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COMPARISION OF DIFFERENT OPTIMIZATION TECHNIQUES FOR NETWORK RECONFIGURATION OF RADIAL POWER SYSTEM INCLUDING DISTRIBUTED GENERATORS

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Abstract: This paper presents a new methodology of placing of Distributed generators along with the network reconfiguration by using Harmony Search Algorithm(HSA) in radial distribution systems. Normally in the classical approach of the placement of DG is performed after the system is reconfigured. But in this paper a new method is proposed for reduction of losses by placing the DGs along with system is reconfigured. To study the proposed method the formulated algorithm is applied on two test cases with 5 scenarios for half and unity load models.
Keywords: Distribution system, Laodflows, Distributed generator, Harmony search, Pso, Pgsa, Ge MATLAB

I. INTRODUCTION

Electric power distribution systems consist of group of interconnected radial circuits and have a number of constrains like radial configuration, all loads served, co-ordinated operation of over current protective devices, and voltage drop within limits etc. Each feeder in the distribution system has a different mixture of commercial, residential and industrial type loads, with daily load variations. There are several operational schemes in electrical distribution systems; one of them is “distribution network reconfiguration”. There are some normally closed and normally opened switches (sectionalizing and the switches) in a distribution feeder [1], [2].

Network reconfiguration is very important for operating the distribution system. Generally, power distribution network reconfiguration provides services to as many customers as possible following fault coding and during planned outage for maintenance purposes with system loss minimization and load balancing of the network [3]. Network reconfiguration problem is a complex non-linear combinational problem due to non-differential status of switches and the normally open tie switches, determined to satisfy system requirement. From optimization point of view, the reconfiguration method have been used for loss reduction using different techniques on the other hand from service restoration point of view, the reconfiguration allows to relocate loads by using an appropriate sequence of switching operations with operating constraints taken into account [4].

For load balancing, the loads are required to be rescheduled more efficiently by modifying the radial structure of the distribution feeders. There are many existing methods for determining feeder configuration. A Neural Network based method with mapping capability to identify various network configurations corresponding to different load levels was proposed in [6]. An experts system using heuristic rules to shrink the search space for reducing the computation time was presented in [7]. Kashem et al. [8] proposed an algorithm called “distance measurement technique” (DMT) that found a loop first and then a switching operation was determined in that loop to improve load balancing. Aoki et al. [9] formulated the load balancing and service restoration problems by considering the capacity and voltage constraints as a mixed integer nonlinear optimization problem and converted the problem into a series of continuous quadratic programming sub problems. Baran and Wu [10] formulated the problem of loss minimization and load balancing as an integer programming problem. H. D. Chiang et al. [11] proposed a constrained multi objective and non differentiable optimization problem with equality and inequality constraints for both loss reduction and load balancing. G. Peponis et al. [12] developed an improved switch-exchange method for load balancing problem, using switch exchange operations. Mukwanga [13] proposed a new load-balancing index and applied it to the network for load balancing. In [14] presented a new load balancing and unbalanced algorithm in distribution system for loss reduction.

Increasing trend of load growth in distribution systems and the necessity for constructing new power plants as its consequence, tendency toward applying clean energies and independence from fossil fuels, have caused distributed generation (DG) to draw attention to a great extent. Distributed generation (DG) is small-scale power generation that is usually connected to or embedded in the distribution system.

The benefits of DG are numerous and the reasons for implementing DGs are an energy efficiency or rational use of energy, deregulation or competition policy, diversification of energy sources, availability of modular generating plant, ease of finding sites for smaller generators, shorter construction times and lower capital costs of smaller plants and proximity of the generation plant to heavy loads, which reduces transmission costs . Among advantages of DGs one can mention improvement in power quality and reliability and reduction of loss, meanwhile using DGs leads to complexity in operation, control and protection of distribution systems . Injection of DGs currents to a distribution network results in losing radial configuration and consequently losing the existing coordination among protection devices.

