ENERGY LOSS MINIMIZATION IN RDF USING MAPSO METHOD CONSIDERING HARMONICS

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Abstract: *This paper presents new techniques for capacitor placement in radial distribution feeders, with harmonics consideration, in order to reduce the real power loss, to improve the voltage profile and to achieve economical saving. The identification of the weak buses, where the capacitors should be placed is decided by a set of rules given by the fuzzy expert system. Power loss index and node voltage are used as inputs to the fuzzy expert system and the output is sensitivity index which gives the weak buses in the system where the capacitor to be placed. The sizing of the capacitors is modeled by an objective function to obtain maximum savings using Multi Agent Particle Swarm Optimization (MAPSO).To illustrate the applicability of the above algorithms, simulation is performed on an existing IEEE 34 bus distribution feeders. The results of the proposed approaches are compared with PSO and HPSO techniques.*

Key words: *harmonic Load flow analysis, fuzzy expert system, multi agent particle swarm optimization, radial distribution feeders.*

1. Introduction.

In the Radial Distribution Feeders (RDF), capacitors are installed at suitable locations for the improvement of voltage profile and to diminish the energy losses in the distribution system. It is estimated that as much as 13% of total power generation is dissipated as I^2R losses in the distribution networks [1]. Reactive currents flowing in the network account for a portion of these losses. By the installation of shunt capacitors, the losses produced by reactive currents can be reduced.

This is also vital for power flow control, improving system stability, power factor correction, voltage profile management, and reduction in active energy losses. Hence it is essential to find the optimal location and size of capacitors required to maintain a nominal voltage profile and to reduce the feeder losses [7].

Ng et al. [1] presented the guidelines for the implementation of appropriate capacitor allocation techniques. Ng et al. [2] presented a novel approach using approximate reasoning to determine suitable candidate nodes in a distribution system for capacitor placement problem. The numerical procedure to determine the size of capacitors has been presented. EL-Dib et al. [3] proposed a solution technique for finding the optimum location and sizing of the shunt compensation devices in a transmission system. Here, the objective function is formulated based on the voltage stability by maintaining the acceptable voltages profile.

KY-Lee et al. [4] proposed the Particle Swarm Optimization (PSO) techniques for economic dispatch problem. Here the weighing function of PSO varies per iteration within the maximum and the minimum limit and proved the applicability with advantages and disadvantages for economic dispatch problem. Das [5] considered the capacitor as a constant reactive power load and as a constant impedance load. The genetic algorithm approach is used to size the fixed and switched capacitor for varying load conditions. Zhao et al [6] proposed the Multi-Agent Particle Swarm Optimization technique for reactive power dispatch problem. Here PSO is integrated with the Multi agent system. The MAPSO techniques with the advantages of both PSO and Multi-agent system proved their feasibility to apply to any non-linear problem. Abdelsalam et al [8] considered the PSO and HPSO to find global optimal solution. The developed hybrid particle swarm optimization was integrated with a harmonic power flow algorithm to minimize the overall cost of the total real power loss.Arunagiri et al [9] presents a multilayer feed forward ANN with error back propagation learning algorithm for the calculation of bus voltages and power loss for different harmonic components on a 33-bus Radial and the results are reported for various harmonics by which its viability for harmonic load flow assessment for radial systems has been indicated. For given a harmonic load, BPN gives the voltage solution with minimum time and maximum accuracy.

In this paper, Fuzzy Expert System (FES) has been developed with reference to [2] to identify the suitable locations for capacitor placement. The reason for using FES method is that the capacitor allocation problem is highly nonlinear in nature. Also, capacitor location at a particular bus depends on the values of power loss and voltage magnitude. The power loss and bus voltage exhibits a nonlinear relation. Owing to these facts, FES method is used in this work to address the capacitor allocation problem.

Multi Agent Particle swarm Optimization (MAPSO) is used to solve the capacitor sizing problem with harmonic for constant load. Although capacitor sizing is discrete in nature, it is necessary to select the capacitor size at suitable locations within a narrow band, necessitating the need for a continuous optimization procedure. In this paper, MAPSO method has been used to find the size of the capacitors. The capacitor sizings are designed with the objective function, which minimizes the power loss in the feeders. The proposed method has been tested on an existing IEEE 34 bus system.

