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LOSS REDUCTION IN RADIAL DISTRIBUTION SYSTEM BY OPTIMAL PLACEMENT OF CAPACITOR USING DIFFERENTIAL EVOLUTION METHOD

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ABSTRACT: Distribution system plays an important role in supplying the electricity from generation to the consumers via transmission system. The power system is one of the most complex systems in the world. Because of the high R/X value the losses in the distribution system is more. The one of the roles of capacitor is reducing the losses in the distribution system. This paper presents an improved method for capacitor placement with optimum size in radial distribution feeders to reduce the real power loss and to improve the voltage profile. In this paper, the total work is mainly divided in to three sections. In the first section load flow of the system. In the section –II location and size of the capacitors is determined by using Differential Evolution and In the section-III the results are compared with existing method which is proposed by D.Das.

Keywords: Element Incidence matrix, radial distribution power flow, linear recursive equations, transmission loss, Differential Evolution.

Notations:

N-no of buses
Nb –total number branches in a system
Np- size of the population
G – Number of generations.
lm-Element between bus l and bus m
I_{lm}-Branch current flowing through lm
I_m-Bus current of bus m
V_m-Bus voltage of bus m
S_{lm}-Complex power flowing from bus l and bus m
S_m-Specified Bus power at bus m
Z_{lm}-Impedance of element between bus l and bus m
TL_{lm}-Transmission loss of element lm
χ- Element Incidence Matrix
β- New Variable

1. INTRODUCTION

Electric power has become a fundamental part of the infrastructure of contemporary society, with most of today's daily activity based on the assumption that the desired electric power is readily available. Each component is essential to the process of delivering power from the site where it is produced to the customer who uses itOne of the most fundamental calculations related to any system is the determination of the steady state behavior. In power systems, this calculation is the steady state *power flow* problem, also called *load flow*. It is essentially involves finding the steady state voltages at each node, given a certain set of generation and loading conditions.

Capacitors are generally used for reactive power compensation in distribution systems. The purpose of capacitors is to minimize the power and energy losses and to maintain better voltage regulation for load buses and to improve system security. The amount of reparation provided with the capacitors that are placed in the dissemination network depends upon the stance, range and type of the capacitors placed in the system [1]. A lot of research has been made on the location of capacitors in the latest past [2,3]. All the methods are differing with one another by their path of solving the problem. In some approaches the objective function painstaking was for organize voltage. A few proposals were planned for determining the optimal design and control of switched capacitors with non-simultaneous switching [4]. It is also very important to consider the problem resolution methods employed to solve the capacitor placement problem, such as gradient search optimization, local variation method, optimization of equal area criteria method for fixed capacitors and dynamic programs [5-7]. A differential evolution algorithm (DEA) is an evolutionary computation method that was originally introduced by Storn and Price in 1995 [16]. DEA uses quite gluttonous selection and less stochastic approach to solve optimization problems than other classical EAs. Number of Advantages and uses of DE is explained in one of the proposals [19]. The majority of the early researches used the Differential Evolution which is originally proposed by Storn and Price [17, 19, 20, 21]. The system 12.66kV, 100 MVA 69-bus radial distributions feeder is taken as case study. The time varying loads is assumed with 0.5, 1.0, 1.6 pu.

2. DISTRIBUTION POWER FLOW

Distribution power flow is used to determine steady state bus powers, bus voltages and losses of the system. In the earlier methods of load flow studies only PQ buses are considered and flat voltage profile of all buses is assumed at the starting of the load flow. On this paper a new approach is used for the load flow to determine the steady state voltages and powers of each bus without flat voltage profile. If the system consists of PV buses the same load flow is used by modifying certain equations.

As we know the equation for complex power

$$S = VI^* \quad (1)$$

According to ohms law

$$I=VY \quad (2)$$

$$S = (V)V^*Y^* \quad (3)$$

If lm is the branch element in the RDS then Eqn(3) is represented as follows

$S_{lm} = V_l(V_l^* - V_m^*)Y_{lm}^*$ (4)

The term $V_l(V_l^* - V_m^*)$ is taken as new variable and represented as β. So the equation for β is represented as

$\beta = V_l(V_l^* - V_m^*)$ (5)

The load flow is summarized as follows

FOR LOAD BUSES

1. Assume the Transmission losses are zero.
2. From the specified bus powers the branch powers are determined as per Eqns1and2.

