Genetic Algorithm based Conductor Selection for Maximum Loading

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Abstract-*In this paper genetic algorithm based conductor selection is proposed for enhancement of maximum loading of radial distribution systems. The enhancement is done by the optimal conductor selection of radial distribution system. The effect of load models on the enhancement of maximum loading is also investigated. The load growth period is also considered in the investigation. With the proposed method optimal set of conductors are selected by maintaining acceptable voltage limits and current carrying capacity of the feeders. The effectiveness of the proposed method is illustrated with 32-node practical radial distribution system.*

Keywords-Genetic algorithm, Conductor selection, Maximum loading, Distribution system, Load flow

1.INTRODUCTION

The power losses in distribution systems are significantly high because of lower voltages and higher currents compared to high voltage transmission system. If a conductor is loaded near to its thermal rating, losses will be increased. Hence, line conductors are loaded under their thermal limit. Reduction of total loss in distribution systems is very essential to improve the overall efficiency of power delivery. The pressure of improving the overall efficiency of power delivery has forced the power utilities to reduce the loss, especially at distribution level.

It is important to select proper size of conductor of distribution system because it increases the loading of the system. In [1] an algorithm is proposed for selecting the optimal size of conductor of feeder segments of radial distribution networks based on analytical approach. The approach discussed by Wang *et al.* [2] included an economical current density based method and a heuristic method, which together enabled a satisfactory solution that could be easily achieved. Miu and Chiang [3] proposed a solution algorithm to determine distribution loading capability. A solution algorithm suitable for large-scale unbalanced distribution networks with capacitor control actions was developed and tested. However, their model was suitable only for constant current load and for radial main feeder only. Das [4] presented a simple algorithm for determining the maximum loading of the feeders without violating the maximum current capacity of branch conductor. A predetermined annual load growth was also considered to determine allowable load growth period without violating the minimum voltage limit of the feeder. A dynamic model for the development of primary and secondary circuits supplying a residential area had been proposed by Kirn and Adler [5]. S.Ghosh et al [6] presented an analytical method for enhancement of loading of radial distribution system. S.Sivanagaraju et al[7] presented a heuristic method for improving the maximum loading by optimal conductor selection of radial distribution systems. In this analysis is also did for load modeling. But the practical load modeling is not considered.

In this paper a method is proposed for enhancing the maximum loading of radial distribution system using genetic algorithm. The effect of load models on conductor selection of radial distribution system is also investigated.

2. OPTIMAL BRANCH CONDUCTOR SELECTION

The problem of choice of the optimal type of conductor for each feeder segment is presented as an optimization problem using branch wise minimization technique. The detailed algorithm of the technique is given in [8]. Nevertheless, the salient features of the algorithm are explained in this section.

2.1Objective function

The objective function for optimal selection of conductor for branch j with k type conductor is

Minimize F (j, k) = CL (j, k) +CC (j, k) (1)

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

ii) $CL(j, k) = \text{Peak Loss}(j, k) \times Ke \times Lsf \times 8760$ (2)

Where

Ke = annual cost of energy loss (Rs/KWh)

Lsf = loss factor

Peak Loss (j, k) = real power loss of branch j under peak load conditions with k type conductor.

ii) Depreciation on capital investment (CC): the annual capital cost for branch j with k type conductor is,

$$CC(j,k) = \alpha \times \cos t(k) \times len(j) \quad (3)$$

Where

α = interest and depreciation factor

Cost (k) = cost of k type conductor (Rs/km)

Len (j) = length of branch j (km)

The loss factor is expressed in terms of the load factor as

$$Lsf = 0.2\,Lf + 0.8\,Lf^2 \quad (4)$$

1)Constraint equations

i) Feeder voltage: the feeder voltage at every node in the feeder must be above the acceptable voltage level, i.e.
$V(m_2, k) > V_{min}$ for m2=2, 3, ---nn (5)

ii) Maximum current carrying capacity: current flowing through branch j with k type conductor should be less than the maximum current carrying capacity of k type conductor, I_{max} (k), i.e.
$|I(j, k)| < I_{max}(k)$ for all branches j=1, 2, -- nb. (6)

