Optimal Placement and sizing of capacitor in Radial Distribution System using Harmony Search Algorithm

Devabalaji K.R, Ravi K

***Abstract*— Nowadays the number of consumer in the distribution system is increasing, the electricity demand and the number of capacitor bank installing is also increasing. Improper placement of capacitor bank leads to decrease the benefits of the system. In this article harmonic search algorithm is proposed to find the optimal size of the capacitor and Loss Sensitivity analysis is used to determine the location of the capacitor. In the proposed method the location for capacitor placement is chosen differently in order to minimize the power losses and Aggregative Voltage Deviation (AVD) simultaneously. The objective of this work is to minimize AVD. The proposed method is implemented on IEEE 34 bus radial distribution system and the results are compared with DE-PS and PGS method. The simulation results show the effectiveness of the proposed method.**

Index Terms*—*Power loss Minimization, Harmony Search Algorithm, Aggregative Voltage Deviation

I. Introduction

As we move away from the substation the voltage of the radial distribution system will decrease. This is happening due to lack of reactive power in distribution system. In the distribution system 10-13% of generated power is consumed as I2R losses [1]. Improper placement of capacitor will leads to reduce the benefits and even it collapse the entire distribution system [2]. The researchers used classical methods to solve optimal location and sizing of the capacitor placement [3]. Genetic algorithm is used to identify the location and sizing and results were compared.[4] The particle swarm optimization has been used to obtain location and sizing for the capacitor bank[5] Direct search algorithms was implement to locate and sizing of the capacitor placement[6]. A Non-dominated sorting genetic algorithm was used to find the placement of capacitor in electric radial distribution system [7]. Hybrid SA is introduced for solving the optimal capacitor placement in distribution system [8]. Antunes Chet al. proposes the non-dominated sorting genetic algorithm to solve the optimal capacitor placement in radial distribution system for reactive power compensation [10]. Baran et al introduce mixed integer programming for the capacitor placement [11]. Chis et al has chosen more sensitivity nodes for optimal location and sizing by heuristic search strategies to maximize the net savings [12]. Harmonic search algorithm has been used to solve optimal placement and sizing of capacitor bank. Fuzzy based GA has been used to determine the optimal size with the multi objective of minimize the energy cost and enhance voltage profile [13]. Direct search algorithm has been introduced to find the optimal location and size of fixed and switched capacitor and it is tested on IEEE 22, 69, 85 bus radial distribution system with the objective function of maximize net savings and minimize the power losses [14]. W.F. Mohammad et al introduced the supervisory control and data acquisition system (SCADA) with fuzzy based decision maker to calculate the suitable capacitor required to enhance the power factor according to the measured parameters [15]. Prakash and sydulu introduced the particle swarm optimization to determine the optimal size of the capacitor bank to minimize the power losses [16]. Sayyad Nojavan et al proposed mixed integer nonlinear programming approach to determine the location and size of the capacitor to minimize the power losses and increasing the net benefits [17].

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In this paper, harmony search algorithm is proposed to find the optimal size of the capacitor. LSF is used to find the optimal location for the capacitor placement. In this work the optimal location followed is slightly different from the existing method and it is discussed in the simulation result section. The proposed method is tested on IEEE 34 bus radial distribution system successfully and the obtained results is better than the other existing techniques.

II. Problem Formulation

A. Load flow analysis

The direct approach for distribution load flow is used to find the real and reactive power losses and also the voltage at each branch. The figure 1 shows the sample distribution system.

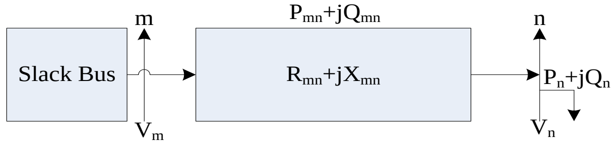

Fig. 1. Sample Distribution System.

The voltage at node n is given by

$$V_n = V_m - I(R_{mn} + jX_{mn}) \qquad (1)$$

Where

V_n is the voltage magnitude of the bus n.

V_m is the voltage magnitude of the bus m.

R_{mn} is the resistance of the line between m and n.

X_{mn} is the reactance of the line between m and n.

$$I = [BIBC][i] \qquad (2)$$

$$i_m = \frac{(P_n + jQ_n)^*}{V_n} \qquad (3)$$

Where P_n is the real power load at bus n.

Q_n is the reactive power load at bus n.