$I_{branch} = \chi^{-1} I_{bus}$ (6)

$S_{bus} = \chi[S_{branch}^{sending} - TL_{branch}]$ (7)

The size of the element incidence matrix is "Nb X Nb." It is constructed by using the following procedure.

a) The diagonal elements of the matrix is always '1'

b) If any branch element is connected at the receiving end of the preceding branch element then the value which relates the two branch elements is '-1'

c) Otherwise the value of the matrix element is '0'

3. The variable β_{lm} is calculated foe every element by using the Eqn (8)

$S_{lm} = P_{lm} + Q_{lm} = \beta_{lm} Y_{lm}^*$ (8)

4. The bus voltages, branch currents and branch voltages are calculated by using χ_{lm}

$V_m = V_l - \frac{x_{lm}^*}{V_l^*}$ (9)

$I_{lm} = \frac{x_{lm}^*}{V_l^*} Y_{lm}$ (10)

5. The bus currents are calculated by using Eqn (1)

As the transmission losses are ignored for the first iteration and the disparity between the specified powers and calculated powers which is a part of the transmission loss .TL_{lm}^r is the transmission loss part for 'lm^{th}' element for 'r^{th}' iteration.

$TL_{lm}^r = S_m^{spec} - V_m^{r-1}.I_m^{r-1}$ (11)

$S_{branch}^{receiving} = S_{branch}^{sending} - TL_{loss}$ (12)

$TL_{lm} = \sum_{lm=1}^{nb} TL_{lm}$ (13)

Where 'r' is the iteration count

The criteria is continuing up to this load flow meeting of the convergence which is the tolerance of 0.0001

HANDLING TO THE VOLTAGE CONTROLLED BUSES :

When the power is supplied at multiple ends of the system, other supplying buses except slack bus are treated as voltage controlled buses. The equation is as follows

Equation (5) is modified for the mth voltage controlled bus

$real(S_{lm}) = P_{lm} = real(\beta_{lm} Y_{lm}^*)$ (14)

$\beta_{lm} = X_{lm} + iY_{lm}$ (15)

Where

X_{lm} is the real value of the β_{lm}

Y_{lm} is the imaginary value of the β_{lm}

$P_{lm} = real((X_{lm} + iY_{lm})(G_{lm} + iB_{lm}))$ (16)

$\frac{G_{lm}|V_l^2| - P_{lm}}{|Vl||Vm|} = G_{lm}\cos(\phi_{lm}) - B_{lm}\sin(\phi_{lm})$ (17)

The trigonometric equation is to be solved to get the phase angle ϕ each PV bus m and the reactive power can be updated as

$Q_{lm} = B_{lm}(|V_l^2| - |V_l||V_m|\cos(\phi_{lm})) - G_{lm}|V_l||V_m|\sin(\phi_{lm})$ (18)

The similar method which is explained for the load buses is conceded out till the convergence.

3. DIFFERENTIAL EVOLUTION

Differential evolution is a very simple but very powerful stochastic global optimizer. Since its inception, it has proved to be a very efficient and robust technique for function optimization and has been used to solve problems in many scientific and engineering fields

The DE method which is proposed in [] is not applied for the power system problems. But in some papers which is proposed by D.Das, is used fuzzy for optimal location and size of the capacitor is determined by using Genetic Algorithm. Although Genetic algorithm gives better solution but the time taken to full of the population with the total generations is more when compared with the other optimized equations. In some other placement of the optimal capacitor is determined y using Fuzzy only but the sizre of the capacitor is determined by Differential Evolution. In this paper the optimal capacitor location and size is determined by using Differential evolution. An optimization task consisting of DE parameters can be represented by a D-dimensional vector. In DE, a population of NP solution vectors is randomly created at the start. This population is successfully improved by applying mutation, crossover and selection operators. The main steps of the DE is given below

1. Mutation
2. Crossover
3. Selection

Mutation: Differential mutation is the key to the success of differential evolution. For each target vector Xi,G , a mutant vector $V_{i,G+1}$ is generated according to the equation (17)

$V_{i,G+1} = X_{best,G} + F(X_{r1,G} - X_{r2,G})$ (19)

Where r1≠r2with randomly chosen integer indexes r_1, r_2, r_3 ,……={1,2,3,…… NP}.

F is called Mutation factor and its value is typically $0 \le F \le 1.2$. By using the Eqn (19) the target vectors which have size of "Np X D" are initialized with random numbers which represents the bus numbers for optimal location criteria and other target vectors are initialized with representation of size of the capacitors at the optimal locations. Finally the mutant vector is extracted from the target vectors by using one of the strategies which is mentioned in the table 1. The mutant vector also consists the elements which relates to bus numbers for optimal location and for size of the capacitor for optimal size for that location

The equation is one of the strategies of differential evolution. The other forms of the strategies is shown in the following table 1

Table 1. The mutation mechanism of DE

Mechanism	***Mathematical Equation***
Best/1/exp	$V_{i,G+1} = x_{best,G} + F(x_{r1,G} - x_{r2,G})$
Rand/1/exp	$V_{i,G+1} = x_{r3,G} + F(x_{r1,G} - x_{r2,G})$
Rand-to-Best	$V_{i,G+1} = x_{i,G} + F(x_{r1,G} - x_{r2,G})$
Best/2/exp	$V_{i,G+1} = x_{best,G} + F(x_{r1,G} + x_{r2,G} - x_{r3,G} - x_{r4,G})$
Rand/2/exp	$V_{i,G+1} = x_{r5,G} + F(x_{r1,G} + x_{r2,G} - x_{r3,G} - x_{r4,G})$