2)Algorithm for Optimal Type of Conductor Selection

The detailed algorithm to determine optimal size of the conductor is given below

Step 1: Read the system data
Step 2: Perform load flow
Step 3: Initialize population.
Step 4: Set the iteration count to '1'.
Step 5: Calculate the objective function using eqn. (1).
Step 6: Calculate the fitness value using $f = \frac{1}{1+F(j,k)}$
Step 7: Sort data in the ascending order of fitness.
Step 8: Now copy the best string of chromosomes of old population to new population.
Step 9: Now perform crossover and mutation operations respectively for generating remaining chromosomes.
Step 10: Now, replace old population with new population.
Step 11: Increment iteration count. If iteration count <max. count, go to Step 4. Else go to Step12.
Step 12: Print the total real power loss, reactive power loss, and voltages.

3. OVERLOADING

The derivation of the loading factor is explained in [7]. However, some important points are explained in this section. After performing load flows, I_j for j=1,2,---nb must be computed. After that a loading factor $\Delta\delta_j$ must be computed using $\Delta\delta_j = \frac{CC_j - |I_j|}{|I_j|}$. The minimum of all the values of $\Delta\delta_j$ must be selected.

$$\Delta\delta_{min(l)} = \min[\Delta\delta_j] \quad (7)$$

Update the values of loading factor $\Delta\delta = \Delta\delta + \Delta\delta_{min(l)}$

The real and reactive power loads of all the nodes beyond the branch l must be increased by a factor $\Delta\delta_{min(l)}$ and the rest of the loads remain unchanged.

$$\begin{aligned} P_m &= (1+\Delta\delta)P_{om} \\ Q_m &= (1+\Delta\delta)Q_{om} \end{aligned} \quad (8)$$

4. LOAD MODELING

To calculate the effectiveness of various load models on loading of conductor practical voltage dependent load models are considered. Practical voltage dependent load models i.e., residential, industrial and commercial given in [9] have been adopted for investigation. The load models mathematically expressed as

$$P_L = P_{LO}|V_{m2}|^{K1} \quad (9)$$

$$Q_L = Q_{LO}|V_{m2}|^{K2} \quad (10)$$

Where P_{LO}, Q_{LO} are the active and reactive load powers respectively, at the nominal voltage of 1.0 p.u. and $|V_{m2}|$ is the actual voltage magnitude of node m_2 in p.u. In a constant power load model, conventionally used in power flow studies k1=k2=0. The values of the real and reactive exponents used in the present work for residential, industrial and commercial loads are given in table.1[9]

Table-1: Load types and exponent values

Load type	K1	K2
Constant power	0	0
Residential	0.92	4.04
Industrial	0.18	6.00
Commercial	1.51	3.40

5. LOAD GROWTH

The growth in feeder load may be due to addition of new loads to the feeder or due to the incremental addition to the existing loads. Once, the load exceeds the feeder capacity, limited by voltage regulation or thermal constraints, new facilities such as substations or additional feeders need to be created. Till such time, the substation feed area and the configuration of the feeders may be assumed to remain unchanged. It is further assumed that the feeder load grows at a predetermined annual rate, in proportion to the connected loads.

Real and reactive power load at any year 'h' is given by

$$PL(h)=PL(0)(1+g)^h \quad (11)$$

$$QL(h)=QL(0)(1+g)^h \quad (12)$$

Where

g=Annual load growth rate

PL(0)=Real power loads in the base year(0th year)

QL(0)=Reactive power loads in the base year(0th year)

PL(h)=Real power loads in the year 'h'

QL(h)=Reactive power loads in the year 'h'

The eqn. (11) and (12) can be used to determine the maximum allowable load growth in a period of 'h' years. It is assumed that the annual load

growth rate g=8%.

6. RESULTS AND ANALYSIS

The effectiveness of the proposed method is illustrated with a practical 32-node system existing in Anantapur town, India. The line and load data of the system is given in [1].

