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Simultaneous Optimal Shunt Capacitor Placement and Network Reconfiguration of the Radial Distribution Network for Power Loss Minimization

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Abstract
The electrical power distribution system is said to be well designed if it delivers good quality of power to each and every consumer especially remote end consumer in the system. The quality of power is always referred with respect to voltage profile. Voltage at various locations in the system is mainly depends on the reactive power flow in the system. The voltage can be maintained closed to rated voltage by connecting shunt capacitor banks in the system. Voltage profile of the system can also be improved by the concept of reconfiguration of the system in which topological structure of the system is changed by opening/closing the sectionalizing/tie switches. Inclusion of shunt capacitors along with the optimal network reconfiguration also reduces the losses in addition to the voltage profile improvement. Inclusion of shunt capacitors with distribution system provides the reactive power support for inductive loads and reconfiguration alters the power flow patterns such that voltage profile of the system improves and reduces the power losses. In this work an algorithm based on modified particle swarm optimization is proposed to find the optimal sizes of the capacitors and modified discrete particle swarm optimization is used for optimal network reconfiguration. The optimal locations of the capacitors are obtained by conducting the sensitivity analysis. The proposed algorithm is tested on IEEE-33 bus radial distribution systems and results are presented.

Keywords: *Distribution Systems, Shunt Capacitors, Network Reconfiguration, Modified Particle Swarm Optimization.*

Introduction:

Delivery of electrical power from substation to the consumers' end always associated variation of voltages which causes in certain power losses. In general, the losses in the system can be reduced by providing reactive support by including the shunt capacitor banks into the distribution systems. Inclusion of shunt capacitors with distribution system improves the voltage profile of the system and hence reduces the losses. Power losses can also be reduced by another usual and simple technique called "Network Reconfiguration".

In general, any distribution network consisting of two types of switches, viz., sectionalizing switches which are normally in closed position and tie-switches which are generally be kept in open. Tie-switches are generally operated under maintenance and repair conditions in order to continuously feed the electrical power to all the loads without disturbance. Network reconfiguration is the process of changing the on/off statuses of tie-switches and sectionalizing switches that alters the power flow patterns reduces the power losses and also improves the voltage profile. Carrying separately optimal capacitor placement and network reconfiguration is easy tasks for the system engineers. But simultaneous allocation of shunt capacitor bank sitting and sizing along with network reconfiguration is challenge for researchers and practicing engineers.

Reactive power compensation is the challenging and important aspect of distribution system design to achieve the maximum loss reduction, system capacity release and acceptable voltage profile. There are many alternatives for reducing the losses that the engineers follow: distributed generators (DG), load balancing and introduction of higher voltage levels. This work

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mainly focuses on the optimal capacitor and network reconfiguration on the radial distribution system network.

Over the past few years, several researches are carried out to find the optimal locations and optimal sizes of capacitors when they are required to installed in the distribution systems using several optimization techniques such as classical methods [1-3], mixed integer linear programming [4], hybrid simulated annealing [5], particle swarm optimization [6], genetic algorithms (GA) [7,8], and biogeography based optimization (BBO) [9].

In recent years, the demand for electrical power is keeping on increasing sharply due to economical and environmental issues. At the same time with the advent of deregulation in the power industry, there is a great focus on managing network assets efficiently rather than reinforcing the networks' capacity. Process of network reconfigurations would allow the transfer of load from heavily loaded portion of the network to relatively lightly loaded portions of the system. Therefore, reconfiguration and capacitor allocation procedures are attractive alternatives for loss reduction [10, 11].

Several researchers addressed the concept of network reconfigurations in their work. Franscisco et al. [12] used mixed integer linear programming (MILP) for calculating the active power loss of balanced large scale distribution system. Franco et al. [13] reported MILP model of reconfiguration of distribution systems considering the presence of distributed generators.

Pfitscher et al. [14] reported a procedure to determine the best sequences of switching of distribution network for reconfiguration of the network. Milani et al. [15] performed an optimal reconfiguration in order to reduce the total cost of operation, including the cost of switching and benefit of loss reduction.

Lopez et al. suggested an efficient online evaluation technique [16] for solving distribution feeder reconfiguration problem. Khodr et al. used optimal power flow (OPF) based on benders decomposition approach [17] for loss reduction as well as the load balancing among the feeder. Oliveira et al. reported mixed integer non linear programming (MINLP) [18] for reconfiguration under the presence of capacitor allocation to minimize energy losses on radial electrical networks considering different load levels. The Lagrange multipliers were used to evaluate sensitivity index for distribution reconfiguration.