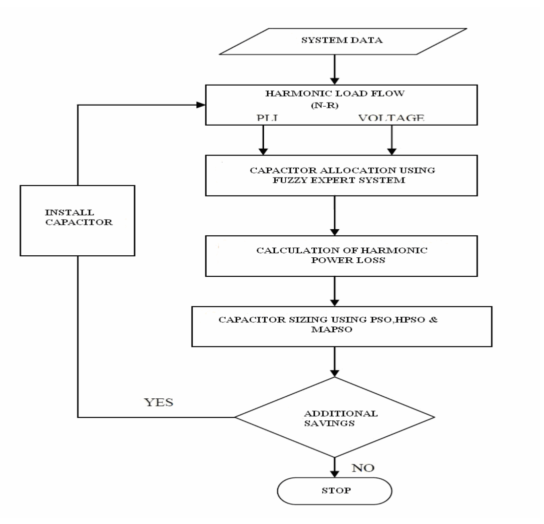

Fig. 1 Framework of the approach

2. Problem formulation and Implementation

The entire framework of the approach to solve the optimal capacitor allocation problem includes the use of numerical procedures, coupled to the Fuzzy Expert System (FES) [2]. Initially, a load flow program is used to calculate the power loss reduction by compensating the total reactive load current at every node of the distribution system. The loss reductions are then linearly normalized into [0, 1] range with the largest loss reduction having a value of 1 and the smallest one having a value of 0.

The power loss reduction indices at various nodes along with the per-unit node voltages are the inputs to FES, which determines the suitable node for capacitor installation by fuzzy inferencing method. The savings function S, is maximized by the capacitor sizing algorithm [5] .The above procedure is repeated until no further additional savings from the capacitor installations are achieved. The capacitor sizing procedure takes into account the discrete nature of the capacitor sizes and the piecewise cost function. Figure 1 illustrates the flow diagram of the proposed work.

2.1 *Objective function for capacitor sizing*

The size of the capacitor to be installed at the selected locations in the feeder system is estimated by minimizing the following objective function [5, 8].

The cost function 'C' is expressed as

$$\text{Min} \quad C = k_e * 365 * 24 * Ploss + \sum_{i=1}^{ncap} (k_{cf} + k_c Q_{ci}) \quad (1)$$

The total real power loss is defined by

$$\text{Ploss} = \sum_{i=1}^{nb} \text{Ploss}_i^{(1)} + \sum_{i=1}^{nb} \sum_{h=h_o}^{h_{\max}} \text{Ploss}_i^{(h)} \quad (2)$$

Where

nb = number of branches.

h_o = smallest harmonic order of interest.

h_{max} = highest harmonic order of interest.

Subject to

$$Q_{cmin} \le Q_c \le Q_{cmax}$$
$$V_{min} \le V \le V_{max}$$

Where Ploss= Total power loss. Q_{ci} = reactive power injection from capacitor to node i. Q_{cmax} = maximum rating value of capacitor in KVAR (1500KVAr). Q_{cmin} = minimum rating value of capacitor in KVAR (100KVAr),V_{max} = maximum value of voltage in p.u.(1.1pu) , V_{min} = minimum value of voltage in p.u.(0.9pu) ,C = Sum of Energy loss cost and capacitor cost, ncap = number of capacitor locations, K_e = capacitor energy cost of losses (0.06$/kWh), K_{cf} = capacitor installation cost (1000$), K_c = capacitor marginal cost (3$/KVAR).

2.2 *Savings mathematical formulation*

The capacitor allocation and sizing problem and annual saving can be found from the following function [10] stated as:

$$Max.S = KP + KF + KE - KC \quad (3)$$

$$KP = \Delta\ KP * CKP * IKP \quad (4)$$

$$KF = \Delta\ KF * CKF * IKF \quad (5)$$

$$KE = \Delta\ KE * r \quad (6)$$

$$KC = Q_C * \ ICKC * IKC \quad (7)$$

where S = net savings ($), KP = benefits due to released demand (kW), KF = benefits due to released feeder capacity (kVA), KE = benefits due to savings in energy (kWh), KC = cost of installation of capacitor ($), Δ KP = reduced demand (kW), CKP = cost of generation (taken as $200/kW), IKP = annual rate of generation cost (taken as 0.2), Δ KF = released feeder capacity, CKF = cost of feeder (taken as $3.43/kVA), IKF = annual rate of cost of feeder (taken as 0.2), Δ KE = savings in energy, r = rate of energy (taken as $0.06/kWh), Q_c = total KVAR, ICKC =cost of capacitor (taken as $4/KVAR),IKC = annual rate of cost of capacitor (taken as 0.2).

