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RECENT ADVANCES IN ELECTRONICS & COMMUNICATION ENGINEERING (RAECE-2K17)

MODELLING TECHNIQUES IN RADIAL DISTRIBUTION SYSTEM FOR OPTIMAL CAPACITOR PLACEMENT AND CONDUCTOR SELECTION

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***Abstract*— In this paper, a methodology techniques used for the radial distribution system for determining size of the conductor, location and number of capacitors to be placed in the system and also selection of optimal conductors. The main Objective of this paper is for two purposes. One is to minimize the real and reactive power losses in the system and to maximize the total saving in cost of conducting material while maintaining the acceptable voltage levels in order to better quality supply to consumers. In this paper, an Index Vector based Algorithm for determining the suitable candidate nodes, for capacitor allocation in the radial distribution systems is presented. This method also gives the size and the number of capacitors to be placed in the system. As capacitor placement problem is a non-linear optimization problem, Genetic Algorithm technique is used to determine the rating of the capacitors. Further, Genetic Algorithm is proposed for selecting the optimum size of conductors, of feeder segment of radial distribution networks to meet the increasing demands more reliably and economically. The effectiveness of the proposed method has been tested on Agricultural feeders of Andhra Pradesh Northern Power Distribution Company Limited (APNPDCL).**

Keywords—Index Vector, Non-linear optimization problem and Genetic Algorithm Technique.

I. INTRODUCTION

Distribution system provides a final link between high voltage transmission systems and consumer services. The power loss is significantly high in distribution systems because of lower voltages and higher currents, when compared to that in high voltage transmission systems. Reduction of total loss in distribution systems is very essential to improve the overall efficiency of power delivery.

In recent years, considerable attention has been focused in planning of a distribution system, to reduce the power and energy losses, to reduce the capital investment involved and to provide better quality supply to consumers. Improved modeling techniques and certain optimization and programming approaches has been presented to determine the best location, and suitable interconnections between sub-stations so as to meet the increasing demands more reliably and economically.

Capacitors have been very commonly used to provide reactive power compensation in distribution systems. They are provided to minimize power and energy losses and to maintain the voltages within the acceptable limits. The amount of compensation provided is very much linked to the placement of capacitors, which is essentially determination of location, size and number of capacitors in radial distribution systems.

In this paper Index-Vector based algorithm is introduced for capacitor placement problem. This method identifies the sensitive nodes that have a very large impact on reducing the losses in distribution systems. These nodes are very small in number when compared to the total number of load nodes. In formulating the Index-Vector, bus voltage, ratio of reactive current to active current and reactive power concentration of that node are considered.

Further, Genetic Algorithms are proposed for selecting the optimal size of conductor for radial distribution networks. The conductor, which is determined by this method, will satisfy the maximum current carrying capacity and maintain acceptable voltage levels of the radial distribution systems. In addition, it gives the maximum saving in capital cost of conducting material and cost of energy loss.

II. DISTRIBUTION SYSTEM LOSSES

The losses in power system are classified as Demand Losses (Instantaneous), Energy Losses (Technical and Commercial), and Technical Losses: Generator Losses, Line Losses, Transformer Losses, and Losses of Other Equipment Commercial Losses: Metering and Billing errors, Unauthorized Usage.

Factors that contribute to increase in loss in Distribution systems are Feeder Length, Inadequate size of conductors, Location of distribution transformers, Use of over rated distribution transformers, Low voltage, Low power factor and Pilferage of Energy.

III. LOSS REDUCTION STRATEGIES

Transmission systems: Network Reinforcement, Using Facts Devices, New Lines and Reactive compensation;

Distribution Systems: Rehabilitation of the system, Load balancing, Erecting new Substations and Reactive compensation.

IV. DISTRIBUTION LOAD FLOW

A. *Basic theory of the method*

In this Vector Based Distribution load flow method (VDLF) is presented. Consider a line connected between two nodes as shown in fig. 1.

