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Optimal Placement of Capacitor in Radial Distribution Networks by Harmony Search Algorithm

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Abstract—

This paper includes a meta heuristic approach in which shunt capacitors in the radial distribution network have been employed using a Self Adaptive Harmony Search Algorithm (SAHSA). The capacitor placements mainly includes location, type and size of the capacitors. The main objective function of this method is to reduce the power loss and to improve the voltage profile.

The main constraints used in this paper are Voltage limit, number and locations of capacitors and also the loss sensitivity factor is employed for selecting the candidate bus location for the capacitor placement.

The proposed method has been tested on standard IEEE 69 BUS Radial distribution system for the three different test cases.

Index Terms — Capacitor placement, Distribution loss reduction, Harmony Search Algorithm.

I. INTRODUCTION

In the capacitor placement phenomenon, widely preferred type of the capacitor is shunt type. The present distribution network is complex and sluggish in nature because of this the power and energy loss takes place. It has been considered that, in the overall generated power, approximately 13% of the power consumed as loss in the distributed system level. Hence, it is required to employ or build a suitable method to reduce distribution power losses and energy losses. The main reason for power and energy losses is reactive power imbalance, due to this there will be a considerable amount of voltage drop takes place in the feeder system at the distribution level, this will disturb the voltage profile. Thus the capacitors are required to be placed optimally at the suitable location. By doing this, net amount of savings, maintains the voltage profile and considerable amount of loss reduction takes place by using the suitable method of optimality. For the optimal capacitor placement different methods or algorithm have been considered, many studies have been proposed on the different algorithms. In the literature review based on the optimal capacitor placement many techniques have been classified into different categories viz. Analytical method, Numerical programming method, Heuristic based method and Meta Heuristic based method [1]. By considering different techniques now a day's Heuristic and Meta Heuristic based techniques are widely used methods in solving and analyzing the optimal capacitor placement problems [2] - [10]. For some instance the Genetic Algorithm and Fast energy loss competition techniques for capacitor placement in distribution system will explain the customers with different load conditions [2] has been considered. Another paper on Genetic Algorithm is capacitor placement and sizing of capacitor banks in distorted distribution network. By Genetic Algorithm which explains the for the simultaneous power quality improvement and optimal placement and sizing of fixed capacitor banks in radial distribution network. But the problems associated with the Genetic algorithm method is that it is likely to get stuck at local optimum and effect of divergence [3]. This Genetic Algorithm method will come under meta heuristic category. Another approach is the Fuzzy Logic control for optimal capacitor placement is Radial distribution system to minimize the loss. In this location of nodes where the capacitors should be placed can be decided by Fuzzy Expert System (FES) by incorporating a set of rules [4],[5]. Another one is loss reduction in radial distribution systems by capacitor placement using fuzzy technique, here the capacitors have been placed based on the highest priority of suitability [5]. But drawback of this method is, it is suited only for fundamental frequency signal. Another meta-heuristic approach is the Ant Colony Algorithm for loss reduction mainly for reconfiguration and capacitor placement. It is inspired by natural behavior of ant colonies on how they used to find the food source and bring them back to their nest by building a suitable construction and will find the very shortest distance for food processing [6].The other approach is the Particle Swarm Optimization (PSO) for optimal capacitor placement and sizing in unbalanced distribution systems with harmonic consideration explains that, it is a heuristic technique used for determining sizes of the capacitors [7], and then for the combined process viz. loss sensitivity factor and the loss reduction criteria has been considered [8]. By

considering above methods, we choose a suitable method which will give better results than the above mentioned method viz. Harmony Search Algorithm. This method is a meta heuristic method which is inspired the nature or it is also called as Musical Phenomenon, it was inspired by Jazz Musicians by improvisation process, in which the musicians (who have never played before together) can quickly refine their sounds resulting in an Aesthetic Harmony [9]. It has several advantages as it does not require any initial valve settings. In the recent works also it explains about the Engineering and Reliability problems [10]. In this paper Efficiency and Robustness are the main criteria's.

II. PROBLEM FORMULATION

A. Objective Functions:

The objective function of the optimal capacitor placement is to determine the location and size of the capacitor bank to be installed on the distribution system. Such a plant should reduce a real power loss.