The application of shunt capacitors in distribution systems has always been an important subject to distribution engineers. The general capacitor placement problem consists of determining the number, location, type, size and control settings at different load levels of the capacitors to be installed. Capacitors are widely installed in distribution systems for reactive power compensation to improve the efficiency of power distribution via power and energy loss reduction, to improve service quality via voltage regulation and to achieve deferral of construction, if possible, via system capacity release . Capacitor placement in distribution feeder is the well known efficient method for improving overall power delivery in an electric distribution system. The power loss in distribution system is determined as function of square of branch current which consists of real and reactive component.

This paper emphasizes the advantage of network reconfiguration to the distribution system in the presence of DG units and capacitors placement for load balancing and bus voltage improvement. The application of Tabu Search is applied to determine the optimal on/off patterns of the switches to minimize the load balancing index subject to system constraints. The effectiveness of the methodology is demonstrated by a practical distribution system consisting of 69 buses

II. Power Flow Equations

Power flow in a radial distribution network can be described by a set of recursive equations called dist flow branch equations that use the real power, reactive power and voltage at the sending end of a branch to express the same quantities at the receiving end of the branch [3]. Considering the single-line diagram depicted in Fig. 1

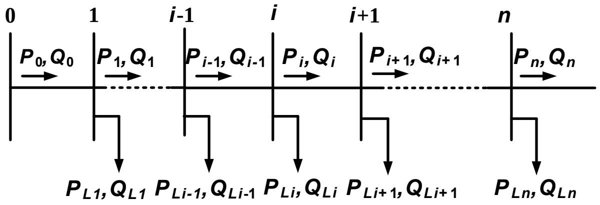


Fig 1. Single-diagram of main feeder

$$P_{i+1} = P_i - P_{Li+1} - R_{i,i+1}\left[\frac{(P_i^2+Q_i^2)}{|V_i^2|}\right] \quad (1)$$

$$Q_{i+1} = Q_i - Q_{Li+1} - X_{i,i+1}\left[\frac{(P_i^2+Q_i^2)}{|V_i^2|}\right] \quad (2)$$

$$|V_{i+1}|^2 = V_i^2 - 2\left(R_{i,i+1}P_i + X_{i,i+1}Q_i\right) + \left(R_{i,i}^2 + X_{i,i+1}^2\right)\left[\frac{(P_i^2+Q_i^2)}{|V_i^2|}\right] \quad (3)$$

The power loss of the line section connecting between buses *i* and *i*+l may be computed as

$$P_{Loss}(i, i+1) = R_{i,i+1}\left[\frac{(P_i^2+Q_i^2)}{|V_i^2|}\right] \quad (4)$$

Where P_i, Q_i = active and reactive power at bus i

V_i = voltage of bus i

$R_{i,i+1}$ = resistance of line section between buses i and i + 1

III. HARMONY SEARCH ALGORITHM

Harmony search tries to find a vector $\mathbf{x}$ which optimizes (minimizes or maximizes) a certain objective function.

The algorithm has the following steps:

Step 1: Generate random vectors ($\mathbf{x}^1, \ldots, \mathbf{x}^{hms}$) as many as hms (harmony memory size), then store them in harmony memory (HM).

$$HM = \begin{bmatrix} x_1^1 & \cdots & x_n^1 & | & f(x^1) \\ \vdots & \ddots & & & \vdots \\ x_1^{hms} & \cdots & x_n^{hms} & | & f(x^{hms}) \end{bmatrix}$$

Step 2: Generate a new vector $\mathbf{x}'$. For each component x_i',

- with probability $hmcr$ (harmony memory considering rate; $0 \le hmcr \le 1$), pick the stored value from HM: $x_i' \leftarrow x_i^{int(u(0,1)*hms)+1}$
- with probability $1 - hmcr$, pick a random value within the allowed range.

Step 3: Perform additional work if the value in Step 2 came from HM.

- with probability par (pitch adjusting rate; $0 \le par \le 1$), change x_i' by a small amount: $x_i' \leftarrow x_i' + \delta$ or $x_i' \leftarrow x_i' - \delta$ descretevariable or $x_i' \leftarrow x_i' + fw \cdot u(-1,1)$ for continuous variable.
- with probability $1 - par$, do nothing.