SENSITIVITY ANALYSIS:

Sensitivity analysis [19, 20] is a powerful and simple technique that can be used to find the sensitive nodes or buses to place the devices like Distributed generators, shunt capacitors and voltage regulators. Thus sensitivity analysis gives the list of candidate locations for placing shunt capacitors. Estimation of these candidate locations helps in reduction of the search space considerably for any optimization procedure.

First of all, load flow based on forward and backward load flow algorithm is carried out and next loss sensitive factors are to be determined and arranged in descending order.

Consider a branch 'b' of distribution system with $R_b + jX_b$ as impedance and is connected between buses '$m-1$' and 'm' as shown in fig. 1.

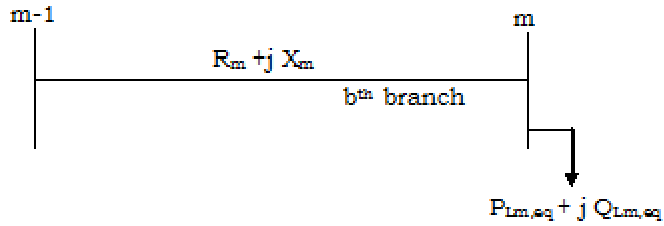

Fig. 1: Branch of a radial distribution system

Real power loss in the b^{th} branch connected between *'m-1'* and *'m'* can be observed as

$$P_{loss} = R_m \times \left[\frac{P_{Lm,eq}^2 + Q_{Lm,eq}^2}{V_m^2} \right] \quad \ldots(1)$$

Where $P_{Lm,eq}$ is total real power dispatched ahead of bus *'m'*

$Q_{Lm,eq}$ is the total reactive power dispatched ahead of bus *'m'*

The loss sensitive factor (variation of real power loss with respect to reactive power $Q_{Lm,eq}$) of bus 'm' can be calculated with the equation

$$\frac{\partial P_{loss}}{\partial Q_{Lm,eq}} = 2 \times \left(\frac{Q_{Lm,eq}}{V_m^2} \right) \times R_m \quad \ldots(2)$$

Using the above equation, loss sensitive factors are evaluated for all the buses from the

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load flow and these values are arranged in descending order. The buses at the top of this list are more sensitive with respect to reactive power losses and hence these buses can be chosen to install shunt capacitor units to minimize the real power loss.

LOAD MODELLING:

In this work, the problem of optimal capacitor placement and network reconfiguration is carried out by considering four load models. The four load models considered here are

1. Constant power load model
2. Constant current load model
3. Constant impedance load model
4. Composite load model

The mathematical equations for active and reactive power loads for the above load models can be written as

$$PL(n) = PL_0(n) \times \left\{c_1 + c_2 \times |V(n)| + c_3 \times |V(n)|^2\right\} \quad \ldots(3)$$

$$QL(n) = QL_0(n) \times \left\{d_1 + d_2 \times |V(n)| + d_3 \times |V(n)|^2\right\} \quad \ldots(4)$$

In the above equations, (c_1, d_1), (c_2, d_2) and (c_3, d_3) are the compositions of constant power, constant current and constant impedance loads respectively.

For constant power loads $c_1 = d_1 = 1$ and $c_2 = d_2 = c_3 = d_3 = 0$;

For constant current loads $c_2 = d_2 = 1$ and $c_1 = d_1 = c_3 = d_3 = 0$;

For constant power loads $c_3 = d_3 = 1$ and $c_1 = d_1 = c_2 = d_2 = 0$; and

For composite loads $c_1 = d_1 = 0.4$ and $c_2 = d_2 = 0.3$ and $c_3 = d_3 = 0.3$

Modified Particle Swarm Optimization (MPSO):

In conventional PSO, the velocity of a particle in any iteration at any situation can be updated by using the equation (5).

$$v_{id}^{k+1} = \omega v_{id}^{k} + c_1 rand * \left(Pbest_{id} - s_{id}^{k}\right) + c_2 rand * \left(gbest_{id} - s_{id}^{k}\right) \quad \ldots (5)$$

But in modified PSO in addition to the particles with best solution, particles with worst solution are also considered and the velocity update equation can be modified as

$$V_{id}^{k+1} = \begin{bmatrix} \omega.V_{id}^{k} + c1 \times r1 \times k1 \times (Pbest_{id} - S_{id}^{k}) + c2 \times r2 \times k2 \times (Gbest_{id} - S_{id}^{k}) + \\ c3 \times r3 \times k3 \times (Pworst_{id} - S_{id}^{k}) + c4 \times r4 \times k4 \times (Gworst_{id} - S_{id}^{k}) \end{bmatrix} \quad \ldots (6)$$