Crossover: Crossover probability is more like a fine-tuning element. In this operator, the trail vector $u_{i,G+1}$ is extracted by taking some parts of mutation vector $v_{i,G+1}$ and other parts are taken from the target vector $x_{i,G}$. The crossover operator of DE is shown in figure.1

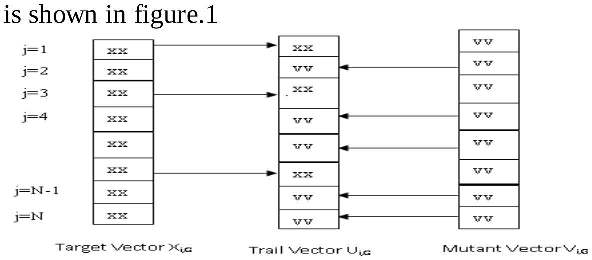

Figure 1: Crossover mechanism in DE

Selection operator:

The completion of the mutation and crossover operation leads to enter to the selection criteria of the random number with the desired function. The trail vectors are evolved after the completion of mutation and crossover operation .The values for the next generation will generated ,after comparing the trail vector $u_{i,G+1}$ with the individual vector,$x_{i,G}$.The selection operator is listed in the following description

$$x_{i,G+1} = u_{i,G+1}, if\ f(u_{i,G+1}) > f(x_{i,G})$$

$$x_{i,G+1} = x_{i,G}, if\ f(u_{i,G+1}) \le f(x_{i,G}), \quad i=1,2,3,4........Np \quad (20)$$

The above equation reveals that ,if the value of the function of trail vector is less than or equal the value of the function of the individual vector then same trial value is proceed for the next generation ,if not the trial vector is taken as the next generation of the individual vector.

COST FUNCTION:

Min S = $K_E \sum_{i=1}^{L} T_i P_i + \sum_{k=1}^{ncap} K_c Q_c$ (21)

Where

S is the cost of losses in $/year

K_E is the factor to convert energy losses to Rupees

L is the load level

T_i is the time duration for i^{th} load level

P_i is the power loss at Load level i

ncap number of capacitors

K_c is cost of capacitor RS /kVAR

Q_c is the size of the capacitor in kVAR

Algorithm for the optimal location and size of the capacitor by using DE:

1. Initialize the population and generations for placement and size of the capacitor
2. By using the equations (17) and(18), realize the placement variable value for one dimension
3. By using the equation (17),(18) and (19) realize the size of the capacitor for one dimension value
4. Repeat step (2) for two dimension variable
5. Repeat step (3) for two dimension placement variable.
6. Compare the cost function value for preceding and succeeding dimension variables.
7. If the succeeding dimension cost function value is less than the preceding dimension cost function values take the final value as succeeding dimension. Otherwise take preceding dimension
8. Halt the criteria

ALGORITHM FOR PROPOSED METHOD

1.Take the slack bus voltage as 1.0 pu and run the load flow as mentioned in the section 1

2. The bus voltages, bus powers and system losses are determined.

3. The value of the cost function is determined by using Eqn (19) without capacitor placement

4. The system losses and bus voltages are determined after capacitor placed at suitable location by using DE.

5. Calculate the cost function value after placement of capacitor

4. RESULTS AND CONCLUSIONS

In order to test the proposed method, 69 bus system has taken. Table 2 specifies the load levels and load duration time data for the given system. Table 3 specifies the minimum per-unit bus voltage, cost of energy losses during all load levels a with and without capacitor placement.

Table 3 shows the capacitor placement locations and size of capacitor for each load level. Table 5 shows the system conditions when capacitor placement is implemented as per the optimal solution.

The DE parameters for the system are taken as follows G_{max}=800

F =0.8

CR = 0.8

NP = 100

The Table 5 gives variation of DE method with Fuzzy-GA method. The total savings of the Fuzzy-GA method are Rs.16, 98,345 where as the savings of DE method are Rs.21, 41,095. So it is concluded that proposed method gives more savings than Fuzzy-GA

Table 2 Load level and Load duration time

Time	0.5	1.0	1.6
Duration(hrs)	2000	5260	1500

Table 3 Comparison of he results without and with capacitors placement for IEEE 69 Bus System

	Without Capacitor	With capacitor (Proposed Method)	With capacitor Fuzzy-GA
Total cost losses(Rs/year)	74,74,775	50,42,950	52,64,985
Total KVAR required	0	1800	3100
Total cost(Rs/year)	74,74,775	53,33,625	5776485
Total Annual savings (Rs/year)	--	21,41,150	16,98,290