The real and reactive power losses of the system is calculated by using the following equation

$$P_{loss}(m,n) = \left(\frac{P_{mn}^2 + Q_{mn}^2}{|V_m|^2}\right) R_{mn} \qquad (4)$$

$$Q_{loss}(m,n) = \left(\frac{P_{mn}^2 + Q_{mn}^2}{|V_m|^2}\right) X_{mn} \qquad (5)$$

Where P_{mn} is the real power flow in the line between m and n.

Q_{mn} is the reactive power flow in the line between m and n.

The total real and reactive power losses of the system can be easily find by summing of all branch power losses.

B. Objective function.

The objective function of this work is to minimize aggregative voltage deviation and it can be expressed [1] by

$$Min\, F = \min(AVD) \qquad (6)$$

The objective function is subjected to satisfy the real and reactive power flow balance equation and also subjected to inequality constraints.

Aggregative voltage deviation (AVD)

In order to achieve good voltage performance, the voltage deviation at each bus will keep closer to zero. The aggregative voltage deviation can be expressed as

$$AVD = \begin{cases} 0, if\ 0.95 \le V_m \le 1.05 \\ \sum_{i=1}^{N} \left|V_{ref} - V_m\right|, else \end{cases} \qquad (7)$$

Where V_i is the voltage magnitude at bus m and V_{ref} is the reference voltage(1.0 P.U), N is the number of the buses.

Power Balance

Power generation is equal to power demand and power losses.

Voltage limit

$$V_{m,\min} \le |V_m| \le V_{m,\max}$$

Where $V_{m,\min}$ and $V_{m,\max}$ are the minimum and maximum voltage limits at bus m, respectively.

Reactive power compensation

$$Q_{cm}^{\min} \le Q_{cm} \le Q_{cm}^{\max}, m = 1,......, N_B$$

Where $Q_{cm}^{\min}$ and $Q_{cm}^{\max}$ are the minimum and maximum reactive power limits of compensated bus m, respectively.

Loss Sensitivity factor

The loss sensitivity factor is used to identify the location in order to install the capacitor [5]. The node which have high value of LSF have more chance to install capacitor. Another advantage of using this method leads to reduce the search space for optimization process. The equation (4) is partially differentiate with respect to reactive power and it is given by

$$\frac{\partial P_{loss}(m,n)}{\partial Q_{mn}} = \frac{2Q_{mn}R_{mn}}{|V_m|^2} \qquad (8)$$

The LSF values are sorted in descending order for all the lines and the buses which have the higher value has more chance for selecting candidate location to install capacitor.

III. Harmonic search algorithm.

The steps involved in the Harmonic search algorithm is
Step 1:
Initialize the input data
NVAR (2): The number of variables, i.e the number of

capacitor Placement
NG (2) : The number of inequality constraints
NH (1) : The number of equality constraints.
maxItr (1000) : The maximum number of iteration for this problem.
HMS (6) : Harmony memory size.
HMCR (0.9) : Harmony consideration rate 0< HMCR <1
PARmin (0.4) : Minimum pitch adjusting rate.
PARmax (0.9) : Maximum pitch adjusting rate
Bwmin (0.0001): Minimum bandwidth
Bwmax (1.0) : Maximum bandwidth

Step 2:
Initialize Harmony Memory as

$$x_j^i = x_j^L + rand(0,1)*(x_j^U - x_j^L)$$

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

Step 3:
Update the member for all result vector in Harmony search Generation of the random number according to minimum and maximum limit.
Step 4:
Test for convergence.
Compare previous AVD value with the new AVD value. If the AVD value is small then the preset value (0.00001), then the process will end and the last calculated AVD value will be accepted, otherwise the process will continue until the AVD value difference smaller than the preset value. The figure 2 shows the flow chart of the harmony search algorithm. Finally the algorithm will give the optimal size of the capacitor bank.

