Genetic Algorithm Based Scheduling Of Reconductoring For Multistage Power Distribution System Planning

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Abstract - Distribution system is one from which the power is distributed to various users through feeders, distributors and service mains. Feeders are conductors of large current carrying capacity, carrying the current in bulk to the feeding points. Conductor is often the biggest contributor to distribution system losses. Economic conductor sizing is therefore of major importance. If a conductor is loaded up to or near its thermal rating, the losses will be increased. Therefore, line conductors are loaded below their thermal limit. In this paper an attempt has been made for reconductoring of branch of radial distribution feeders based on Genetic Algorithm Optimization. The solution gives the scheduling of reconductoring of the conductors. Total planning is considered 12 and 20 years here the whole 12 and 20 years are divided into four stages for each of which conductor size is determined by genetic approach. Numerical tests have shown that the proposed algorithm has found good solutions that considerably enhance the solutions found by incremental method. The reconductoring which is determined by this method will maintain acceptable voltage levels and current of the radial distribution system.

Keywords - Genetic Algorithm, Power Distribution, Multi-stage, Reconductoring.

I. INTRODUCTION

The distribution system constitutes a significant part of total power system. A distribution is one from which the power is distributed to various users through feeder distributor and service main. Feeders are conductor of large carrying current carrying capacity .carrying the current to bulk to the feeder points. Power losses in the lines account for the major portion of the distribution losses. These power losses mainly depend on the type of conductor and its resistance, size and length. To meet the present growing domestic, industrial and commercial load day by day, effective expansion planning and scheduling of radial distribution network is required. Increasing costs of energy and costs of generating capacity are encouraging the electric utility to spend capital to improve the efficiency of the distribution system. The objective of distribution system expansion planning and scheduling is to assure that the growing demand for electricity, in terms of increasing growth rates and high load densities, can be satisfied in an optimum way by additional distribution system.

The distribution system planning scheduling goal is to assure that a demand growth can be satisfied in an optimal way from the secondary feeders to the substations from where energy must be delivered to the final client economically while complying with several technical specifications that also ensures to minimize the above mentioned risk of frequent breakdown. The design of a distribution system planning scheduling is to determine reconductoring of feeder and the optimum locations and numbers of distribution substations and optimum way of connecting the load demand nodes to these substations through the radial interconnection of feeders. The basic function of modern electric power distribution system engineering is to provide electric power to its customers or customers at the lowest possible cost with minimum interruption (maximum acceptable reliability) levels. In present days the distribution system planners, engineers, managers, and operators are facing many of the typical problems. One of the problems may be stated as frequent power service interruptions.

It is well known that distribution systems are in constant evolution, subject to load increasing in different places at different times, which leads to the need of successive system expansions The methods proposed in [1,2] were very time consuming

and the complexity. Kersting and Mendive [3] and Kersting [4] proposed a load−flow technique for solving radial distribution networks by updating voltages and currents using the backward and forward sweeps with the help of ladder−network theory. Stevens et al. [5] showed that themethod proposed in [6,7] became fastest but could not converge in five out of twelve cases studied. Shirmohammadi et al. [9]

This feature puts the network expansion design problem within the class of dynamic programming (DP) problems. This means that there is a sequence of design actions (the expansion in each step) that are interdependent (the design of the expansion in a stage affects the design problem statement for the subsequent stages). This class of problems is usually associated with a large computational complexity, since the variable space is composed of the number of decision variables in each stage multiplied by the number of stages (This is sometimes called the curse of dimensionality.). Such difficulties possibly explain why there are few works dealing with electric distribution expansion planning from the viewpoint of DP. For related problems that are treated via DP

II. GENETIC ALGORITHM BASED RECONDUCTORING OF DISTRIBUTION NETWORK

1) Genetic Algorithm

Genetic Algorithms are adaptive algorithms for finding the global optimum solution for an optimization problem. The Genetic Algorithm is characterised by binary representation of individual solutions, simple problem-independent crossover and mutation operators, and a proportional selection rule. The population members are strings or chromosomes, which as originally conceived are binary representations of solution vectors. GA undertakes to select subsets (usually pairs) of solutions from a population, called parents, to combine them to produce new solutions called children (or offspring). Rules of combination to yield children are based on the genetic notion of crossover, which consists of interchanging solution values of particular variables, together with occasional operations such as random value changes (called mutations). Children produced by the mating of parents, and that pass a survivability test, are then available to be chosen as parents of the next generation. The choice of parents to be matched in each generation is based on a biased random sampling scheme, which in some (non standard) cases is carried out in parallel over separate Sub populations whose best members are periodically exchanged or shared. The key parts are described in detail as follows

a) Initialisation

In the initialisation, the first thing to do is to decide the coding structure. Coding for a solution, termed a chromosome in GA literature, is usually described as a string of symbols from {0, 1}. These components of the chromosome are then labelled as genes. The number of bits that must be used to describe the parameters is problem dependent. Let each solution in the population of m such solutions xi, i=1, 2, .. ., m, be a string of symbols {0, 1} of length l. Typically, the initial population of m solutions is selected completely at random, with each bit of each solution having a 50% chance of taking the value 0. The binary string representing the reconductoring problem consisting of size of each stage