1) Power Loss Reduction:

The power loss of a distribution system is calculated as:

f= *Minimize {Yearly Power Loss Cost + Yearly Capacitor Cost}* (1)

Subject to:

$Yearly\ Power\ Loss\ Cost = K_p.P_{loss}$ (2)

$Yearly\ Capacitor\ Cost = \sum_{i=1}^{n} K_i^c Q_i^c$ (3)

where f is the objective function, P_{loss} is total power loss, n is number of candidate locations for capacitor placement, Kp is the equivalent annual cost per unit of power loss in \$/(kW-year); The constant K_i^c is the annual capacitor installation cost, and i=1,2,3...,n are the indices of the buses selected for compensation.

B. Operation Constraints

The voltage magnitude at each bus after the placement of capacitors must be within a permissible range and is expressed as

$V_{min} \leq V \leq V_{max}$;

where V_{min} and V_{max} are the lower and upper limits of bus voltage.

III. HARMONY SEARCH ALGORITHM

Recently a Meta-Heuristic optimization algorithm inspired by playing music has been developed and it is called as the Harmony Search Algorithm (HSA). This method is proposed by the scientist Z.W. Geem.et.al in the year 2001. HSA is inspired by the operation of Orchestra music to find the best harmony [11]. Music players improve their experience based on aesthetics standards while design variables in computer memory can be improved based on objective function.

Fig-1 shows a comparison of information between musical improvisation and engineering optimization. In music improvisation, each musicians plays within possible pictures to make a harmony vector. If all the pictures create good harmony, the musicians saves them in memory and increases good or bad harmony for next iterations. 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 the memory, and it increases the possibility of good or bad solutions for the next iterations.