The system cannot be overloaded before conductor modification as the current in some of the feeder segments is violating the current constraint. Hence, the conductors selected based on genetic algorithm optimization technique are tabulated in Table2.

Table-2: Modifications in the feeder conductor type after conductor selection of 32-node radial distribution system

Branch Number	Existing Conductor (From)	Modified Conductor (To)
1 to 9	Weasel	Raccon
10	Weasel	Rabbit
12	Weasel	Rabbit
14 to 19	Weasel	Raccon
22	Weasel	Squirrel
23 to 25	Weasel	Raccon
26 to 27	Weasel	Rabbit
28 to 29	Weasel	Squirrel
31	Weasel	Raccon

With the new set of conductors, the system can be overloaded and table 3 shows the values of loading factor and maximum allowable load.

Table-3: Loading factor and maximum load before conductor selection

Type of load model	Loading factor	Before optimal conduction selection Base loads		Before optimal conduction selection Max. Loads		Nmax (years)
		Total real power load (kW)	Total reactive power load (kVAr)	Total real power load (kW)	Total reactive power load (kVAr)	
Constant power load	0.098	1680.00	1260.00	1844.64	1383.48	1.2
Industrial Load	0.207	1676.37	1172.85	2023.37	1415.63	2.4
Residential Load	0.326	1661.56	1200.55	2203.22	1591.93	3.6
Commercial Load	0.335	1649.86	1209.75	2202.56	1615.01	3.8

Table-4: Loading factor and maximum load after conductor selection

Type of load model	Loading factor	After optimal conduction selection Base loads		After optimal conduction selection Max. Loads		N_{max} (years)
		Total real power load (kW)	Total reactive load (kVAr)	Total real power load (kW)	Total reactive power load (kVAr)	
Constant power load	0.521	1680.00	1260.00	2555.28	1916.46	5.4
Industrial Load	0.683	1678.08	1213.01	2824.20	2041.49	6.8
Residential load	0.863	1670.22	1228.14	3111.62	2288.02	8.1
Commercial load	0.903	1663.97	1233.12	3166.53	2346.62	8.4

From these tables 3 & 4, it is observed that the maximum loading condition is improved after optimal branch conductor selection. Eqn.11 & 12 is used to determine the maximum allowable load growth period. From Table.3, for constant power load, $TPL_{(N=Nmax)}$ = 1844.64 kW and as mentioned earlier real power load at the base year, $TPL_{(0)}$ = 1680 kW. Therefore, using Eqn. (11), N_{max} can be obtained as:

$$1844.64 = 1680\ (1+0.08)^{N_{max}}$$

Or N_{max} = 1.2 years

Similarly for Industrial, residential and commercial loads N_{max} are obtained as 2.4, 3.6, and 3.8 years for before conductor modification respectively. The N_{max} values after conductor modification are given in Table 4 for constant power, industrial, residential and commercial loads as 5.4, 6.8, 8.1 and 8.4 years respectively. The load growth of the feeder is allowed as long as the voltage limit is not violated. The summary of load flow results of 32- node system is given in Table.5. From table.5 it is observed that minimum voltage is improved from 0.9825 to 0.9906 and total losses are also reduced from 25.37 to 10.17 kW.

Table-5: SUMMARY OF RESULTS OF 32-NODE SYSTEM

Description	Base Case	After Conductor Selection
Min. Voltage(p.u)	0.9825	0.9906
Total Real Power Losses(kW)	25.3780	10.1762
Total Cost(Rs.)	1,35,595/-	55,472/-

7. CONCLUSIONS

A simple genetic algorithm method has been proposed for improving the maximum loading of the radial distribution feeder by using optimal conductor selection algorithm for different types of practical load models by considering the maximum current carrying capacity of branch conductors. Voltage and current constraints have also been satisfied by allowing the feeders to take the load growth up to a specified period of time. The effectiveness of the proposed method is demonstrated with practical 32-node system in India. It is found that loading capability is highest for commercial loads, lowest for constant power loads and lie in between for residential and industrial loads.

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