Step 4: If $\mathbf{x}'$ is better than the worst vector $\mathbf{x}^{Worst}$ in HM, replace $\mathbf{x}^{Worst}$ with $\mathbf{x}'$.

Step 5: Repeat from Step 2 to Step 4 until termination criterion (e.g. maximum iterations) is satisfied.

The parameters of the algorithm are

- hms = the size of the harmony memory. It generally varies from 1 to 100. (typical value = 30)
- $hmcr$ = the rate of choosing a value from the harmony memory. It generally varies from 0.7 to 0.99. (typical value = 0.9)
- par = the rate of choosing a neighboring value. It generally varies from 0.1 to 0.5. (typical value = 0.3)

- δ = the amount between two neighboring values in discrete candidate set.
- fw (fret width, formerly bandwidth) = the amount of maximum change in pitch adjustment. This can be (0.01 × allowed range) to (0.001 × allowed range).

It is possible to vary the parameter values as the search progresses, which gives an effect similar to simulated annealing. Parameter-setting-free researches have been also performed. In the researches, algorithm users do not need tedious parameter setting process.

The general optimization problem is specified as follows

Minimize f(x) Subject to x_i belongs ti X_i i=1,2,3…………..N

Where f(x)is an objective function; x is set of each decision variable x_i; N is the number of decision variables.

IV. PROBLEM FORMULATION AND RESULTS

The reduction of power loss in distribution is done through various techniques such as placing of capacitors, DGs , D-statcoms , but DG is the only device which compensate real power , reactive power and both real and reactive power. But the scope of the paper is only for compensating the real power of the load. The reduction of losses is carry out through five scenarios , which are

i) The losses of the system is calculated without placing DG and without applying the reconfiguration of the system.

ii) The losses of the system is calculated by applying the reconfiguration to the system

iii) The losses of the system is calculated by placing DG at suitable locations of the system.

iv) The looses of the system are calculated by placing the dg after apllying the reconfiguration of the system

v) The losses of the system is calculated by placing the DG along the reconfiguration of the system.

The proposed algorithm is tested on two cases which 33 Radial Distribution System and 69 Radial Distribution System.The losses at second scenario of the system are compared by using various heuristic algorithms like Genetic algorithm (GA),Particle swarm Optimization (PSO), Plant growth algorithm (PGA)and Harmony search algorithm. This is given in the table .1

Table 1: comparison of various techniques for reconfiguration of distribution system for 33bus

Heuristic algorithm	Tie line switches opened	Losses at Half load
PSO	7 9 14 32 37	33.37
PGSA	7 9 14 32 37	33.32
GA	7 9 14 32 37	33.38
HSA	7 9 14 32 37	33.27

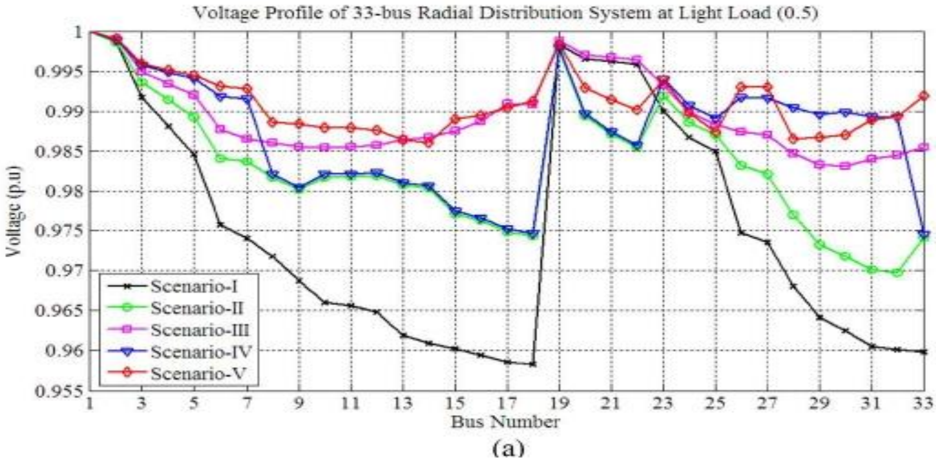
From the table.1 the power losses is minimum in the HAS technique so this technique is extended to the other scenarios which is given the above analysis

The table 2 shows the results of the scenarios by using HSA technique. In table 2 the results of other scenarios are shown . The DG placements with, without and along with reconfiguration is cleared shown in that table. With the scenario V the system provide less losses , so the same concept can be applied other test case. The figure 1 shows the voltage profile of the 33 bus radial distribution system at different load levels. The figure 2 is the single line diagram of 33 bus radial distribution system along with DG placement. The fifth scenario has good voltage profile and low power loss. So the same formulation is also applied to 69 bus radial distribution system.

