches, network reconfiguration and DG placement in distribution networks are considered independently. However, in the proposed method network reconfiguration and DG installation are dealt simultaneously for improved loss minimization and voltage profile.

REFERENCES

[1] A. 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.

[2] D. Shirmohammadi and H.W. Hong, "Reconfiguration of electric distribution networks for resistive line losses reduction," IEEE Trans. power Del., vol. 4, no. 2, pp. 1498, Apr. 1989.

[3] S. Civanlar, J. Grainger, H. Yin, and S. Lee, "Distribution Feeder Reconfiguration for Loss Reduction", IEEE Trans. Power Del., vol. 3, no. 3, pp. 1217-1223, Jul. 1988.

[4] D. Das, "A Fuzzy Multi-Objective Approach for Network Reconfiguration of Distribution Systems", IEEE Trans. Power Del., vol. 21, no. 1, pp. 202-209, Jan. 2006.

[5] 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

[6] J.Z. Zhu, "Optimal Reconfiguration of Electrical Distribution Network using the Refined Genetic Algorithm", Elect. Power Syst. Res., vol. 62, pp. 37-42, 2002.

[7] C.Wang and M.H. Nehrir, "Analytical Approaches for Optimal Placement of Distributed Generation Sources in Power Systems", IEEE Trans. Power syst., vol. 19, no. 4, pp. 2068-2076, Nov. 2004.

[8] G. Celli, E.Ghiani, S. Mocci, and F. Pilo, "A multi-objective evolutionary algorithm for the sizing and the sitting of distributed generation," IEEE Trans. Power syst., vol.20, no.2, pp. 750-757, May 2005.

[9] 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.

[10] 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.

[11] S. Ghosh and K. S. Sherpa, "An efficient method for load-flow solution of radial distribution networks," Int. J. Elect. Power Energy Syst. Eng., vol. 1, no. 2, pp. 108–115, 2008.

[12] Bala JL, Kuntz PA, Pebles MN. Optimum capacitor allocation using a distribution-analyzer-recorder. IEEE Trans PWRD 1997; 12(1): 464–9.

[13] N. Acharya, P. Mahat and N. Mithulananthan, "An Analytical Approach for DG Allocation in Primary Distribution Network", Int. J. Electr. Power energy syst., 2006, 28, (10), pp. 669-746.

[14] 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.

[15] S. Das, A. Mukhopadhyay, A. Roy, A. Abraham, and B. K. Panigrahi, "Exploratory power of the harmony search algorithm: Analysis and improvements for global numerical optimization," IEEE Trans. Syst., Man, Cybern. B, Cybern, vol. 41, no. 1, pp. 89-106, 2011.

[16] Z. W. Geem, C. Tseng, and Y. Park, "Harmony search for generalized orienteering problem: Best touring in China," in Proc. ICNC, 2005, vol. 3612, pp. 741–750, Springer Heidelberg.

[17] 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.

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