Table 4: Optimal capacitor placement location and size

optimal location	Control setting (KVAR)			Optimal size
	0.5(Light)	1.0(medium)	1.6(peak)	
61	300	1200	1760	1800

Table 5 System Conditions With and without Capacitor

Load level	Min vol/real power losses	Without capacitor	With capacitor using Proposed method	With capacitor using Fuzzy-GA method
0.5 (Light)	Min vol(pu)	0.9567	0.9809	0.9622
	P_{loss} (KW)	51.6	39.76	40.48
1.0 (Medium)	Min vol(pu)	0.9093	0.9364	0.9369
	P_{loss} (KW)	225	157.6	156.6
1.6 (Peak)	Min vol(pu)	0.844	0.8769	0.9001
	P_{loss} (KW)	652.5	432.9	460.45

REFERENCES

[1] Sundharajan s, Pahwa A. Optimal selection of capacitors for radial distribution systems using Genetic Algorithm. IEEE Trans Power Systems 1994; (August): 1499-507.

[2] Miller, T.J.E, Reactive Power Control in Electric System, New York, John Wiley & Sons Inc1982.

[3] Barn, M.E. and WU, F.F, Optimal Capacitor Placement on Radial Distribution System, IEEE Transaction on Power Delivery, 4(1), 1989, 725-734.

[4] Chen, C.S. Shu, C.T and Yan Y.H, Optimal Distribution Feeder Capacitor Placement Considering Mutual Coupling Effect of Conductors, IEEE Transactions on Power Delivery, 10(2), 1995, 987-994

[5] R.Hooshmand and M.Joorabian, Optimal Choice of Fixed and Switched Capacitors for Distribution Systems by Genetic Algorithm, Proceedings of Australian Universities Power Engineering Conference (AUPEC'02), Melbourne, Australia,2002.

[6] L.Furong, J.Pilgrim, C.Dabeedin, A.Cheebo and R.Aggarwal, Genetic Algorithms for Optimal Reactive Power Compensation on the National Grid System, IEEE Transactions on Power Systems, 20(1), 2005, 493-500.

[7] Robert S.Agniar, Paolo Cuervo, Capacitor Placement in Radial Distribution Network through a Linear Deterministic Optimization Model. Electricity Engineering Department, University of Brasilia, Brazil.

[8] A.Charette, J.Xu, A.Ba-Razzouk, P.Pillay, V.Rajagopalan, The Use of the Genetic Algorithm for insitu Efficiency Measurement of an Induction Motor, IEEE Power Engineering Society Winter Meeting, 1(1), 2000, 392-397.

[9] Z.Y Dong, D.J.HILLAND, V.Y.MAKAROV, Power System VAR Planning with Genetic Algorithm, Technical Report: EE-98015, Department Of Electrical Engineering, University of Sydney, Australia, 1998.[10] Electrical Transient Analyzer Program (ETAP)

[10] www.etap.com
[11] D.DAS, Optimal placement of capacitors in radial distribution system using a Fuzzy-GA method, International journal of Electrical power and Energy systems, 2008.
[12] Turan Gonen, Electric Power Distribution System Engineering, McGraw-Hill,1986.
[13] RM Saloman Danaraj, "An algorithm for radial distribution power flow in complex mode including voltage controlled buses", Indian Journal of Science and Technology, Vol. 1, No. 2, Dec. 2007.
[15] Particle swarm optimization based capacitor placement on radial distribution systems, K.Prakash and M.Sydulu, Power Engineering Society General Meeting, 2007. IEEE.
[16] R. Storn and K. Price, "Differential evolution: a simple and efficient adaptive scheme for global optimization over continuous spaces," *Technical Report,*International Computer Science Institute, Berkley, 1995.
[17] K. V. Price, R. M. Storn and J. A. Lampinen, *Differential evolution*: *a practical approach to global optimization*, Springer, 2005.
[18] K. V. Price, "An introduction to differential evolution in *New ideas in optimization*, D. Corne, M. Dorigo and F. Glover, Ed., McGraw-Hill, 1999.
[19] R. Storn and K. Price, "Differential evolution: a simple and efficient heuristic for global optimization over continuous spaces," *Journal of Global Optimization*, Kluwer Academic Publishers, vol. 11, pp. 341-359,1997
[20] K. Price and R. Storn, "Differential evolution: a simple Evolution strategy for fast optimization," *Dr. Dobb's Journal*, vol. 264, pp. 18-24, Apr. 1997.
[21] R. Storn, "On the usage of differential evolution for function optimization," in *Proc. the 1996 Biennial Conference of the North American Fuzzy Information* 135 *Processing Society*, (*NAFIPS 1996*), pp. 519 – 523,
19th- 22nd Jun. 1996.