Table 2 Analysis of 33 bus radial distribution system with reconfiguration along with DGs

scenario		Light(0.5)	Normal (1.0)
Scenario 1	Switches opened	33,34 ,35, 36, 37	33,34 ,35, 36, 37
	Power Loss(Kw)	47.06	202.67
	Min voltage(P.u)	0.9583	0.9131
Scenario II	Switches opened	7,14,9,32,37	7,14,9,32,37
	Power Loss(Kw)	33.27	238.06
	%loss reduction	29.3	31.88
	Min voltage(P.U)	0.9698	0.9342
Scenario III	Switches opened	33,34,35,36,37	33,34,35,36,37
	Size of DG in MW(bus num)	0.1313(18) 0.1777(17) 0.5029(33)	0.1070(18) 0.5724(17) 1.0462(33)
	Power loss(Kw)	23.29	96.76
	%loss reduction	50.5	52.26
	Min voltage(P.U)	0.9831	0.9670
Scenario iv	Switches opened	7,14,9,32,37	7,14,9,32,37
	Size of DG in MW(bus num)	0.1015(32) 0.1843(31) 0.2568(30)	0.2686(32) 0.1611(31) 0.6612(30)
	Power loss(Kw)	23.54	97.13
	%loss reduction	49.98	52.07

Scenario v	Switches opened	7,14,11,32,27	7,10,14,28,32
	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)
	Power loss(Kw)	17.78	73.05
	% loss reduction	62.22	63.95
	Min voltage(p.u)	0.9859	0.9700



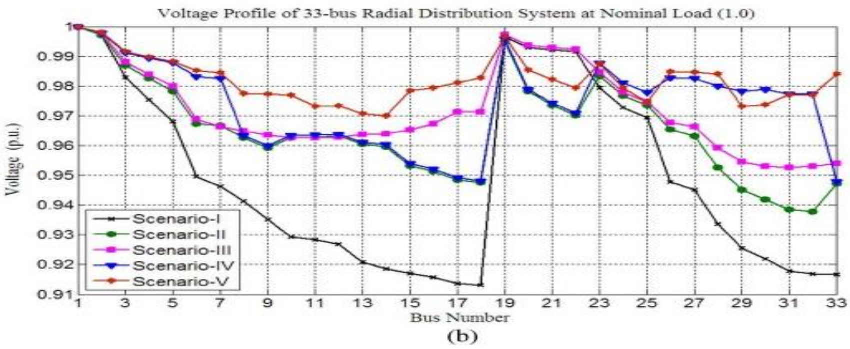


Figure 1: voltage profile of 33 bus with five scenarios for half and unity loads.