Where,

C1 and C3 are the cognitive acceleration coefficients, C2 and C4 are the social acceleration coefficients, G_{best} is the global best of the entire swarm, G_{worst} is the global worst of the entire swarm, k is the previous iteration number, k+1 is the current iteration number, $K = [k1, k2, k3, k4]$ is switch matrix and its value is $[1,1,0,0]$ for best particles and $[0,0,1,1]$ for worst particles, P_{best} is the particle's best, P_{worst} is the particle's worst, and r1, r2, r3 and r4 are the random numbers between 0 to 1, S_{id}^{k} is the position of i^{th} particle, V_{id}^{k} is the velocity of i^{th} particle

The position of any element in $(k+1)^{th}$ iteration can be modified according to equation (1.6) and weight function used is given in equation (7).

$$\omega_i = \omega_{max} - \frac{\omega_{max} - \omega_{min}}{k_{max}} . k \quad \ldots (7)$$

Modified Discrete Particle Swarm Optimization (MDPSO):

In basic particle swarm optimization, the values of parameters $P_{best,id}$, $G_{best,id}$ and S_{id}^{k} may have any real values in equation (6), but in reconfiguration problem the particle consists of status values of tie switches and sectionalizing switches that may be either 0 or 1 ('0' represents open and '1' represent the close). Therefore it is required to consider these values of $P_{best,id}$, $G_{best,id}$, S_{id}^{k} and V_{id}^{k} either '0' or '1'. The values of updated values of $(P_{best,id} - S_{id}^{k})$ and $(G_{best,id} - S_{id}^{k})$ will takes a values of [-1, 0 or 1]. In order to achieve this, a sigmoid logical transformation $Sig(V_{id}^{k})$ is used. Therefore the resulting change in position is then defined by the rule:

$$S_{id}^{k} = \begin{cases} 1 \cdots\cdots rand(.) \le Sig.\left(V_{id}^{k}\right) \\ 0 \cdots\cdots otherwise \end{cases}$$

… (8)

$$Sig.\left(V_{id}^{k}\right) = \frac{1}{1+\exp(-V_{id}^{k})}$$

… (9)

Each particle of a swarm is randomly initiated in values '0' or '1' and then objective function is determined according to this initial guess. Next, for each iteration, $P_{best,id}$ is calculated according to the results obtained for each particle, and $G_{best,id}$ is found based on all the previous iterations. Then in the next iteration, two partial probability values (Pbest,id - S_{id}^{k}) are added to or subtracted from the previous state of each element.

In this work, the optimal locations of shunt capacitor banks are obtained by sensitivity analysis in which loss sensitive factors that represent the variation of real power loss with respect to reactive power flow are found for each bus in the system by forward backward sweep distribution load flow. The optimal sizes of these shunt capacitor banks are obtained by modified particle swarm optimization in which the experience of -bad particles are also taken into account while updating the velocity of each particle. The modified discrete particle swarm (MDPSO) is used to obtain the optimal configuration of the network to minimize the loss subjected to a set of practical constraints

PROBLEM FORMULATION AND OBJECTIVE FUNCTION

Problem Formulation

In this work, the main problem studied is to find optimal locations and optimal sizes of capacitor in radial distribution system along with the optimal reconfiguration of the network that will gives the minimization of real power loss subjected to a set of constraints.

First of all it is required to find the loss sensitive factors (LSFs) according to equation (2), for all the nodes/buses and arrange these LSFs of all the buses in descending order from that we can choose top three buses to place the shunt capacitor units. The optimal size of the capacitor units (reactive power rating) can be obtained by Modified PSO and the optimal network reconfiguration is obtained by using Modified Discrete PSO.

Objective Function:

Reconfiguration of distribution system along with optimal capacitor placement is considered with the objective of minimization of real power loss. The real power loss of the system is obtained as [21]

$$P_{loss} = \sum_{m=1}^{N_B}\sum_{n=1}^{N_B}\left\{\begin{array}{l} \frac{R_{m,n}}{V_m \times V_n} \times \cos(\delta_m - \delta_n) \times (P_m.P_n + Q_m.Q_n + \\ \frac{R_{m,n}}{V_m \times V_n} \times \sin(\delta_m - \delta_n) \times (Q_m.P_n - P_m.Q_n \end{array}\right\}$$

… (10)

Where $R_{m,n}$ is the resistance of the distribution line section connected between m^{th} and n^{th} bus, V_m is the bus voltage at m^{th} bus and V_n is the bus voltage at n^{th} bus; N_B is the total number of buses in the distribution system, P_m, Q_m are the net active and reactive powers at m^{th} bus and δ_m, δ_n are the angles of voltages at m^{th} bus and n^{th} bus.