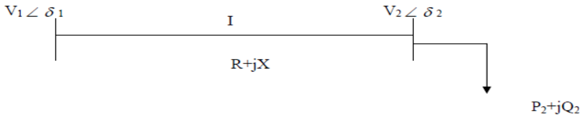

Fig:1 Electrical equivalent of line connected between two nodes of a distribution line.

In fig 1 V_1 and V_2 are the voltages magnitudes of the two nodes 1 and 2. Let the current flowing through it be I. The substation voltage (at sending end) is assumed to be 1+j0 p.u. Let the power factor angle of load P_2+jQ_2 be θ_2. The phasor diagram of this line is

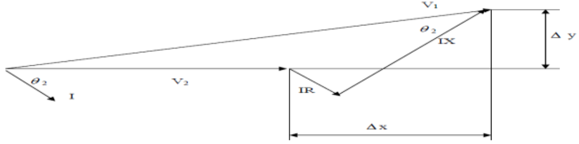

Fig: 2 Basic phasor diagram of a line connected between two nodes

From fig 2 the following equations are derived

$V_1^2=(V_2+\Delta x)^2+\Delta y^2$ ----------- 1

Where $\Delta x = IR\cos(\theta_2) + X\sin(\theta_2)$ -------- 2

$\Delta y = IX\cos(\theta_2) - IR\sin(\theta_2)$ -------- 3

Using the equations 2 and 3 in 1 we have

$V_1^2= (V_2+ IR\cos(\theta_2)+IX\sin(\theta_2))^2+(IX\cos(\theta_2)-IR\sin(\theta_2))^2$

$V_1=[(V_2+IR\cos(\theta_2)+IX\sin(\theta_2))^2+(IX\cos(\theta_2)-IR\sin(\theta_2))^2]^{1/2}$--5

To eliminate I from the equation 4 use

$I\cos(\theta_2) = P_2/V_2$ $\qquad$ $I\sin(\theta_2) = Q_2/V_2$

Where P_2=Total active power load including active power loss beyond node 2.

Q_2=Total reactive power load including reactive power loss beyond node 2.

Thus $\Delta x= IR\cos(\theta_2) + IX\sin(\theta_2) = (P_2R+Q_2X)/V_2$

Thus $\Delta x= IR\cos(\theta_2) + IX\sin(\theta_2) = (P_2R+Q_2X)/V_2$

Thus equation 4 becomes

$V_1^2= (V_2+ (P_2R+Q_2X)/V_2)^2+ ((P_2X-Q_2R)/V_2)^2$

$=V_2^2+2V_2(P_2R+Q_2X)/V_2+(P_2R+Q_2X)^2/V_2^2+(P_2X-{}_2R)^2/V_2^2$ $V_1^2\ V_2^2= V_2^4+ (P_2R+Q_2X)^2+2\ V_2^2(P_2R+Q_2X)+(P_2X-Q_2R)^2$

$V_2^4+2V_2^2=(P_2^2+Q_2^2)(R_2^2+X_2^2) - V_1^2V_2^2=0$

$V_2^4+2V_2^2=(P_2R+Q_2X-V_1^2/2) + (P_2^2+Q_2^2)(R_2^2+X_2^2) = 0$ --- 5

Equation 5 is in the form of $ax^2+bx+c=0$, the roots of this equation are $(-b+ (b^2-4ac)^{1/2})/2a$ and $(-b-(b^2-4ac)^{1/2})/2a$. From the two solutions for V_2 only positive root of quadratic equations gives a realistic value. Thus V_2 is solved as follows:

$V_2=\{[(P_2R+Q_2X+0.5V_1^2)-(P_2^2+Q_2^2)(R_2^2+X_2^2)]^{½}-P_2R+Q_2X+ 0.5\ V_1^2)\}^{½}$ -------- 6

The equation 6 can be written in general form as

$V_2= (B_{[j]}-A_{[j]})^{½}$ ----- 7

Where subscript '2' is the receiving end of jth branch.

subscript '1' is the sending end of jth branch.