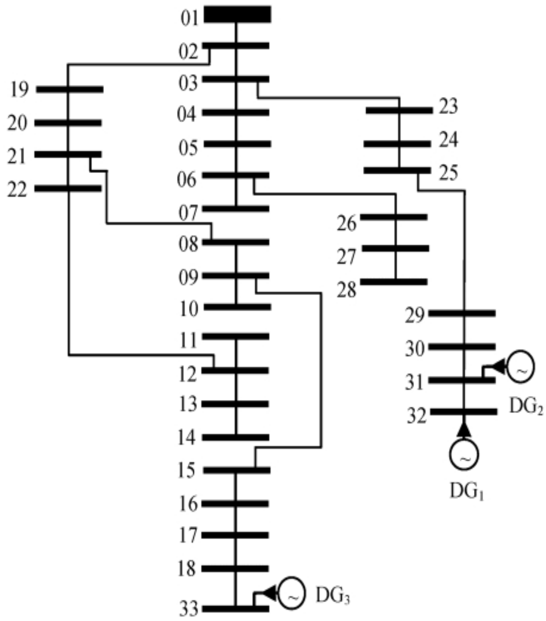
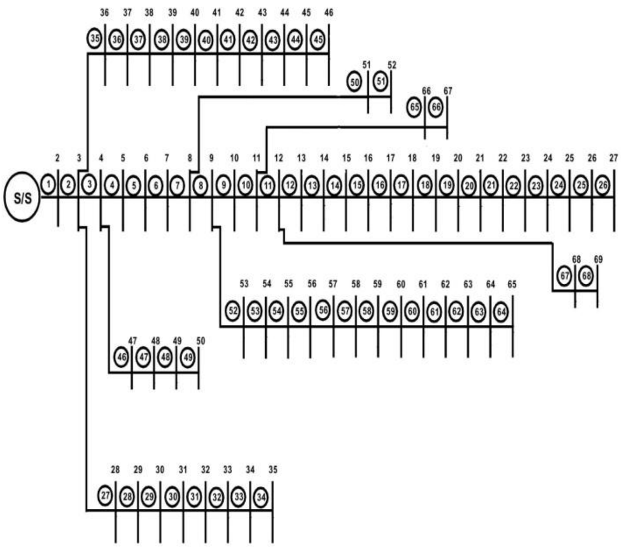


Fig 2 Single line diagram of 33 bus RDS with DGS

Test system 2: **69 bus RDS system**



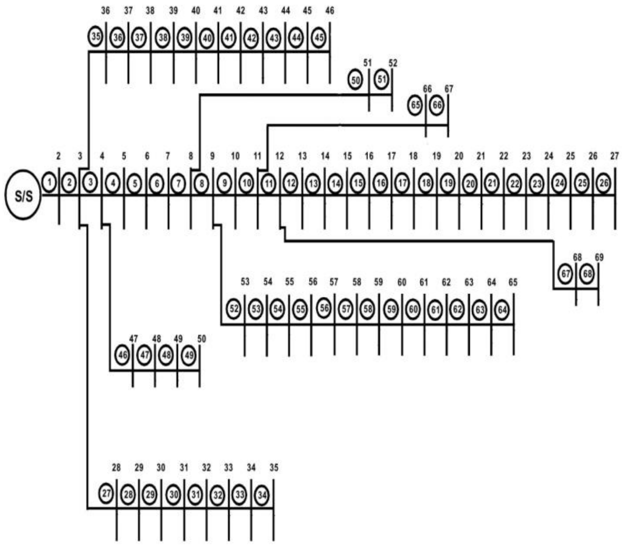


Fig 3 single line diagram of 69 bus RDS

Table 3: Comparative analysis of various heuristic algorithms for 69 rds bus system

Heuristic method	Tie switches	P_L(Kw)
GE HALF LOAD GE FULL LOAD	10 13 20 55 61 9 14 19 58 63	25.268 99.6151
PSO HALF LOAD PSO FULL LOAD	13 58 63 69 70 13 55 63 69 70	23.5410 99.71
PGSA HALF LOAD PGSA FULL LOAD	69 70 14 55 61 69 70 14 55 61	23.7233 99.6255
HSA HALF LOAD HAS FULL LOAD	69 70 14 57 61 69 13 18 56 61	23.21 99.352

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Table 4: Analysis of 69 RDS with five scenarios and three load levels

scenario		Light(0.5)	Normal (1.0)
Scenario 1	Switches opened	33,34 ,35, 36, 37	33,34 ,35, 36, 37
	Power Loss(Kw)	47.06	202.67
	Min voltage(P.u)	0.9583	0.9131
Scenario II	Switches opened	7,14,9,32,37	7,14,9,32,37
	Power Loss(Kw)	33.27	238.06
	%loss reduction	29.3	31.88
	Min voltage(P.U)	0.9698	0.9342
Scenario III	Switches opened	33,34,35,36,37	33,34,35,36,37
	Size of DG in MW(bus num)	0.1313(18) 0.1777(17) 0.5029(33)	0.1070(18) 0.5724(17) 1.0462(33)
	Power loss(Kw)	23.29	96.76
	%loss reduction	50.5	52.26
	Min voltage(P.U)	0.9831	0.9670
Scenario iv	Switches opened	7,14,9,32,37	7,14,9,32,37
	Size of DG in MW(bus num)	0.1015(32) 0.1843(31) 0.2568(30)	0.2686(32) 0.1611(31) 0.6612(30)
	Power loss(Kw)	23.54	97.13
	%loss reduction	49.98	52.07
Scenario v	Switches opened	7,14,11,32,27	7,10,14,28,32
	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)
	Power loss(Kw)	17.78	73.05
	% loss reduction	62.22	63.95