Constraints:

The above objective function is minimized subjected to a set of practical constraints as:

(i) Voltage magnitude constraint:

Voltage magnitude at each bus should be within the specified limits even after placing a capacitor and reconfiguration i.e., it should be greater than $V_{\min}$ and less than $V_{\max}$ and is represented as

$$V_{\min} \le V_j \le V_{\max}$$

…(11)

(ii) Feeder capacity constraint:

The magnitude of the current through all the line sections should be within the tolerable limits of the respective section i.e.

$$I_k \le I_k^{\max}, k \in \{1,2,3......l\}$$

…(12)

Where

$I_k^{\max}$ is maximum current capability of branch k

(iii) Power balance constraint

$$P_m + j.Q_m = V_m \times I_{m,n}$$

…(13)

(iv) Capacitor bank constraint:

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The size of the capacitor should be within the ratings of the shunt capacitors banks

$$Q^{C}_{m,\min} \le Q^{C}_{m} \le Q^{C}_{m,\max} \quad \ldots(14)$$

Where $Q^{C}_{m,\min}$ and $Q^{C}_{m,\max}$ are the minimum and maximum allowable reactive powers of the m^{th} capacitor.

(v) Radial nature of the network constraint:

This constraint is checked by the following way

Det [A] =1 or -1 for radial system … (15)

Det [A] = 0 not a radial system … (16)

And the system should satisfy

$$N_l = N_t - N_{iso} \quad \ldots (17)$$

$$N_{iso} = Sub \quad \ldots (18)$$

Where

N_l is the number of connected lines, N_t is the number of nodes or terminals, N_{iso} is the number of isolated areas and is generally equal to number of substations *'Sub'*

MPSO and MDPSO

In this section the algorithm to create a set of population in modified particle swarm optimization and modified discrete particle swarm optimization is presented. The particle of a swarm actually consisting of size of the capacitor banks, tie switches and sectionalizing switches.

In this work, following four cases are considered:

Case-1: Original system without capacitors and network reconfiguration.

Case-2: Optimal capacitor placement without reconfiguration

Case-3: Optimal network reconfiguration without capacitors.

Case-4: Simultaneous optimal placement of capacitor along with network reconfiguration

Generation of a particle:

In this section an algorithm to generate the particles for different cases are presented. The particles for different cases are defined here as:

For case-2

$$(Q_{C1}, Q_{C2}, \ldots\ldots\ldots\ldots Q_{CN_C}) \quad \ldots (19)$$

For case-3

$$(TS_1, TS_2, \ldots\ldots\ldots TS_n, SS_1, SS_2, \ldots\ldots\ldots SS_n) \quad \ldots (20)$$

For case-4

$$X = \begin{Bmatrix} TS_1, TS_2, \ldots\ldots\ldots TS_n, SS_1, SS_2, \ldots\ldots\ldots SS_n, \\ Q_{C1}, Q_{C2}, \ldots\ldots\ldots\ldots Q_{CN_C} \end{Bmatrix} \quad \ldots (21)$$

Where

TS_i is the i^{th} tie switch, n is the number of switches and SS_i is the sectionalizing switch of any randomly selected line from the group of lines that forms the loop by closing i^{th} tie switch

Initialization: Following algorithm is used to generate a particle consisting of optimal size of the shunt capacitor banks, status of tie-switches and sectionalizing switches.

Step 1: Set i=1

Step 2: Select the reactive power rating of first capacitor bank within its reactive power rating.

Step 3: Repeat step 2 for all shunt capacitor banks.

Step 4: Select the next element representing the status of first tie switch, and fix this value either 0 or 1 ('0' represents open and '1' represents closing)

Step 5: Repeat step 4 for all tie switches

Step 6: Select the next element by considering the status of first tie switch, if its value is '1', then select any one of sectionalizing switch from a list of switches that forms a loop with first tie switch to open otherwise its value is zero by considering the radial nature constraint.

Step 7: Repeat step 6 for all tie switches

Step 8: increment the particle number i.e., *i=i+1*

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Step 9: If all particles are generated stop the initialization process otherwise go to step 2.

The individual particle as created above is taken as list the initial optimal sizes of capacitors, set of sectionalizing and tie switches.

For case-4 all the steps are to be used where as for case-2 steps 4 to 7 can be excluded, for case-3 steps 2 to 4 are excluded.