$A_{[j]} = P_2R_{[j]} +Q_2X_{[j]}-0.5V_1^2$ ---- 8

$B_{[j]} = [A_{[j]}^2- (P_2^2+Q_2^2)(R_{[j]}^2+X_{[j]}^2)]^{1/2}$---- 9

Where P_2 and Q_2 are total real and reactive power load feed through node 2.

After calculating the effective loads at all nodes, the voltages can be calculated using equations 7, 8 and 9.

Let $P_{loss[j]}$ and $Q_{loss[j]}$ be the real and reactive power loss of branch 'j', then the initial estimates of loads are taken as the loads are taken as the effective loads at all nodes and then losses are calculated using the equations:

$P_{loss[j]} =R_{[j]}^* (P_2^2+Q_2^2)/V_2^2$ ---- 10

$Q_{loss[j]} =X_{[j]}^* (P_2^2+Q_2^2)/V_2^2$ --- 11

B. *Algorithm*

```
1. Read the system line data and bus data
        a) System data: no of buses, no of lines, reference bus or slack bus
        b) Line data: from bus, to bus, line resistance, line reactance
        c) Bus data: Bus no, $P_{load}$, $Q_{load}$.
        d) Read itermax, epsilon, base kva, base voltage and initial voltages at all buses.
2. Form idegree, itagf, itagto, adjq, and adj1 vectors.
3. Calculate effective load at each bus starting from the last bus
    $P_{p\ effective\ load}$ = $P_p$+ sum of all loads beyond the node P.
    $Q_{p\ effective\ load}$ = $Q_p$+ sum of all loads beyond the node p.
Initialize sum of active power loss slp=0, sum of reactive power loss slq=0, previous iteration active power loss pl=0, reactive power loss ql=0.
4. Start iteration count it=1
5. Initialize total active power loss tploss[i] =0, total reactive power loss tqloss[i] =0
        for i=1 to n. (tploss[i] = total active power loss,
            tqloss[i] = total reactive power loss)
7. Assign slp=pl, slq=ql, pl=ql=0.
8. If iteration it=1 go to step 10 else go to step 9
9. Find the effective losses at each bus
for i=n to 1    for j=itagf[i] to itagto[i]    q=adjq[j], k=adjl[j]
tploss[i]= tploss[i] +tploss[q] +ploss[k]
tploss[i]= tqloss[i] +tqloss[q] +qloss[k]
where ploss[k] = active power loss of kth line, qloss[k] = reactive power loss of kth line.
10. Calculate load at each bus with losses
Active power P[i]= $P_{effective\ load[i]}$ + tploss[i]. Reactive power Q[i]= $Q_{effective\ load[i]}$ + tqloss[i].
11. for bus no i=2 to n
        for j=itagf[i], q=adjq[j], k=adjl[j]
        A= (P[i]*r[k] + Q[i]*x[k])-(0.5* V[q]*V[q])
        B= sqrt (A*A –(r[k]*r[k] +x[k]*x[k])*( P[i]*P[i] +Q[i]*Q[i])) V[i]= sqrt(B-A)
        ploss[k] = r[k]* (P[i]*P[i]+Q[i] *Q[i])/V[i]*V[i]
        qloss[k] = x[k]* (P[i]*P[i]+Q[i] *Q[i])/V[i]*V[i]
        pl = pl+ploss[k]    ql=ql+qloss[k]
12. Δploss= slp-pl; Δqloss= slq-ql
            set ploss[i] =qloss[i] =0 for 1 to nline
13. if Δploss< epsilon and Δqloss<epsilon go to step 100
    else go to step 5
14. If iteration > itermax go to step 15
15. Problem is not converged in itermax iterations
```

16. Problem is converged in it iterations. Calculate phase angle at each bus using equation $\delta_2 = x+\delta_1-\theta$. Print voltages and phase angles at each bus and total active power loss.

V. Index Vector Method For Optimal

A. *Objective Function*

The Objective function in the capacitor placement problem comprises of the minimization of the total real power losses in the given Radial Distribution System.

