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Analysis of Capacitor Placement in Radial Distribution System Using DPSO

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ABSTRACT: This paper Presents Discrete Particle Swarm Optimization based way to deal with accomplishes ideal capacitor position in the radial distribution network. Discrete nature of capacitors and its area are taken to considerations of problem formulation. Scientifically, the capacitor placement issue is a non-linear and optimized one with a set of operation constraints. The proposed technique utilizes to search for ideal areas, types, and sizes of capacitors to be set at various load levels.

KEYWORDS: Radial Distribution Systems, DPSO, Capacitor Placement, Load Flow

I. INTRODUCTION

The objectives of the capacitor placement in the radial distribution network is try to maintain constant voltage profile in that way to minimize the power loss in the radial distribution network feeder. Subsequently, feeder limit can be used in effective way during the peak hours load usages.The technique was selected because of its strength and its capacity to deal with numerous functional requirements and investigate reasonable amount of computation time [8]. Anyway heuristic strategies for feeder reconfiguration and capacitor arrangement had been exhibited [9]. The capacitor placement is very important in the distribution network. This gives reactive power compensation to the network due to this reason the voltage profile in the distribution network could be improved with its angle. The Placement of capacitor in the radial distribution network analyzed by various researchers. The dynamic programming techniques solved the problem of size and placement of the capacitor. Due to growing of power requirement and atomization in the power world, the placement of the capacitor is major role to reduce the power loss. Its necessary to investigate the placement of the capacitor in the radial distribution network

To analysis the distribution network the first step is to know the existing values in the system. There are many load flow algorithm has been developed based on the transmission network[1,2]. Basically this algorithm is not suitable for the distribution network due to the reason of high R/X ratio values in the distribution network. The major load flow solution techniques namely Newton-Raphson (NR) method [3], the Fast Decoupled Load Flow (FDLF) method [4] and their modifications [5] are not suitable for solving the load flow problem in distribution system. Capacitor Placement Problem is presented in two ways [6]. One is based on cost of the capacitor and its life time. The other is based on performance of the capacitor in the radial network. Implementation of the capacitor placement problem in the radial network is solved by Genetic Algorithm based. The feeder voltage reduction and implementation of the capacitor is discussed [7,8,9].In this paper , the proposed algorithm is going to determine the size and place of the capacitor in radial distribution system. These problem could be solved in two methods; first find out the weaken node in the feeder and then select the capacity of the capacitor. These above two problems is solved by power loss index method used to find the location of the capacitor and capacity of the capacitor is calculated by using DPSO method.

All through the enhancement procedure both the capacitor size and its area are being treated as discrete factors. Throughout the optimization process both the capacitor size and its location are being treated as discrete variables. In this objective function is to maximize the net saving by capacitor placement. In order to obtain the fitness values, a load flow calculation has to be carried.

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II. LOAD FLOW ANALYSIS

A simple load flow method is used to find the placement capacitor in the radial distribution feeders.

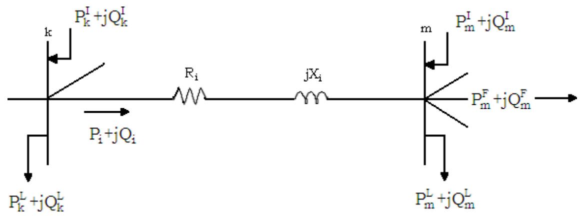

Fig. 1 Circuit model of branch i

Fig. 1 shows a single line diagram of simple radial distribution system. The branch is marked as *i*, node *k* is represented sending end side and node *m* is represented by receiving end side . The voltage at k node is 1.0 p.u. The voltage at node m, can be written as

$$Vm = Vk - Ii\ Zi \quad (1)$$

The branch 'i' real and reactive power loss can calculated as

$$P_L = |I_i|^2 R_i \quad (2)$$

$$Q_L = |I_i|^2 X_i \text{ , for i=1,2,…nb} \quad (3)$$

The total real and reactive power loss of radial distribution system can be calculated as

$$T_{PL} = \sum_{i=1}^{nb} P_{Li} \quad (4)$$

$$T_{QL} = \sum_{i=1}^{nb} Q_{Li} \quad (5)$$

III. MATHEMATICAL FORMULATION

The main aim of this method is to reduce the cost of the capacitor and reduce the power loss by placing the capacitor in the proper place in the radial network,Also maintain the node voltage within the limit

Objective function

The objective function is:

Max. SAV=K kinetic - K installation (6)

Where,

SAV= saving in (Rs)

$K_{kinetic}$= energy saving (kWH).