Algorithm of MPSO and MDPSO for optimal sizing of capacitor units and optimal reconfiguration:

The algorithm to find the optimal sizes of shunt capacitors and optimal reconfiguration is:

Step 1: Read the line and load data of the system and DG units data

Step 2: Calculate the power loss using the distribution load flow based on backward and forward sweep algorithm for the original network

Step 3: Initialize the particles according to the algorithm given above

Step 4: For each particle find the objective function

Step 5: If the objective function of each particle is better than the previous experience, then update its P_{best}

Step 6: Find the G_{best} by considering the objective function value of all the particles

Step 7: Find the velocity of each particle

Step 8: Update the velocity and position

Step 9: If the iteration number reaches the maximum limit print the results,

Step 10: Otherwise set increase iteration count by one and go back to step 4.

Finally the optimal size (reactive power outputs) of capacitors and optimal configuration of the network can be observed from final G_{best}

Results & Analysis:

The proposed optimal capacitor placement and optimal network reconfiguration of distribution system by MPSO and MDPSO is tested on IEEE 33 bus systems and results are presented.

The proposed algorithm has been implemented in MATLAB 7.0 version on Pentium IV, 2.4 GHZ Personnel Computer with 4 GB RAM. The optimal locations of are selected by determining the sensitive nodes according to sensitivity analysis and is found that for an IEEE-33 bus system buses 30 and 24 are chosen to place capacitor units.

At each test system, 50 trails were performed using the proposed method to observe the solution quality, convergence characteristic, and execution time.

An IEEE-33 bus radial distribution system [22] shown in fig. 2 consisting of 33 buses or nodes, 32 lines, 32 sectionalizing switches and 5 tie switches is considered here as test system.

The proposed algorithm has tested for four cases as

Case-1: Original system without capacitors and network reconfiguration.

Case-2: Optimal capacitor placement without reconfiguration

Case-3: Optimal network reconfiguration without capacitors.

Case-4: Simultaneous optimal placement of capacitor along with network reconfiguration

Case-1: Original configuration of the system:

The results of distribution load flow for the original system without capacitor placement and reconfiguration is given in Table 1

Table 1: Simulation results of IEEE-33 bus system for case-1 for different types of loads

S. N o.	Aspect	For const ant Powe r type loads	For const ant Curre nt type load	For constan t impeda nce type load	For compo site type load
1	Switche s to be opened	33, 34, 35, 36, 37			
2	Real power Loss(k	210.9 9	182.1 7	160.72	184.19

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	W)				
3	Minimum voltage(p.u)	0.9038	0.9116	0.9176	0.9103

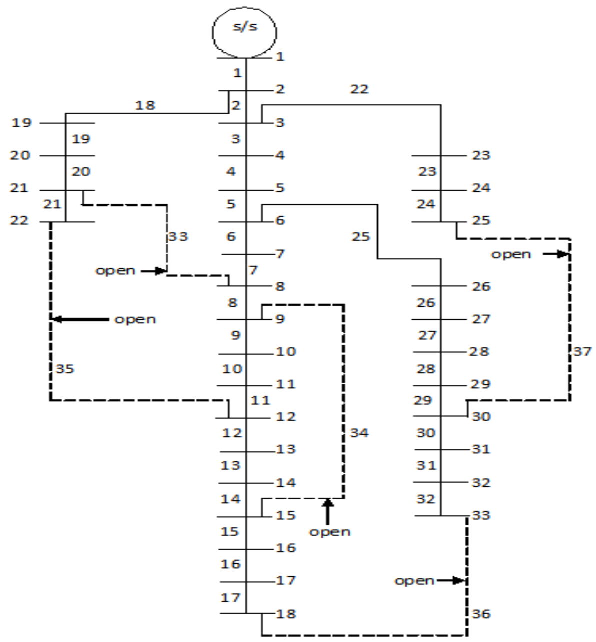

Fig.2: IEEE-33 bus radial distribution system

From the simulation results it is observed that for original configuration of the system i.e., before placing the capacitor and without reconfiguration of the system, the real power loss for IEEE-33 bus system for constant power, constant current, constant impedance and composite loads are observed to be 210.99 kW, 182.17 kW, 160.72 kW and 184.19 kW.

Case-2: Optimal capacitor placement without reconfiguration

By conducting sensitivity analysis, for case-2 the loss sensitive factors $\left(\partial P_{loss} / \partial Q_{Ln,eq}\right)$ for all buses are evaluated and are arranged in descending order given in Table 4.3, from this list buses 30 and 24 are selected to install capacitor units. Variation of these LSFs for all the buses is given in fig 3.