B. *Index Vector Based Method*

Index Vector based method is the conventional approach for optimal capacitor placement. Index Vector is formulated by running the base case load flow on a given radial distribution network, and calculating reactive component of current in the branches and reactive power load concentration at each node. Based on the elements of the Index Vector, this method identifies a sequence of nodes to be compensated. The sequence of priority of the nodes is mainly determined by the Index-Vector.

The Index-Vector for bus n is given by

$\text{Index}[n] = 1/V[n]*1/V[n] + | I_q[k] / I_p[k] | + \text{Qeff}[n] / \text{TotalQ} = Y1 + Y2 +Y3$

Where Index[n] =”Index” for n^{th} bus V[n] = Voltage at n^{th} bus

$I_q[k]$ = Imaginary component of current in k^{th} branch

$I_p[k]$ = Real component of current in k^{th} branch Qeff[n] = Effective reactive load at n^{th} bus

TotalQ = Total reactive load of the given Distribution system

Y1 = Stands for the amplification of voltage deviation from the normal value.

Y2= Indicates the amount of reactive current to be compensated

Y3= Speaks about the reactive load concentration when viewed from bus-n.

After formulating the Index Vector multiply the index value by the load reactive power at that bus to estimate the size of the capacitor to be placed. Thus, the potential location and size of the capacitor to be placed are obtained directly. Arrange the Index vector in descending order so that highest priority bus will come first and the lowest priority bus will come at end. Now place the capacitor at the first potential location and run the load flow and estimate the losses .Then assume capacitors at first two potential locations and perform load flow again evaluate the corresponding losses. It may be observed that the loss will reduce. Repeat this with estimated capacitors at first “n” busses till losses reduce to minimum and for the first (n+1) potential locations the loss start increasing Then the estimated capacitors at first n potential locations will give optimal location and size for the given radial distribution system.

C. *Algorithm*

1. Read the system data (Line Data, Bus Data, and Base Values).
2. Run the Load Flow using the vector based distribution flow algorithm and estimate the total real power losses (tploss) and reactive power losses (tqloss) in the system without capacitors (Base Case Load Flow).
3. Calculate the real and reactive component currents in each branch.
4. Calculate Index Vector using the equation

   Index[q] = (1/V[q])*(1/V[q]) +Iq[j]/Ip[j] +Qeff[q]/totalQ. for q=1 to n.
5. Multiply the index with reactive power load at the bus.

   Index[i]=Index[i]*qload[I] for i=1 to n.
6. Now arrange the Index Vector in descending order so that highest priority bus comes first and lowest priority bus come at end
7. k=1 //count for number of capacitors
8. Initialize the variables tploss[i] =0 tqloss[i] =0 for i=1 to n.
9. location=kl[i]

   tqload [location] =tqload [location]-Index[i] for i =1 to k

   where kl[i] indicates the buses in the order of highest priority corresponding to the index vector
10. Now run the load flow and estimate the loss in the system.
11. If loss after placing the capacitor is less than the total loss goto step 12

    Else goto step 14
12. k=k+1.
13. Repeat the steps from 8 to 12 until the loss gets increased.
14. Problem Converged .Print out the location and Size of capacitors and Voltages after compensation.

VI. CONVENTIONAL METHOD FOR OPTIMAL

In any radial distribution system, the optimal choice of the size of conductor in each branch of the system, which minimizes the sum of depreciation on capital investment and cost of energy losses, is important. The problem of choice of the optimal size of conductor for each feeder segment is presented as an optimization problem using branch wise minimization technique.

The use of a large number of conductors of different cross sections will result in increased cost of the inventory. A judicious choice can, however be made in the selection of number of size of conductor cross-section for considering the optimal design.