2.3 *Harmonic load flow solution - newton raphson method*

Newton-Raphson method is an iterative method which approximates the set of non-linear simultaneous equations to a set of linear simultaneous equations using Taylor's series expansion and the terms are limited to first approximation.

In presence of harmonics, lines are represented by a series impedance as $z(h) = R + j\,h\,X_L$ Bus data and line data are given as inputs to the load flow program by Newton-Raphson (N-R) method. The load flow solution gives power loss and voltage level at each bus which is taken for further analysis.

3. Capacitor Placement

3.1 Design of fuzzy expert system

The FES contains a set of rules, which are developed from qualitative descriptions. In a FES, rules may be fired with some degree using fuzzy inferencing; whereas, in a conventional expert system, a rule is either fired or not fired. For the capacitor allocation problem, rules are defined to determine the suitability of a node for capacitor installation. For determining the suitability of capacitor placement at a particular node, a set of fuzzy rules has been established. The inputs to the rules are the voltage and power loss indices, and the output is the suitability of capacitor placement. The rules are summarized in the fuzzy decision matrix [2]. These fuzzy variables described by linguistic terms are represented by membership functions. The membership functions for power loss index, bus voltage and sensitivity index are shown in Table 1.

$$PLI_{(n)} = \frac{(\text{Loss reduction}_{(n)} - \text{Loss reduction}_{(min)})}{(\text{Loss reduction}_{(max)} - \text{Loss reduction}_{(min)})}$$

Table 1

Membership function for fuzzy expert system

Variable	Power Loss Index	Bus Voltage	Sensitivity Index
Low	<0.25	<0.94	<0.25
Low-Medium	0-0.5	0.92-0.98	0-0.5
Medium	0.25-0.75	0.96-1.04	0.25-0.75
High-Medium	0.5-1	1.02-1.08	0.5-1
High	>0.75	>1.1	>0.75

The decision matrices formed in the fuzzy expert system for the capacitor placement problem identified in this work are shown in Table 2.

Table 2

Decision Matrix for Determining Suitable Capacitor Location (PLI Vs Voltage)

AND		Voltage				
		Low	Low Normal	Normal	High Normal	High
PLI	Low	Low Medium	Low Medium	Low	Low	Low
	Low Medium	Medium	Low Medium	Low Medium	Low	Low
	Medium	High Medium	Medium	Low Medium	Low	Low
	High Medium	High Medium	High Medium	Medium	Low Medium	Low
	High	High	High Medium	Medium	Low Medium	Low Medium

4. Capacitor Sizing

4.1 Multi Agent Particle Swarm Optimization

The Multi-agent System (MAS) and Particle Swarm Optimization (PSO) are integrated to form the MAPSO method [6]. In this method firstly, a lattice-like environment is constructed, with each agent fixed on a lattice-point. In order to obtain optimal solution quickly, each agent competes and cooperates with their neighbours. Making use of the evolution mechanism of PSO, the transfer of information among agents is speeded up, and the proposed MAPSO method can realize the purpose of optimizing the value of objective function.Ref [7] presents detailed concepts of MAPSO.

4.2 Steps in MAPSO Algorithm

Step 1: Input the system data and specify the lower and upper boundaries of the solution variable (capacitor size).

Step 2: Generate a lattice-like environment, and initialize randomly each agent.

Step 3: Evaluate the fitness value of each agent using Eq. (1).

Step 4: Increment the iteration counter.

Step 5: Perform the neighbourhood competition and cooperation operator on each agent using

$$\alpha_k' = m_k + rand(0,1) * (m_k - \alpha_k) \quad k = 1, 2 \ldots n$$

Step 6: Execute the PSO operator and further adjust its position in the search space on each agent according to the equation given below

$$v_{d+1} = (\omega * v_d + c1 * rand() * (pBest - x_d)$$

$$+ c2 * rand() * (gBest - x_d))$$

$$x_d = x_d + v_{d+1}$$

Step 7: Evaluate the fitness value of each agent using Eq. (1).

Step 8: Identify the best agent having the minimum fitness value.

Step 9: If one of the stopping criteria is satisfied then go to next step. Otherwise go to Step 4.