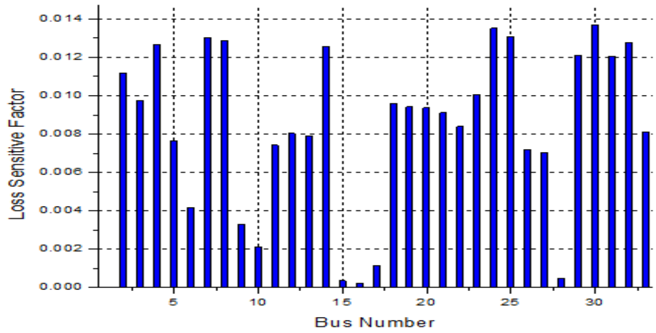

Fig. 3: Loss sensitive factors of IEEE-33 bus system

Table 2 gives the simulation results of MPSO for IEEE-33 bus system for case-2. From this results it is observed that the losses for constant power, constant current, constant impedance and composite type of loads are reduced from 210.99 kW, 182.17 kW, 160.72 kW and 184.19 kW to 152.1145 kW, 136.24 kW, 122.35 kW and 137.61 kW respectively. The voltage profile of the system has also been improved. The convergence characteristics of MPSO algorithm for IEEE-33 bus system for load multiplication factor of 1.0 for case-2 for different load types are given fig. 4.

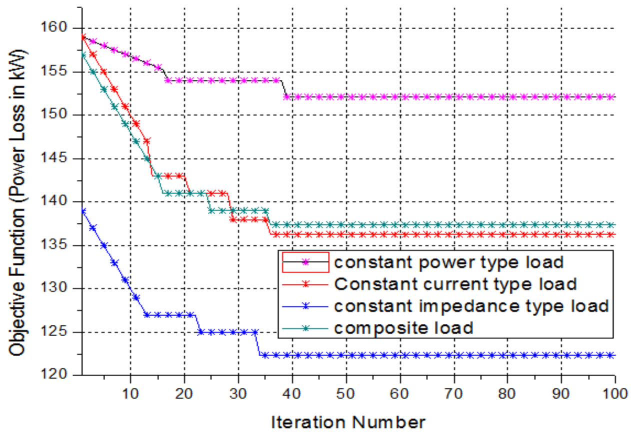

Fig. 4: Convergence characteristics of MPSO for IEEE-33 bus system for case-2 for different loads

Table 2: Simulation results of IEEE-33 bus system for case-2 for different types of loads

S. No.	Type of load	Aspect	Proposed MPSO algorithm
1	Constant Power type loads	Switches to be opened	33, 34, 35, 36, 37
		Real power	152.1145

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		Loss(kW)	
		Min. voltage(p.u)	0.9241
		Opt. location of capacitors	30 and 24
		Size of capacitors	69.21 and 44.36 kVAr
2	Constant Current type load	Switches to be opened	33, 34, 35, 36, 37
		Real power Loss(kW)	136.2489
		Min. voltage(p.u)	0.9284
		Opt. location of capacitors	30 and 24
		Size of capacitors	71.36 and 51.36 kVAr
3	Constant impedance type load	Switches to be opened	33, 34, 35, 36, 37
		Real power Loss(kW)	122.3580
		Min. voltage(p.u)	0.9368
		Opt. location of capacitors	30 and 24
		Size of capacitors	55.32 and 49.37 kVAr
4	Composite type load	Switches to be opened	33, 34, 35, 36, 37
		Real power Loss(kW)	137.3691
		Min. voltage(p.u)	0.9329
		Opt. location of capacitors	30 and 24
		Size of capacitors	49.32 and 47.278 kVAr

Case-3: Optimal network reconfiguration without using shunt capacitors:

In this case, an algorithm based on modified discrete particle swarm optimization (MDPSO) is used to obtain the optimal reconfiguration of the network without installing shunt capacitor banks. The simulation results for this case is given in Table 3, from this simulation results it is observed that, by having network reconfiguration, the losses of the system has been reduced from 210.99 kW, 182.17 kW, 160.72 kW and 184.19 kW to 114.33 kW, 116.37 kW, 119.32 kW and 116.25 kW for constant power, constant current, constant impedance and composite type of loads respectively. The convergence characteristics of MPSO algorithm for IEEE-33 bus system for case-3 for different load types are given fig. 5.