TABLE I

S. No	Conductor Name	Resistance/km (ohms/km)	Reactance/km (Rs/km)	Cost/km (Rs/km)	Imax (in Amps)
1	Squirrel	1.371	0.39	11695	107
2	Weasel	0.911	0.38	11695	139
3	Rabbit	0.514	0.37	17752	193
4	Ferret	0.73	0.36	11700	136

Table I: Electrical properties of various conductors used for 11kv distribution

A. *Objective Function*

The objective is to select optimal size of the conductor in each branch of the system, which minimizes the sum of depreciation on capital investment and cost of energy losses. In detail, the objective function for optimal selection of conductor for branch jj with k type conductor is

$$\text{Min } F(jj,k)= CL(jj,k) +CC(jj,k) \text{ ---- } 1$$

1. Cost of energy losses(CL): The annual cost for the loss in branch jj with k type conductor is,

$$CL_{(jj,\,k)} = \text{Peak loss}_{(jj,\,k)}\ [Kp+Ke*Lsf*8760]\ \text{----}\ 2$$

where Kp=annual demand cost of power loss (Rs/KW)
Ke=annual cost of energy loss (Rs/KWh), Lsf=loss factor
Peakloss = real power loss of branch jj under peak load conditions with k type conductor.

2. Depreciation on capital investment(CC): the annual capital cost for branch jj with k type conductor is,

$$CC_{(jj,K)} = \alpha * [\ cost_{(k)} * len_{(jj)}]\ \text{------}3$$

where α=interest and depreciation factor,
cost $_{(k)}$ =cost of k type conductor(Rs/KM)
len $_{(jj)}$=length of branch jj (KM).

The practical system data for annual cost of power and energy losses are given as follows.

Annual demand cost of power loss (Kp) =4000(Rs/KW)
Annual cost of energy loss (Ke) =2.9(Rs/KWh)
Loss factor (Lsf) =0.208 ,
Interest and depreciation factor. =0.1

B. Algorithm

1. Read the data.
    a. Read Branch data, Conductor data, and Load data.
    b. Read objective function constants (Kp, Ke, Lsf, alpha).
    c. Read Vmin ,Base Mva, Base KV.
2. Form idegree, itag, adjq, adjl vectors.
3. Calculate effective load at each bus starting from the last bus.
4. Set the conductor count 'k' =1.
5. Run the VDLF load flow method.
6. Calculate current and real power losses under peak load condition of branch jj with k type conductor.
7. Calculate the objective function of branch jj with k type conductor.
8. Repeat the procedure from step no 5 for all conductors.
9. Arrange the objective function values of the n different types of conductors for all branches in ascending order.
10. Set the branch count 'jj' =1.
11. Select minimum cost type of conductor for branch jj.
12. Check for voltage & current constraints i.e.
    $V_{(m2,\,k)}$>Vmin for m_2=2, 3……..n
    $I_{(jj,\,k)}$<Imax(k) for jj=1,2………nline

If satisfied, print the result of optimal type of conductor for branch jj. else go to step no 11.

13. Repeat the procedure from step no 11 for all branches.
14. Run the load flow for optimally selected conductors.
15. Print the voltages, total real power losses, reactive power losses& the sum of the total cost of conductor and energy losses per year.

VII. GENETIC ALGORITHMS

A GA is an algorithm with some of the principles of genetics included in it. The genetic principles "Natural Selection" and "Evolution Theory" are main guiding principles in the implementation of GA. The GA combines the adaptive nature of the natural genetics and search is carried out through randomized information exchange.

Genetic Algorithms surpass all the above limitations of conventional algorithms by using the basic building blocks that are different from those of conventional algorithms. It is different from them in the following aspects.

1. GA works with a coding of the parameter set, and not the parameters themselves.
2. GA searches from a population of point and not from a single point like conventional algorithms.
3. GA uses objective function information, not derivative or other auxiliary data.

A. Phases of a Genetic Algorithm

Simplicity of operation and power of effect are two main attractions of the GA approach. It typically consists of three phases.

1. Initialization 2.Evaluation 3.Genetic Operation

B. Implementation of Genetic Algorithm for Optimal Capacitor placement

As the optimal capacitor placement problem is a non-linear optimization problem genetic algorithms are most suitable for such a problem. The potential locations for capacitor placement problem are identified by Index Vector method. The design variables for capacitor placement problem are the size of the capacitors to be placed at potential locations. Population size of 30 and string size of 20 are used. The different steps for implementation of genetic algorithms are described below.