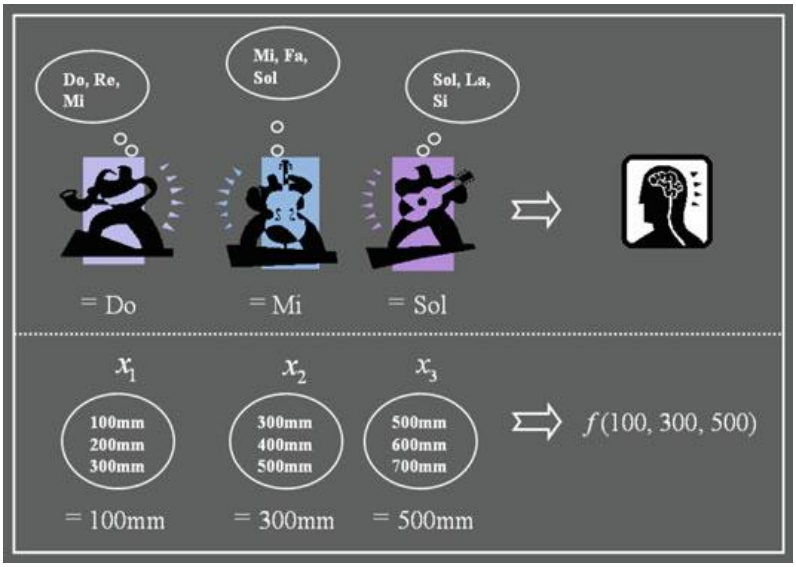


Fig.1.Comparision between Music improvisation and Engineering optimization

The above method can be best explained in the flowchart

FLOWCHART

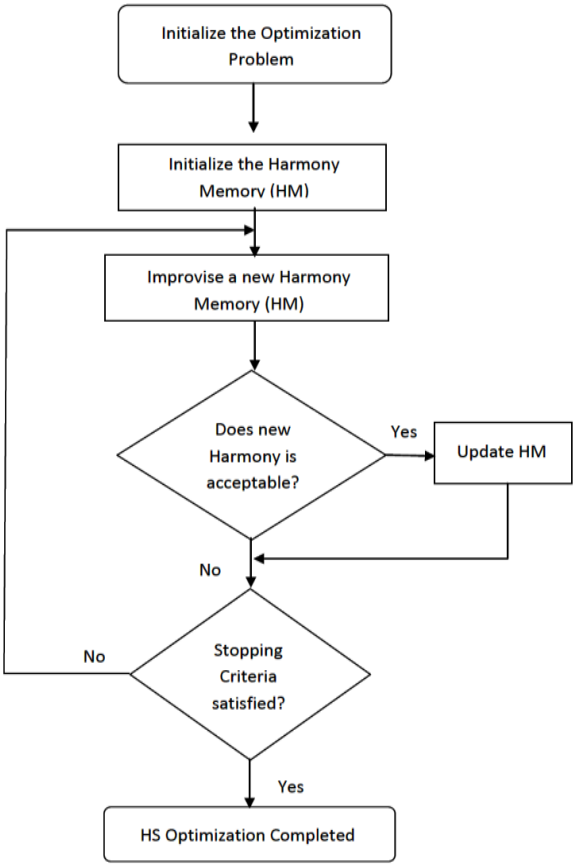


Fig.2. Flowchart of HSA

IV. CASE STUDY AND RESULTS

The proposed method is tested on IEEE 69BUS Radial Distribution System and the result obtained to demonstrate the effectiveness of the Harmony Search Algorithm (HSA) when used for loss minimization via optimal capacitor placement. For IEEE 69BUS Radial Distribution System the total power loss before placing the capacitor is 226kW and the total power loss after placing the capacitor is 164kW. The percentage loss reduction is about 27.43%. The results for IEEE 69BUS Radial Distribution System for 3 different cases are given in Table-1.

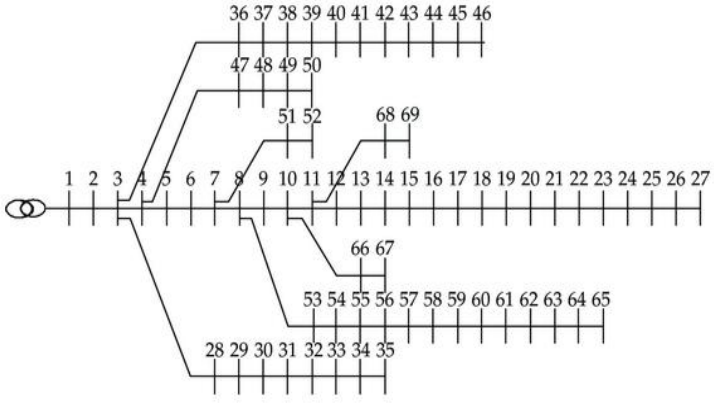


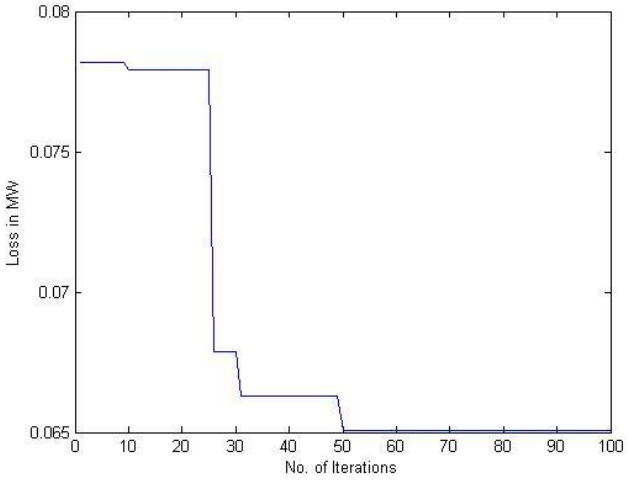
Fig.3. Single Line Diagram of IEEE 69BUS Test system

Table-1. Results for IEEE 69BUS Radial Distribution System

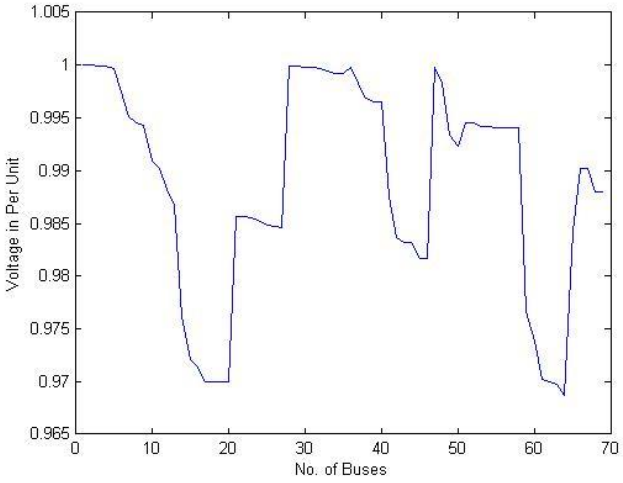
Test Cases	Total Loss Before placing capacitor (kW)	Total Loss After placing capacitor (kW)	Loss Reduction (%)	Capacitor Location
Case1: 50% Load	**128.50**	**74.80**	**41.70**	**50**

Case 2: 100% Load	**226.00**	**164.00**	**27.43**	**61**
Case 3: 150% Load	**51.80**	**38.47**	**25.73**	**63**