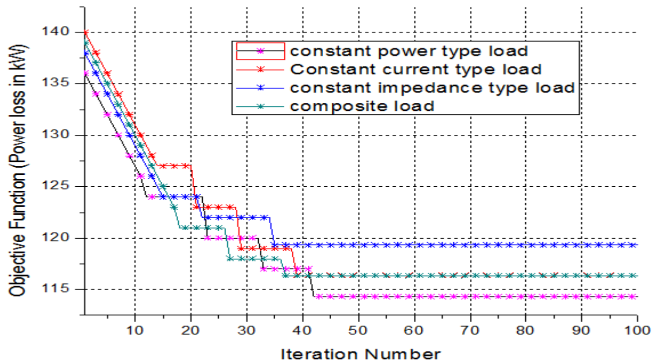

Fig. 5: Convergence characteristics of MPSO for IEEE-33 bus system for case-3 for different loads

Table 3: Simulation results of IEEE-33 bus system for case-3 for different types of loads

S. No.	Type of load	Aspect	Proposed MPSO algorithm
1	Constant Power type loads	Switches to be opened	7, 9, 14, 30, 37
		Real power Loss(kW)	114.3287
		Min. voltage(p.u)	0.9511
2	Constant Current type load	Switches to be opened	7, 10, 14, 32, 37
		Real power Loss(kW)	116.3744
		Min. voltage(p.u)	0.9547
3	Constant impedance type load	Switches to be opened	6, 9, 14, 32, 37
		Real power Loss(kW)	119.3211
		Min. voltage(p.u)	0.9501
4	Composite type load	Switches to be opened	6, 10, 14, 30, 37
		Real power Loss(kW)	116.2498
		Min.	0.9511

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		voltage(p.u)	

Case-4: Simultaneous network reconfiguration and optimal capacitors placement:

In this case, proposed algorithm based on modified discrete particle swarm optimization (MDPSO) and modified particle swarm optimization is used to obtain the simultaneous reconfiguration of the network along with optimal capacitor placement. Table 4 gives the simulation results for case-4. From this simulation results it is observed that the losses are further reduced to 113.45 kW, 97.21 kW, 104.99 kW and 107.36 kW for constant power, constant current, constant impedance and composite type of loads respectively. The convergence characteristics of MPSO algorithm for IEEE-33 bus system for case-4 for different load types are given fig. 6.

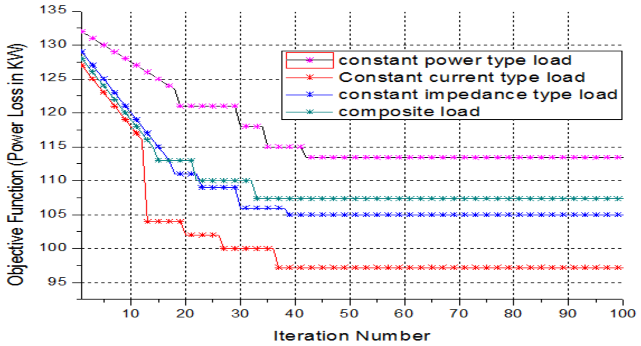

Fig.6: Convergence characteristics of MPSO for IEEE-33 bus system for case-4 for different loads

Table 4: Simulation results of IEEE-33 bus system for case-4 for different types of loads

S.No.	Type of load	Aspect	Proposed MPSO Algorithm
1	Constant Power type loads	Switches to be opened	7, 9, 14, 31, 24
		Real power Loss(kW)	113.4468
		Min. voltage(p.u)	0.9547
		Opt. location of capacitors	30 and 24
		Size of capacitors (kVAr)	78.32 and 39.21
2	Constant Current type load	Switches to be opened	7, 9, 13, 32, 37
		Real power Loss(kW)	97.2149
		Min. voltage(p.u)	0.9559
		Opt. location of capacitors	30 and 24
		Size of capacitors (kVAr)	77.98 and 44.11
3	Constant impedance type load	Switches to be opened	6, 9, 13, 31, 37
		Real power Loss(kW)	104.9974
		Min. voltage(p.u)	0.9562
		Opt. location of capacitors	30 and 24
		Size of capacitors (kVAr)	74.3689 and 44.88
4	Composite type load	Switches to be opened	7, 9, 12, 31, 37
		Real power Loss(kW)	107.36
		Min. voltage(p.u)	0.9511
		Opt. location of capacitors	30 and 24
		Size of capacitors (kVAr)	73.25 and 46.32

CONCLUSIONS

In this method an algorithm based on Modified Particle Swarm Optimization (MPSO) is proposed to find the optimal size of Shunt Capacitor banks and Modified Discrete Particle Swarm Optimization (MPDSO) is used to get optimal Network reconfiguration. Sensitivity Analysis is used to find the sensitive (optimal) nodes to place Shunt capacitor banks. The proposed algorithms are tested for different cases and results are presented. From the simulation results it is observed that losses can be reduced to great extent and can get better voltage profiles by using simultaneous shunt capacitor placement and network reconfiguration.