C. Initialization of Population

The population is initialized with 1's and 0's randomly, so that they can have wide search space.

```
for (i=1; i<=PS; i++)
{
for (j=1; j<=LS; j++)
opn[i][j]=(rand()<RAND_MAX/3)?0:1;
}
```

Where
PS=population size=30 LS= string length=20
opn[i][j]=arrays of population initialized to 1's and 0's

D. Decoding of Population

The resolution of the solution depends upon how many bits are used to represent the capacitor size. In this work, string size is taken as 20.This string is divided into parts equal to number of capacitors to be placed at potential locations. Each part of the string length represents the size of capacitor to be placed at each potential location.

LS= Total String Length LS1+LS2+LS3

D1	D2	D3	D4	………………	D18	D19	D20

$\longleftarrow$ LS $\longrightarrow$

D1	D2	D3	D4	D5	D6	D7	D8
x 2^{-1}	x 2^{-2}	x 2^{-3}	x 2^{-4}	x 2^{-5}	x 2^{-6}	x 2^{-7}	x 2^{-8}

LS 1

Where D_i ε (0,1) I = 1,2,3 ….. LS 1

D9	D10	D11	D12	D13	D14
x 2^{-1}	x 2^{-2}	x 2^{-3}	x 2^{-4}	x 2^{-5}	x 2^{-6}

LS 2

Where D_i ε (0,1) I = 1,2,3 ….. LS 2

D15	D16	D17	D18	D19	D20
x 2^{-1}	x 2^{-2}	x 2^{-3}	x 2^{-4}	x 2^{-5}	x 2^{-6}

LS 3

Where D_i ε (0,1) I = 1,2,3 ….. LS 3

The implementation of decoding is given below.

```
Initialize dec1[i]=0,dec2[i]=0,dec2[i]=0 for i=1 to PS
dec1[i] = dec1[i]+(opn[i][j]*pow(2,-j)) for j=1 to LS1
dec2[i] = dec2[i]+(opn[i][j]*pow(2,-j)) for j= 1 to LS2
dec3[i] =dec3[i]+(opn[i][j]*pow(2,-j)) for j=1 to LS3
qcap1 [i] =capmin+ (capmax-capmin)*dec1 [i]
qcap2 [i] =capmin+ (capmax-capmin)*dec2[i]
qcap3 [i] =capmin+ (capmax-capmin)*dec3 [i]
for i= 1 to PS
```

dec1 [i], dec2 [i], dec3 [i] -- decoded values of each capacitor

qcap1 [i], qcap2 [i], qcap3 [i] - Actual values of each capacitor

E. Evaluation of Fitness Function

In case of optimization problems the fitness is the value of the objective function to be optimized. GA's are basically unconstrained search procedures in the given problem domain. Any constraints associated with the problem could be incorporated into the objective function as a penalty functions. The capacitor placement problem is an optimization problem. The objective function is to minimize the losses in the system and to maintain the desired voltage profile. So the Fitness function is taken as

$Fit[i] = k_1/(k_2+k_3*tqloss/totalQ)$ for i=1 to PS

Where k_1, k_2, k_3 are constants and must be selected suitably

tqloss =total reactive power loss in the system.

totalQ=total reactive load in the system.

F. Algorithm

1. Read the System data.
    a. Read Line Data.
    b. Read Bus Data.
    c. Read Genetic operator values (population size, string length, Pm, Pe, Pc.)
    d. Read Base values.