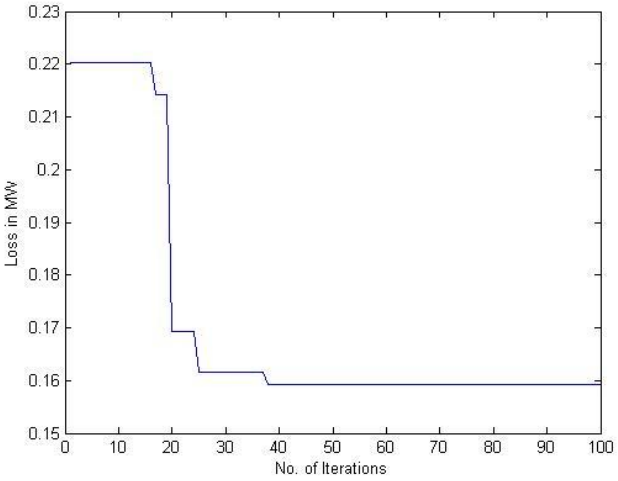
TEST CASES



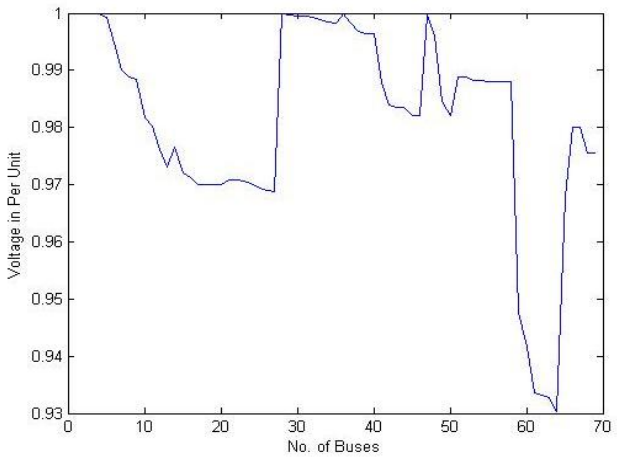
Case-1(a)



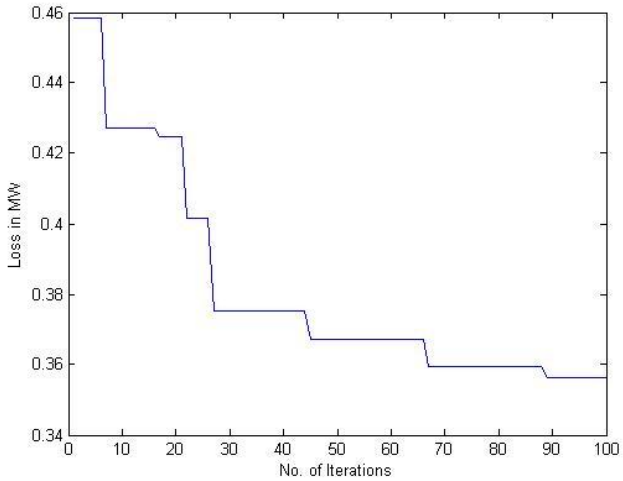
Case-1(b)



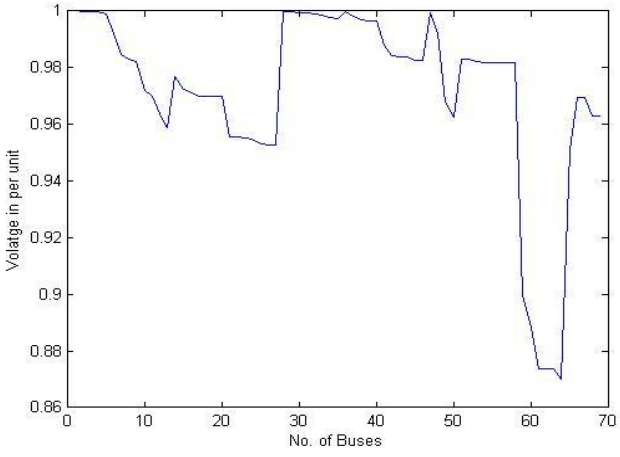
Case-2(a)



Case-2(b)



Case-3(a)



Case-3(b)

V. CONCLUSION

The application of the HSA as a new Meta-Heuristic optimization method for determining the optimal location and size of shunt capacitor in the radial distribution network has been presented on IEEE 69BUS Test System for 3 different test cases. The simulation results on IEEE 69BUS Radial Distribution System performs well and the convergence rate and the accuracy of the obtained results are comparatively efficient than the other methods. In addition, this method gives an accurate results in less number of iterations compared to the other methods.

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