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REFERENCES:

[1] Grainger JJ, Lee SH. Optimum size and location of shunt capacitors for reduction of losses on distribution feeders. IEEE Trans Power Appar Syst 1981;100(3):1105–18.

[2] Hogan PM, Rettkowski JD, Bala JL. Optimal capacitor placement using branch and bound. In: Proceedings of the 37th annual North American Power, symposium 2005; 23rd–25th October: 84–9.

[3] Khodr HM, Yusta JM, Vale Z, Ramos C. An efficient method for optimal location and sizing of fixed and switched shunt capacitors in large distribution systems. IEEE power and energy society general meeting 2008; 20th–24th July: 1–9.

[4] Khodr HM, Olsina FG, Jesus DOD, Yusta JM. Maximum savings approach for location and sizing of capacitors in distribution systems. Elect Power Syst Res 2008;78(7):1192–203.

[5] Ching TS, Lee CS. Feeder reconfiguration and capacitor setting for loss reduction of distribution systems. Elect Power Syst Res 2001;58(2):97–102.

[6] Singh SP, Rao AR. Optimal allocation of capacitors in distribution systems using particle swarm optimization. Int J Elect Power Energy Syst 2012;43(1): 1267–75.

[7] Kalyuzhny A, Levitin G, Elmakis D, Haim HB. System approach to shunt capacitor allocation in radial distribution system. Elect Power Syst Res 2000;56(1):51–60.

[8] Sydulu M, Reddy VVK. Index and GA based optimal location and sizing of distribution system capacitors. In: IEEE power engineering society general meeting 2007; 24th–28th June: 1–4.

[9] Mandal KK, Bhattacharya B, Tudu B, Chakraborty NA. Novel population-based optimization algorithm for optimal distribution capacitor planning. In: International conference on energy, automation, and signal (ICEAS) 2011; 28th–30th December: 1–6.

[10] Sarfi RJ, Salama MMA, Chikhani AY. A survey of the state of the art in distribution system reconfiguration for system loss reduction. Electric Power Syst Res 1994;31(1):61–70.

[11] Grainger JJ, Lee SH. Optimum size and location of shunt capacitors for reduction of losses on distribution feeders. IEEE Trans Power Apparat Syst 1981;100(3):1105–18.

[12] Francisco LI, Jesús RS, Esther RR. Mixed-integer linear programming model for solving reconfiguration problems in large-scale distribution systems. Electric Power Syst Res 2012;88:137–45.

[13] John FF, Marcos JR, Marina L, Rubén Romero. A mixed-integer LP model for the reconfiguration of radial electric distribution systems considering distributed generation. Electric Power Syst Res 2013;97:51–60.

[14] Pfitscher LL, Bernardon DP, Canha LN, Montagner VF, Garcia VJ, Abaide AR. Intelligent system for automatic reconfiguration of distribution network in real time. Electric Power Syst Res 2013;97:84–92.

[15] Armin EM, Mahmood RH. A new probabilistic approach for distribution network reconfiguration: applicability to real networks. Math Comput Model 2013;57:169–79.

[16] Lopez E, Opazo H, Garica L, Bastard P. Online reconfiguration considering variability demand: applications to real networks. IEEE Trans Power Syst 2004;19(1):549–53.

[17] Khodr HM, Martinez-Crespo J, Matos MA, Pereira J. Distribution systems reconfiguration based on OPF using benders decomposition. IEEE Trans Power Del 2010;24(4):2166–76.

[18] Leonardo W, Oliveira D, Sandoval CJ, Edimar JDO, Pereira JLR, Ivo CSJ, et al. Optimal reconfiguration and capacitor allocation in radial distribution systems for energy losses minimization. Int J Electr Power Energy Syst 2010;32(8): 840–8.

[19] K. Prakash, *Member*, *IEEE*, and M. Sydulu " Particle Swarm Optimization Based Capacitor Placement on Radial Distribution Systems" 1-4244-1298-6/07/$25.00 ©2007 IEEE.

[20] R. Srinivasa Rao, K. Ravindra, K. Satish, and S. V. L. Narasimham Power Loss "Minimization in Distribution System Using Network Reconfiguration in the Presence of Distributed Generation" IEEE Trans, 2012

[21] Acharya N, Mahat P, Mithulananthan N. An analytical approach for DG allocation in primary distribution network. Int J Elect Power Energy Syst 2006;28(10):669–78.

[22] Silvestri, A.; Berizzi, A.; Buonanno, S., "Distributed generation planning using genetic algorithms," IEEE PowerTech Budapest 99, pp. 257, 1999.

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