2 Form idegree, itag, adjq, adjl vectors.

3. Calculate effective load at each bus starting from the last bus.

4. Run the vector based conventional load flow method and find out real and reactive power losses.

5. Run the proposed conventional method for optimal capacitor placements and identify the potential locations.

6. Initialize the population randomly.

7. Divide the string into parts equal to number of capacitors to be placed.

8. Set the iteration count to 1.

9. Set the chromosome count to 1.

10. Decode the chromosomes of the population for each capacitor and find out capacitor sizes in the normalized form.

11. Taking the effect of the capacitors, run the load flow and estimate losses in the system.

12. Evaluate the fitness function. fit[l] =k1/(k2+k3*ql/totalQ),where l=chromosome count

13. Repeat the steps from 10 until the chromosome count is greater than population size.
14. Sort out the chromosomes and all their related data in descending order of fitness.
15. Calculate the error (fit [1]-fit [PS]).
16. Check whether error is less than 0.0001, check for voltage constraints, if satisfied go to 21.
17. Now perform elitism i.e. copying 20% of old population into new population starting from the best ones from top.
18. Now perform crossover and mutation for generating remaining chromosomes.

19. Now replace the old population with the new population

20. Increment the iteration count and check whether iter<itermax, if yes goto 9 else goto 22.

21. Print the message "Problem is converged", print out locations and sizes of capacitors, converged voltages and real and reactive power losses.

22. Print the message "Problem not converged in given itermax iterations."

VIII. CASE STUDIES

A. Optimal capacitor placement

Test System : No. of Nodes: 22 No. of Sections: 21

Table 2: System Data of the feeder

Line No	From Bus	To Bus	Resistance (ohm)	Reactance (ohm)
1	1	2	0.3664	0.1807
2	2	3	0.0547	0.0282
3	2	4	05416	0.2789
4	4	5	0.193	0.099
5	4	9	0.7431	0.3827
6	5	6	1.3110	0.6752
7	6	7	0.0598	0.0308
8	6	8	0.2905	0.1496

Table 3: Load Data of the feeder

Bus No	Real Power (Kw)	Reactive Power (Kvar)
1	0	0
2	16.78	20.91
3	16.78	20.91
4	33.80	37.32
5	14.56	12.52
6	19.31	25.87

7	10.49	14.21
8	8.821	11.66
9	14.35	18.59

B. Base Case Load Flow

Program Converged in 3 iterations.
Total Loss before placement of capacitors
Real Power Loss in Kw=15.5045
Reactive Power Loss in Kvar=7.988

Table 4: Converged Voltages and Phase angles

Bus No	Voltage p.u.	Phase Angle (degrees)
1	0.99926	0
2	0.99925	-0.06793
3	0.99495	-0.0581
4	0.99481	-0.0664
5	0.9941	-0.06633
6	0.99409	-0.06592
7	0.99406	-0.06591
8	0.98988	-0.0659
9	0.98987	-0.06469

C. Genetic and cost Data

Population size: 30 String Length: 20
Probability of Elitism: 0.2 Probability of Mutation: 0.01
The Annual Cost of Power Loss in Rs/Kw (Kp) =4000
The Annual Cost of Energy Loss in Rs/Kwh (Ke) =2.9
The Load Factor (Lf) =0.75
The Interest and Depreciation Factor =0.1

Table 5: Comparison of voltages without compensation and with compensation by Index -Vector method and Genetic Algorithm

Bus No	Voltage p.u. without compensation	Index-Vector method	Genetic Algorithm
		Voltage p.u. with compensation	Voltage p.u. with compensation
1	1	1	1
2	0.99926	0.99941	0.99954
3	0.99925	0.99939	0.99952
4	0.99495	0.99597	0.99711
5	0.99481	0.99583	0.99645
6	0.9941	0.99512	0.99634
7	0.99409	0.99511	0.99632
8	0.99406	0.99509	0.99627

Table 6: Comparison of real and reactive power loss before and after placement of capacitors and Energy cost savings between Index-Vector method and Genetic Algorithm

Loss	Total loss before placement of capacitors	Index-Vector method	Genetic Algorithm
		Total loss after placement of capacitors	Total loss after placement of capacitors
Real Power loss (Kw)	15.50415	9.58329	8.784
Reactive Power loss (Kvar)	7.98806	4.93739	4.562
Total real power loss reduction (Kw)		5.92086	6.72015
Total reactance power loss reduction (Kvar)		3.05067	3.42606
Energy cost savings (Rs)		53,777	55,468