Conductor	stage1	satge2	stage3	stage4
1	a_1	b_1	c_1	d_1
2	a_2	b_2	c_2	d_2
3	a_3	b_3	c_3	d_3
4	a_4	b_4	c_4	d_4
5	a_5	b_5	c_5	d_5
.	.	.	.	.
.	.	.	.	.
N	a_n	b_n	c_n	d_n

Fig1: string of the population obtained

a_i b_i c_i and d_i are the sizes of conductoring used for each in each stage.

b) Selection

GA uses proportional selection, the population of the next generation is determined by n independent random experiments; the probability that individual xi is selected from the tuple (x1, x2, . . . , xm) to be a member of the next generation at each experiment is given by This process is also called roulette wheel parent selection and may be viewed as a roulette wheel where each member of the population is represented by a slice that is directly proportional to the member's fitness. A selection step is then a spin of the wheel, which in the long run tends to eliminate the least fit population members.

c) Crossover

Crossover is an important random operator in GA and the function of the crossover operator is to generate new or 'child' chromosomes from two 'parent 'chromosomes by combining the information extracted from the parents. The method of crossover used in GA is the one-point crossover as shown in Fig. 3(a). By this method, for a chromosome of a length l, a random number c between 1 and l is first generated. The first child chromosome is formed by appending the last elements of the first parent chromosome to the first c elements of the second parent chromosome. The second child chromosome is formed by appending the last elements of the second parent chromosome to the first c elements of the first parent chromosome. Typically, the probability for crossover ranges from 0.6 to 0.95.

Cross over point

Parent#1 1001 010010 child #1
0101 010010

Parent#2 0101 111011 child #2
1001 111011

Cross over operation

d) Mutation

Mutation is another important component in GA, though it is usually conceived as a background operator. It operates independently on each individual by probabilistically perturbing each bit string. A usual way to mutate used in GA is to generate a random number v between 1 and l and then make a random change in the vth element of the string with probability pmμ(0, 1), which is shown in Fig. 3(b). Typically, the probability for bit mutation ranges from 0.001 to 0.01.

Parent 1101010010 child 1101 010110

An electric distribution network can be represented as a dynamic system, in which the system variables are its branches. The system should be described as a linear discrete lumped time-invariant dynamic system, as shown in 1.

$$x[k] = x[k-1] + u[k]$$

$$\forall \; k = 1,2,3 \ldots \ldots \ldots n \qquad (1)$$

In which: k is the index of the stage (discrete time), n is the total number of stages in which the time has been discretised, x[k] is the network at stage k, and u[k] is the increment to the network at stage k (New branch installation and reconductoring.).

The distribution network expansion scheduling is interpreted, in this case, as the system evolution in a finite time horizon. The DP problem is determined by defining:

- The initial electric distribution system;
- The design time horizon and the number of stages to be considered;
- The load forecast for each stage within the design time horizon.

2) Objective Function

The basic problem of reconductoring of each branch of radial distribution feeder which will minimize the sum of installation cost maintenance cost energy cost and the replacement cost. While maintaining voltage acceptable voltage limit and acceptable current limit.

Total network cost = (Installation cost + maintenance cost+ replacement cost + energy cost)

3) Constraints

- Feeder Voltage: The feeder voltage at every node of the feeder must be above the acceptable voltage level, i.e., min | V (i) | ≥ Vmin for all i.
- Maximum current carrying capacity: Current flowing through branch-jj with k-type conductor should be less than the maximum current carrying capacity of k-type conductor.

4) Algorithm

The detailed algorithm to determine reconductoring of the network is given below

Step1: (a) Read the genetic data along with initial system load, line and conductor data

(b) Read Vmin, kvab, KVb.

(c) Read the genetic operator values (population size, Pe, Pc, Pm, etc)

Step2: Initialization of population

Step3: Set the iteration count to '1'.

Step4: Set chromosome count equal to '1'.

Step5: Decode the chromosomes of the population and determine the conductor number from the normalized form.

Step6: Run the load flow

Step7: Check the current limit of each branch starting from the first branch if current of any branch is violated the maximum limit replace the conductor by higher size. The size of any conductor will be not higher than the size of the first branch.

Step8:Check the voltage limit if voltage of any bus is lower than the pre specified value the size of conductor is increased by one.

Step9: Calculate the objective function

Step10:Calculate the fitness value of the chromosome, using the formula Fit[w] =1.0/ (1+0.005*obj[w]); where w=chromosome count

Step11:Repeat the procedure from step no.5 until chromosome count>population size.

Step12: Reproduction

Step13: Cross over and mutation

Step14:Calculate the fitness value of the chromosome, using the formula Fit[w] =1.0/ (1+0.005*obj[w]); where w=chromosome count.