$K_{installation}$ = Installation cost of the capacitor.

(i) Energy saving ($K_{kinetic}$) is given by

$$K_{kinetic} = \Delta K_{kinetic} \times r \quad (7)$$

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Where,

$\Delta K_{kinetic} E$ = saving in energy loss.

= (Annual energy loss before installing the capacitor) - (Annual energy loss after installing capacitor).

r = rate of energy in Rs/kWH. (Taken as Rs.3/ kWH).

(ii) Cost of installation of capacitor ($K_{installation}$) is given as

$$K_{installation} = Qc \times ICK_{installation} \times IK_{installation} \quad (8)$$

Where

Qc = size of capacitor (kVAR).

$ICK_{installation}$=cost of capacitor/kVAR (Rs.200/kVAR)

$IK_{installation}$=annual rate of cost of capacitor (taken as 0.2)

Practically, all the capacitor is grouped together to form a capacitor bank, its value is 150kVAR therefore, capacitor sizes are regarded as integer multiples of the standard size of one bank. The candidate node identification for the capacitor placement is explained in the following section.

IV. IMPLEMENTATION OF DPSO

Flow Chart for Optimal place and capacity of the Capacitor is shown in Fig.2

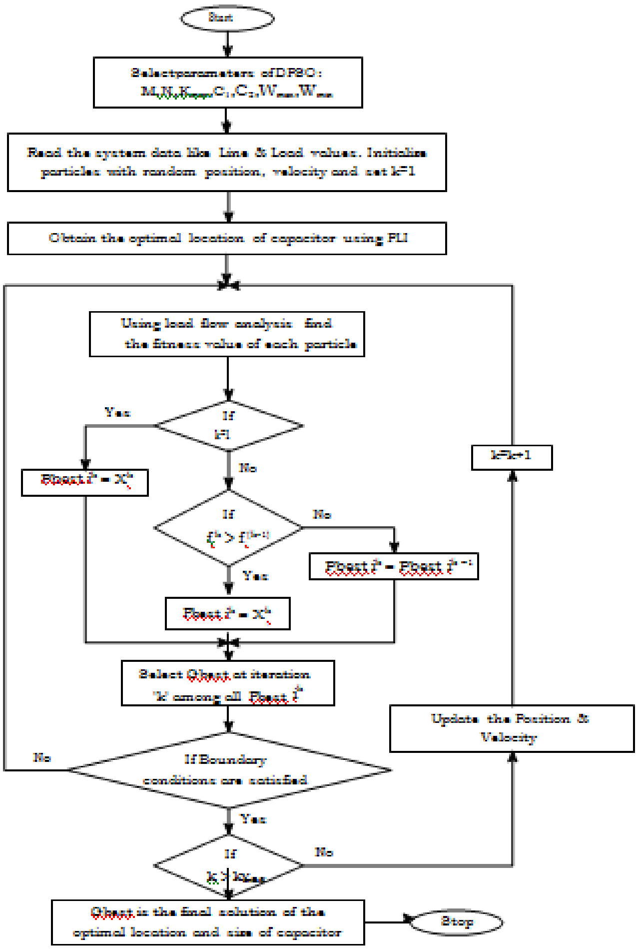

Fig.2 Flow Chart for Optimal placement and value of the Capacitor

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V. RESULTS AND ANALYSIS

The proposed algorithm is tested on 15-node system and 33-node system. The capacitors locations are obtained by using candidate node identification algorithm using PLI and its value of the nodes are obtained from DPSO. These capacitors are kept at reference nodes and conduct the load flow analysis to know the improvement in voltage profile, power loss reduction and net saving for these systems.