	Min voltage(p.u)	0.9859	0.9700

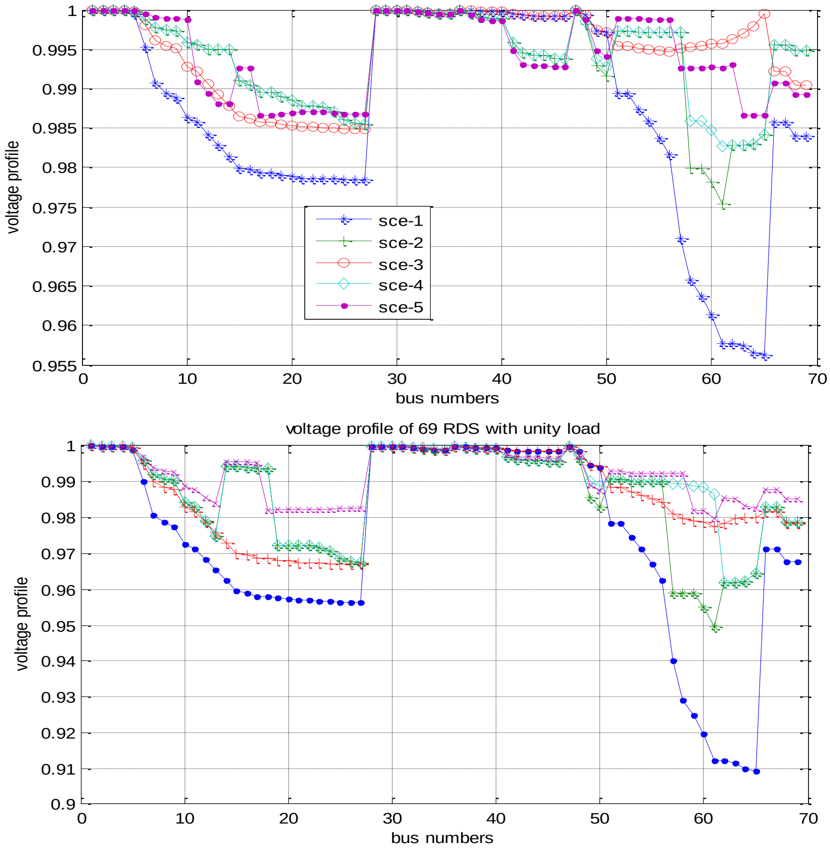

Figure 4: voltage profile of 69bus with five scenarios for half and unity loads

V. CONCLUSION

In this paper, a new approach has been proposed to re- configure and install DG units simultaneously in distribution system. In addition, different loss reduction methods (only network reconfiguration, only DG installation, DG installation after reconfiguration) are also simulated to establish the su- periority of the proposed method. An efficient meta heuristic HSA is used in the optimization process of the network re- configuration and DG installation. The proposed and other methods are tested on 33- and 69-bus systems at three different load levels viz., 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 effect of number of DG installation locations on power loss reduction is studied at different load levels. The results show that the percentage power loss reduction is improving as the number of DG installation locations are increasing from one to four, but rate of improvement is decreasing when locations are increased from one to four at all load levels. However, the ratio of percentage loss reduction to DG size is highest when number of DG installation locations is three. The results obtained using HSA are compared with the results of genetic algorithm (GA), particle swarm optimization(PSO) and plant growth simulated annealing(PGSA) . The computational results showed that performance of the HSA is better than GA ,PSO and PGSA

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