Step15: Now perform crossover and mutation operators respectively for generating remaining chromosomes.

Step16: Now, replace old population with new population add replacement cost in the objective function and go to step5

Step17: Increment iteration count. If iteration count <max. Count, go to 4. else go to 17.

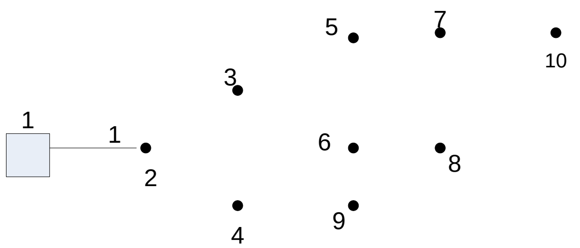
Step18:Print the message “conductor size in different stage and cost of the network”

Example:

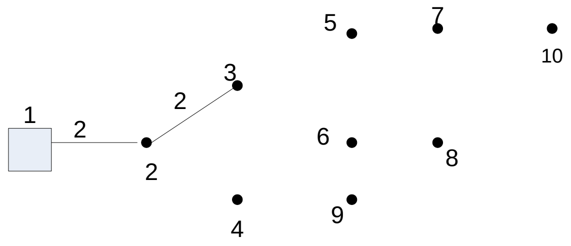
In this section, effectiveness of the proposed method is demonstrated by two examples, 10 nodes, and node radial distribution network expansion and scheduling.

In first case 10 bus distribution feeder expansions planning and scheduling is considered for 12 years. The basic objective is to reconductoring the branch of the feeder for distribution network expansion scheduling. Data of the conductors are given in Appendix A. Line data and Load data for example 1 are given in Appendix B.

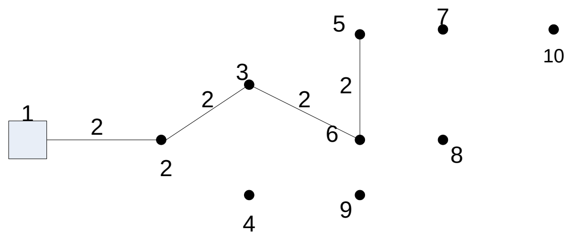
Example: Initial system is shown below.



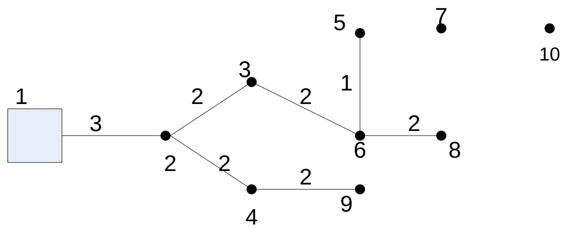
Reconductoring of distribution network for 10 bus system stage wise



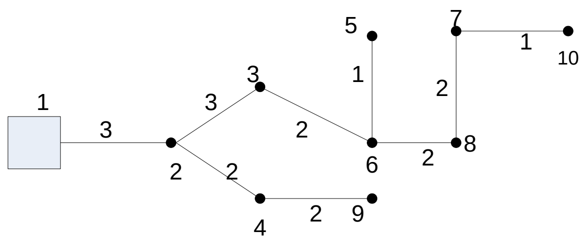
Stage 1.DP-GA Reconductoring solution.



Stage 2 DP-GA solution



Stage3. DP-GA solution



Stage4 DP-GA solution

TABLE 1. DATA FOR CONDUCTORS

Type of conductor	Resistance(Ω/km)	Reactance (Ω/km)	Maximum Power(KW)	Installation Cost ($/km)	Maintenance cost($/km/year)	Replacement cost($/km)
1	1.6118	0.4853	07042.5	32126.23	1733.54	17758.20
2	1.0145	0.4679	09440.0	32321.31	1733.54	17758.20

3	0.6375	0.4505	12787.5	32653.55	1733.54	17758.20

TABLE 2. DESIGN DATA FOR EXAMPLE

S base	100000 (kW)
V base	34.5000 (kV)
Node 1 is a substation: Voltage(node1)	1.00pu, Angle(node 1) = 0 degrees
loss factor	0.6640
design time (years): 10	10
energy tax ($/kWh)	0.06
initial load of each bus	1000 kW / 0 kVAr
annual load increasing factor	1.05 (5%)

III. RESULTS AND DISCUSSION

Cost comparison between Genetic Algorithm and incremental method.

TABLE 3. RESULT

Method used	**Total cost of the network in 12 years**
Genetic Algorithm	608989.95$
Incremental method	946332.8$

IV. CONCLUSION

The results obtained by this approach suggest that the algorithm can find good sub-optimal solutions for large problem instances, within reasonable computational times. The solutions that have been found, when

Compared with other solutions found via INC methods, represent significantly smaller costs. The consistency of the solutions obtained, for different numbers of stages, suggests that finding such good the proposed methodology can be valuable for supporting the decisions on investment policy of energy companies. It permits a better allocation of limited financial resources, achieving solutions with smaller total costs than the ones gained with static design approaches.

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