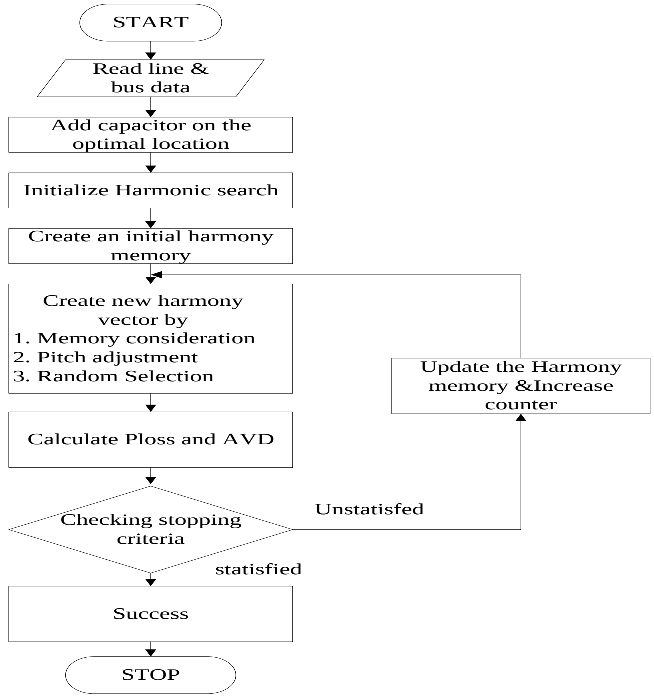

Fig.2. Flow chart of harmony search algorithm.

Hence this steps have to follow in order to minimize the objective function.

IV. Simulation Results

The proposed method is applied to IEEE 34-bus system and the schematic diagram is shown in figure 3. The line data and bus data for this system is given in [9]. The total real power of the system is 4636.5 KW and reactive power of the system is 2873.5 KW. Then the load flow analysis is done in order to calculate the real and reactive power losses of the system. The real and reactive power losses of the system without capacitor is 221.29 KW and 65.1 KW respectively as shown in table 1.

Table 1. Result of 34 bus radial distribution system.

Parameters	Base case	PGSA Method (18)	DE-PS method (1)	Proposed method
Location and Size	----	1200(19), 639 (22), 200(20).	750(19), 850(22), 150(20), 150(21).	1000(19), 800(26)
$V_{\min}$ @ bus no.	1.00(1)	----	0.9490 (27)	0.9501(27)
$V_{\max}$ @ bus no.	221.2860	----	1.00 (1)	1.00(1)
Ploss	----	168.7	169.0590	167.9468
% Ploss reduction	----	23.76%	23.76%	24.10%
Qloss	65.0980	48.9	49.1575	49.0422
% Qloss reduction	----	24.88 %	24.63%	24.65%
AVD	0.3353	----	0.1520	0
Total Compensation (kVAr)	----	2039	1900	1800
Net savings/year	----	$ 18522	$ 17988	$ 20635

The aggregative voltage deviation of the base case is 0.3353. The loss sensitivity factor is calculated using equation (8) and then the calculated value is arranged in descending order. According to the objective function and also in order to reduce power loss, it is planned to install the capacitor at two location only. In the proposed method the first location of the capacitor is corresponding buses of which have the highest value of the LSF. The bus which have the lower voltage among the normalized LSF value has more chance to place the second capacitor. The total KVARs used in this system is 1800KVAr (1000KVAr at 19, 800KVAr at 26).

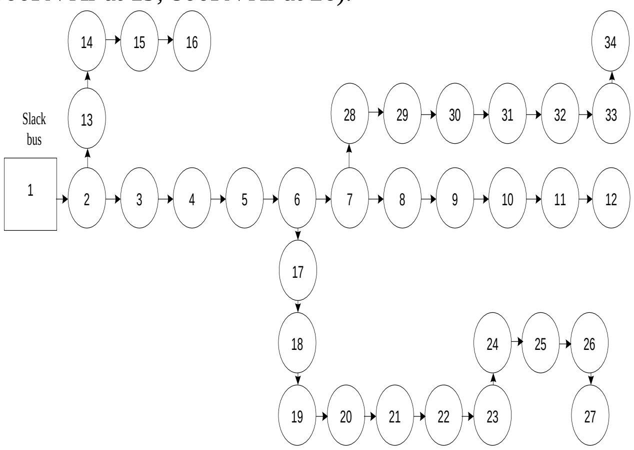

Fig. 3. The schematic diagram of the 34-bus radial distribution system.