Step 10: Output the agent with the minimum fitness value in the last generation.

5. Case Study

To verify the effectiveness of the proposed method, simulation is carried out on the IEEE 34 bus distribution systems. The single line diagram of IEEE 34 bus distribution system [2] is shown in Fig. 2. The test specification of the main feeder is given below:

Radial feeder : 11kV, 100 MVA, 34 bus system

Load : 1.0 p.u.

No. of load level (L) : 1

Load duration (T) : 8760 h

No. of capacitor locations (ncap): 7

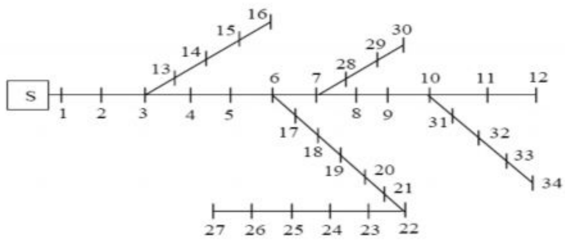

Fig 2. Single line diagram of IEEE 34 bus distribution network

6. Results and Discussion

Simulation is carried in a 2.4 GHz, core2Duo processor, 3 GB RAM running on windows XP operating system. The parameter selection of MAPSO algorithms discussed in previous sections is listed in Table 3 as below.

Table 3
Parameters of PSO, HPSO & MAPSO

Parameter	**PSO values**	**HPSO values**	**MAPSO values**
Population	100	100	10*10
Number of iterations	100	100	100
c1,c2	1	1	1
W_{min}	0.4	0.4	0.4
W_{max}	0.9	0.9	0.9

Table 4 gives the capacitor sizing as below

Table 4
Capacitor Sizing For IEEE 34 Bus Systems

BUS NO	**PSO**	**HPSO**	**MAPSO**
20	1104	1056	1059
21	100	148	132
22	100	156	153
23	402	146	145
24	100	171	145
25	100	108	144
26	100	258	229
TOTAL kVAr	**2006**	**2043**	**2007**

In this case study, viz., 34-bus radial distribution system, the value of Q_{cmin} and Q_{cmax} is assigned as 100 and 1500KVAR respectively and the bus voltage magnitude is taken as between 0.9 and 1.1.

Table 5

SUMMARY OF RESULTS

Parameter	**Before capacitor placement**	**After capacitor placement using**		
		PSO	HPSO	MAPSO
Total KVAR	-------	2006	2043	2007
Average power loss (pu)	0.9239	0.6788	0.6778	0.6778
% of decrease in Average power loss	------	26.5265	26.6355	26.6359
Average voltage (pu)	0.9741	0.9789	0.9791	0.9790
% of increase in Average voltage	-------	0.4980	0.5094	0.5007
Saving in $	------	475,811	477,713	477,750

Table 5 show the comparative results of average power loss and average voltage profile before and after capacitor placement with harmonics consideration. From this table, we infer that energy loss is more reduced by a factor of 26.6359% with harmonics consideration.Also,maximum annual saving is achieved with MAPSO.

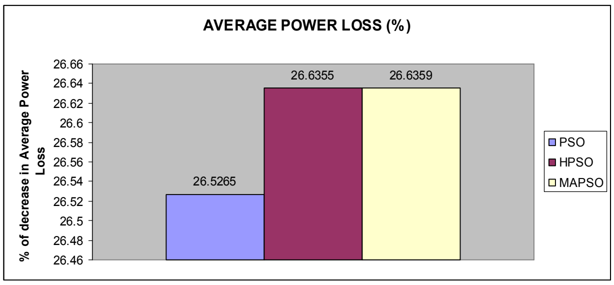

Fig 3. Decrease in Average Power Loss (%)

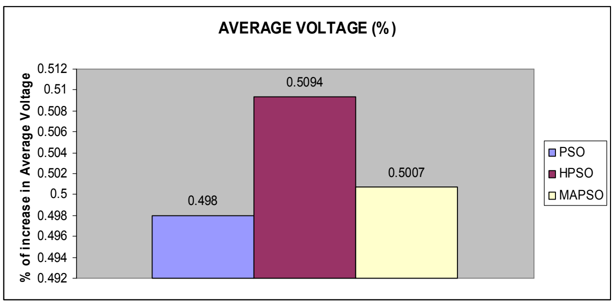

Fig 4. Increase in Average Voltage (%)

Fig 3 and fig 4 shows the comparision graph of Decrease in Average Power Loss (%) and Increase in Average Voltage (%) of PSO,HPSO and MAPSO respectively.Fig 5 shows the saving ahead using various methods.