EXAMPLE:

The proposed algorithm is tested on 15-node radial distribution system whose single line diagrams with capacitors is shown in Fig.1.The net saving for different PLI tolerance values are given in Table 1. From Table 1, it seems that the power loss index (PLI) tolerance of 0.5.is chosen to get maximum net saving and the corresponding nodes are 4, 8, 9, 11, and 15. Hence these nodes are suitable for optimal capacitor placement for obtaining maximum net saving By applying the proposed DPSO algorithm the capacitor sizes are obtained at nodes 4, 8 ,9, 11, 15 are 150,150,300,300,300 kVAR respectively. Power losses of 15-node radial distribution system are given in Table 2. The capacitor allocation and loss reduction are given in Table 3.

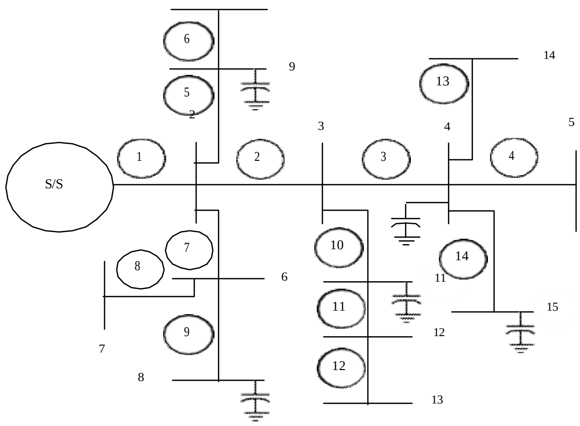

Fig. 3 15-Node RDS with capacitors

Table 1: Net saving for different PLI tolerance values for 15-node RDS for capacitor placement

PLI Tolerance	No. of candidate nodes	Total Capacitor value (kVAR)	Candidate nodes	Net Saving (Rs)
0.9	3	900	4, 11, 15	665069.05
0.7	4	1050	4, 8, 11, 15	741354.54
0.5	**5**	**1200**	**4, 8, 9, 11,15**	**762794.73**
0.3	8	1050	3, 4, 8, 9,11, 12, 14,15	750472.05
0.1	12	1350	3, 4, 5, 6, 8,9, 10, 11, 12, 13, 14,15	563960.27

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Table 2 Power Losses of 15-Node RDS for Capacitor Placement

Br. No	Sending Node	Receiving Node	Without Capacitors		With Capacitors	
			Ploss (kW)	Qloss kVAR)	Ploss (kW)	Qloss (kVAR)
1	1	2	37.72	36.89	17.70	17.32
2	2	3	11.33	14.01	5.26	6.51
3	3	4	2.45	2.40	1.15	1.12
4	4	5	0.05	0.03	0.05	0.03
5	2	9	1.60	1.08	0.88	0.59
6	9	10	0.15	0.10	0.14	0.09
7	2	6	3.01	2.03	1.69	1.14
8	6	7	0.03	0.02	0.03	0.02
9	6	8	0.44	0.30	0.21	0.14
10	3	11	2.18	1.54	1.03	0.73
11	11	12	0.60	0.40	0.57	0.38
12	12	13	0.07	0.05	0.07	0.04
13	4	14	0.20	0.13	0.19	0.13
14	4	15	0.44	0.29	0.46	0.31
Total losses			60.34	59.34	29.97	28.61

Table 3 Capacitor allocation and loss reduction for 15-node RDS

Node no	Without Capacitor	With Capacitor	Q-Cap
	Voltage (p.u)	Voltage (p.u)	(kVAR)
4	0.9489	0.9756	150
8	0.9592	0.9766	150
9	0.9651	0.9825	300
11	0.9478	.9747	300
15	0.9464	0.9753	300
Total kVAR Compensated			1200