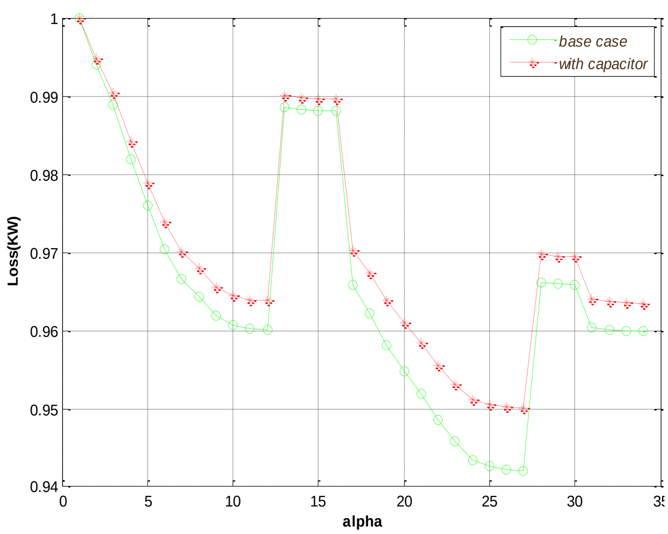

Fig. 4. Voltage profile of the system with and without capacitor.

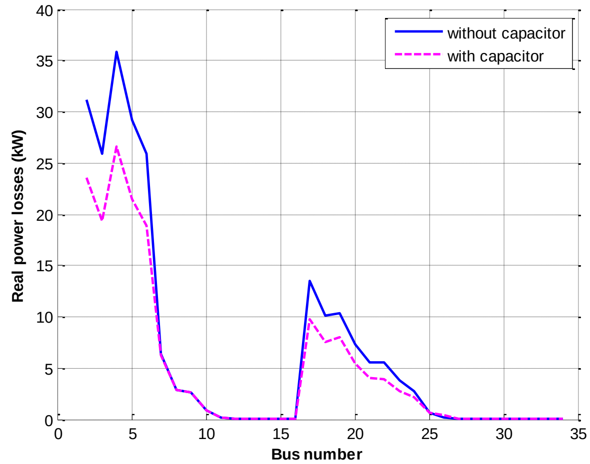

Fig. 5. Real power line losses of IEEE 34-bus radial distribution system.

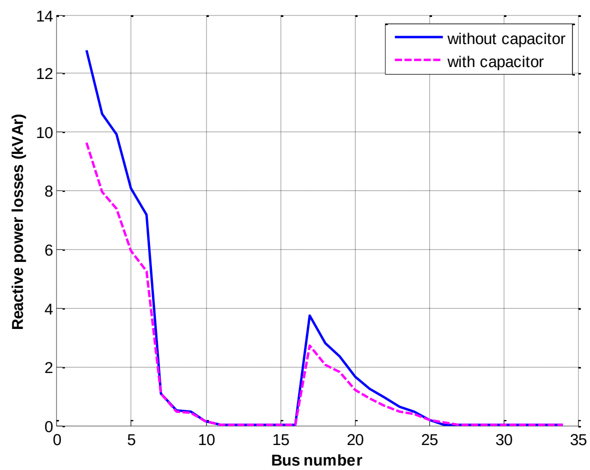

Fig. 6. Reactive power line losses of IEEE 34-bus radial distribution system.

The DE-PS method, the authors are able to reduce the real power losses of 169.0590KW and reactive power losses of 49.1575 kVAr with AVD of 0.1520 with installed 1900 kVAr. In case of proposed method the real power losses of 167.9468 KW and reactive power losses of 49.1489 kVAr with AVD of 0 with installed 1800kVAr.The proposed method of location will gives better voltage profile and achieved the AVD to 0 and losses are also decreased. Hence voltage of the system is within allowable tolerance. The figure 4 shows the voltage profile of the system with and without compensation. The figure 5 and 6 shows the real and reactive power line losses of the IEEE 34-bus radial distribution system.

V. CONCLUSION

In this paper the harmonic search algorithm is implemented to test IEEE 34-bus radial distribution system. The loss sensitivity analysis is used to find the optimal location to install the capacitor. The method of LSF followed in this paper is slightly different form the existing method. The real and reactive power losses of the proposed method have low when compared with existing method. In the proposed method the total reactive power compensation is only 1800kVAr then that of existing method is 1900 kVAr and the AVD is dramatically decreased to zero. The voltage profile of proposed method is also increased then that of DE-PS and PGS method. Then this leads to decrease the intake of MVA from grid and also it ensure the stability of the system. Hence the proposed method can be able to implement to any kind of distribution system to enhance voltage profile and conclude that the proposed method of capacitor location is suitable to minimize both power loss and AVG. In future, it is planned to place the Distribution Generation (DG) and Capacitor simultaneously in the radial distribution system.

VI. REFERENCES

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