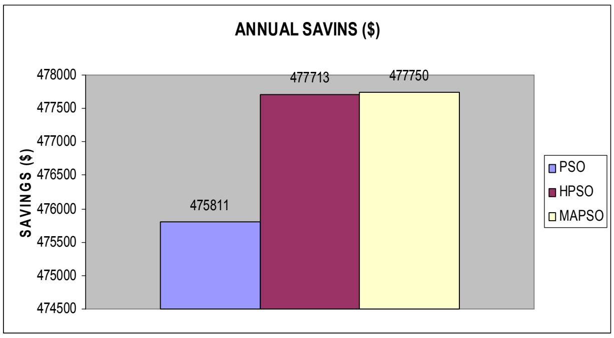

Fig 5. Maximum Annual Saving ($)

7. Conclusion

This paper has presented Multi Agent Particle Swarm Optimization for capacitor sizing in distribution systems. FES is used to determine the nodes for capacitor allocation by finding a compromise between the loss reduction and voltage level improvement. Optimal size of capacitor is obtained by Particle Swarm Optimization, Hybrid Particle Swarm Optimization and Multi-Agent Particle Swarm Optimization methods. However, for IEEE 34 bus network MAPSO was observed to give better result than PSO and HPSO with harmonic consideration. Considering the maximum savings in cost, the MAPSO method is found to give a better performance than all other methods from the economical point of view. However, PSO also has unique merits like improved voltage profile. Simulation results proved the advantages of MAPSO approach over other methods for capacitor sizing in distribution system feeders.

References

[1] H.N.Ng, M.M.A. Salama and A.Y.Chikhani, "Classification of Capacitor Allocation Techniques", IEEE Trans. On Power Delivery, Jan 2000,Vol.15, no.1, p.387-392.

[2] H.N.Ng, M.M.A. Salama and A.Y.Chikhani,"Capacitor allocation by Approximate Reasoning: Fuzzy capacitor placement", IEEE Trans.on Power Delivery, Jan 2000,Vol.15, no.1, p.393-398.

[3] Amgad A.EL. Dib, Hosam M. Youssef, M.M.E.L. Metwally and Z.Osman, "Optimum VAR sizing and allocation using Particle Swarm Optimization", Electrical Power system Research, 2007,Vol.77, p.965-972.

[4] Kwang Y.Lee, Fellow,IEEE and Jong-Bae Park, Member, IEEE, "Application of Particle swarm optimization to economic dispatch problem: advantages and disadvantages", PSCE IEEE, 2006, p.188-192.

[5] D.Das, "Reactive power compensation for radial distribution networks using genetic algorithm", Electrical Power and Energy systems 24, 2002, p.573-581.

[6] B. Zhao, C.X. Gu, Y.J. Cao, " A multiagent particle swarm optimisation approach for optimal reactive power dispatch", IEEE Transactions on Power Systems, May 2005, Vol.20 ,p. 1070-1078.

[7] S.M. Kannan,P. Renuga, S. Kalyani, E. Muthukumaran, " Optimal capacitor placement and sizing using Fuzzy-DE and Fuzzy-MAPSO methods", Applied soft computing, Dec 2011, Vol.11,no.8, p. 4997-5005.

[8] Abdelsalam Eajal A and El-Hawary M.E, "Optimal Capacitor Placement And Sizing in unbalanced Distribution System with Harmonic Consideration using Particle Swarm Optimization",IEEE Trans.on Power Delivery, Jul.2010,Vol.25,no.3,p.1734-1741.

[9] Arunagiri A,Suresh K,Venkatesh B, Ramesh Kumar R and Mustajab Ahmed khan, "Aritifical Neural Network Approach :An Application To Harmonic Load For Radial Systems",ISSN:1658-5321, Oct 2010, Vol.1, p.1-10.

[10] Prasad, P.V., Sivanagaraju, S. and Sreenivasulu, N. "A Fuzzy-Genetic Algorithm for optimal capacitor placement in radial distribution systems", ARPN Journal of Engineering and Applied Sciences, 2007, Vol. 2, No. 3, p. 28-32.