Table 7: Comparison of Location and size of capacitors by Index-Vector method and Genetic Algorithm

Bus No	Index-Vector method	Genetic Algorithm
	Capacitor rating (KVAR)	Capacitor rating (KVAR)
13	128.53	199.805
16	112.41	199.609
4	76.0702	198.437

D. Optimal conductor selection

Test System:

Table 8: System Data of the feeder

Line No	From Bus	To Bus	Line length (KM)
1	1	2	0.502
2	2	3	0.075
3	2	4	0.074
4	4	5	0.265
5	4	9	1.796
6	5	6	0.398
7	6	7	0.082
8	6	8	1.018

Table 9: Electrical characteristics of 11kv Conductors

S. No	Conductor Name	Resistance/km (ohms/km)	Reactance/km (Rs/km)	Cost/km (Rs/km)	Imax (in Amps)
1	Squirrel	1.371	0.39	11695	107
2	Weasel	0.911	0.38	11695	139
3	Rabbit	0.514	0.37	17752	193
4	Dog	0.274	0.35	33576	300
5	Ferret	0.73	0.376	11700	136

Table 10: Load data of the feeder

Bus No	Real Power (Kw)	Reactive Power (Kvar)
1	0	0

2	16.78	20.91
3	16.78	20.91
4	33.80	37.32
5	14.56	12.52
6	19.31	25.87
7	10.49	14.21
8	8.821	11.66
9	14.35	18.59

E. Genetic and Cost Data

Elitism probability=0.15 Mutation probability=0.001
The Annual Cost of Power Loss in Rs/Kw (Kp) =4000
The Annual Cost of Energy Loss in Rs/Kwh (Ke) =2.9
The Loss Load Factor (Lsf) =0.208
The Interest and Depreciation Factor (Alpha) =0.1

Table 11: Comparison of voltages between Conventional method and Genetic Algorithm

Bus No	Voltage (pu)	
	Conventional method	Genetic Algorithm
1	1	1
2	0.9969	0.99754
3	0.99689	0.99753
4	0.99647	0.99704
5	0.99633	0.99692
6	0.99618	0.99674
7	0.99617	0.99674
8	0.99607	0.99667
9	0.98751	0.98995

Table 12: Comparison of real and reactive power loss between Conventional method and Genetic Algorithm

Loss	Conventional method	Genetic Algorithm
	With conductors selected	With conductors selected
Real power loss (Kw)	17.133	12.297
Reactive power loss (Kvar)	8.8823	8.609
Total cost (Rs)	12993.97	11665.311

Table 13: Comparison of best conductor for each line between Conventional method and Genetic Algorithm

Line No	Conventional method	Genetic Algorithm
	Conductors selected	Conductors selected
1	Ferret	Rabbit
2	Weasel	Rabbit
3	Ferret	Rabbit
4	Ferret	Weasel
5	Ferret	Weasel
6	Ferret	Ferret
7	Weasel	Ferret
8	Weasel	Weasel
9	Weasel	Weasel

IX. CONCLUSIONS

In this paper, a simple and efficient method for minimizing the losses associated with the reactive component of branch currents, by placing capacitors in radial distribution systems has been proposed. The method first finds the sequence of nodes to be compensated by formulating the Index Vector. These nodes are very small in number when compared to the total number of load nodes. In formulating Index Vector, bus voltage, and ratio of reactive current to active current and reactive power concentration of that node are considered. The proposed method also gives the size and the number of capacitors to be placed. As capacitor placement is non linear optimization problem Genetic Algorithms are proposed for selecting the optimal size of the capacitors.

Further, Genetic Algorithms are proposed for selecting the optimal size of conductors for radial distribution networks. The algorithm presented meets better feeder voltage support while recognizing feeder loading requirements. In addition, it will give maximum saving in capital cost of conductor and cost of energy loss in radial distribution system. The solution method provides a new global optimum solution to the above problems.

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