Without Capacitor			With Capacitor			% Improvement		
TPL (kW)	TQL (kVAR)	Min Voltage (p.u)	TPL (kW)	TQL (kVAR)	Min Voltage (p.u)	TPL %	TQL %	Min Voltage %
60.34	**59.34**	**0.9423**	**29.97**	**28.61**	**0.9694**	**50.33**	**51.78**	**2.71**

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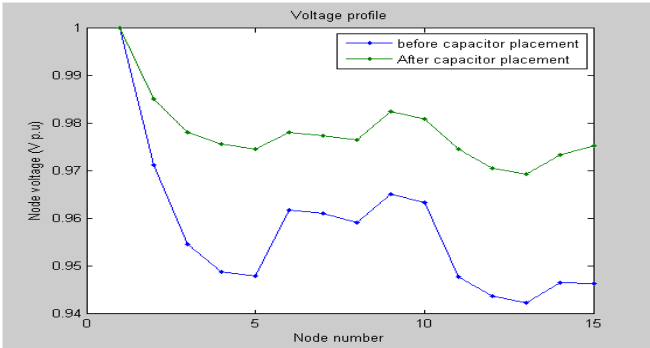

Fig 5. Voltage profile at load level 1.0 for 15-node RDS before and after compensation using DPSO

The proposed DPSO results are compared with existing method for 15-node RDS is given in Table 5. From the Table 5., it is observed that DPSO has succeeded in finding the global solution with a high probability. The total real power losses are reduced from 60.3482 kW to 29.9765 kW, i.e.50.33%, reduction. The total reactive power losses are reduced from 59.3421 kVAR to 28.6149 kVAR, i.e.51.78% reduction. The minimum voltage improved from 0.9423p.u. at node 13 to 0.9694p.u. at node 13. Thus maximum voltage regulation from 5.77% to 3.06%, i.e.,46.96% improved. The net saving is Rs.7,62,794/-with capacitor placement at optimal location. To show the average performance of the algorithm, it is run 100 times, out of which proposed method converged to optimum solution 92 times whereas the existing method converged 71 times. The CPU time for the proposed method is reduced from 2.7545sec to 1.7233sec on Core 2 Duo compared with the existing method.

Table 5 comparison of test results of 15- Node RDS for capacitor placement

		Uncompensated	Compensated			
			Existing Method[10]		**Proposed Method**	
Optimal locations and Size		---	Node	Size (kVAR)	Node	Size (kVAR)
			4	450	4	150
			8	150	8	150
			9	150	9	300
			11	300	11	300
			15	0	15	300
Total Active Power loss(kW)		60.34	29.9960		29.9765	
Total Reactive power loss (kVAR)		59.34	29.1128		28.6149	
Net Saving (Rs.)	Best	---	756168.28		762794.73	
	Worst		530665.67		697370.94	
	Average		742251.61		752365.08	
Percentage loss reduction		---	50.3274		51.1235	
Min.Voltage(p.u)		0.94	0.9677		0.9694	
Voltage Regulation(%)		5.77	3.23		3.06	
No. of times best solution occured		---	71		92	
Execution time (Sec)		---	2.7545		1.7233	

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VI. CONCLUSIONS

A DPSO algorithm for solving the capacitor placement problem in radial distribution systems has proposed in this chapter. With full considerations of different load levels, and practical aspects of fixed or switched capacitor banks, the target problem is reformulated by a comprehensive objective function .This chapter aims at discussing the placement of capacitors in order to reduce the real power losses and improve the voltage profile to maximize the net saving. The proposed method deals with selection of nodes by using power loss index (PLI) and then Discrete Particle Swarm Optimization (DPSO) has used for size with type of the capacitors to reduce the real power losses by cancelling part of the reactive power flowing in the system and to improve voltage profile. The proposed algorithm is tested with three distribution systems consisting of 15node, 33 node and 69 node radial distribution systems. From the results, we concluded as The proper placement of the capacitor reduces the power loss in the radial distribution system.In addition of power loss reduction, the voltage profile can be improved.

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