ENHANCED DESIGN OF DISTRIBUTION NETWORKS, USING BE & GA METHODS

Sara KHAYYAMIM
Niroo Research Institute- Iran
skhayyamim@nri.ac.ir

Hamideh GHADIRI
Niroo Research Institute- Iran
hghadiri@nri.ac.ir

Ahad KAZEMI
University of Science & Technology- Iran
kazemi@iust.ac.ir

Mojtaba GILVANEJAD
Niroo Research Institute- Iran
mgilvanejad@nri.ac.ir

Safar FARZALIZADEH
Niroo Research Institute- Iran
sfarzalizadeh@nri.ac.ir

Akbar YAVARTALAB
Tavanir-Iran
yavartalab@tavanir.org.ir

ABSTRACT

Distribution network is the connection point between power network and consumers, therefore adequate network planning whether from the power quality viewpoint or economical considerations is significant.

This paper presents the comparison between two optimal distribution network design algorithms using loss reduction approach: Branch Exchange (BE) and Genetic Algorithm (GA) (which are for two different categories: knowledge based methods and methods based on evolutionary techniques). Both extended algorithms with their characteristics, innovations, advantages and disadvantages are described and their results on the same pilot in the part of Karaj City in Iran are illustrated. At the end some suggestions for improving optimal distribution network design algorithms are offered.

INTRODUCTION

Designing distribution network for new towns or developing parts of cities is a routine job for electrical engineers. This procedure calculation is still done manually in even some developing countries. Using practical softwares to design electrical networks which need less input data can lead the distribution network to be more standard and more economical. For this reason, efficient planning tools are needed to allow planners to reduce costs. Computer optimization algorithms improve system structure and reduce cost compared with systems designed by hand. Hence, in recent years a lot of mathematical models and algorithms have been developed [1, 2].

A distribution network consists of a number of medium voltage substations and radial network with technical constraints (voltage drop and equipment capacity) and geographical constraints and quality of supply limits to feed the load demands.

According to the historic development, the computational searching methods are classified in three large groups. Knowledge-based methods, methods based on evolutionary techniques and mixed methods [3, 4].

In this paper one of the methods based on evolutionary techniques (Genetic Algorithms) and one of the methods based on Knowledge-based techniques (Branch exchange technique) have been used and their results have been applied for distribution network planning in a real sample network area, located in Karaj-Iran.

STATEMENT OF THE PROBLEM

As mentioned, the problem is concentrated on how to optimize distribution network planning. Thus, in the optimization process it is essential to define an objective function, which could completely satisfy the planning goals. All the objective functions used in distribution network planning have two significant parts: Investment Costs, Operational Costs.

Regarding to the aforementioned parts, the objective function could be expressed as below [5]:

$$TC = C_f + C_{sub} + C_{EL} + C_{PL} + C_{\text{maintenace}} \quad (1)$$

Where,
TC: Total cost
C_f: Feeder installation cost
C_{sub}: Substation installation cost
C_{EL}: Energy loss cost
C_{PL}: Power loss cost
$C_{maintenance}$: Maintenance cost

This type of objective function has highlighted the loss cost and consequently the designed network has low energy loss, whereas the investment and maintenance costs are minimized simultaneously.

To do the summation which has shown in relation (1), it is needed that the operational costs assimilate with investment costs (that is relevant to present time). In this regard, the present worth of the operational costs should be considered. After finding the present worth of the operational costs, the value of objective function is achieved by adding the investment costs to the present worth of operational costs.

ALGORITHMS DESCRIPTION

Genetic Algorithm

Genetic Algorithm is a stochastic search and optimization technique shaped by evolutionary theory. Fig.1 shows general steps of genetic algorithm.

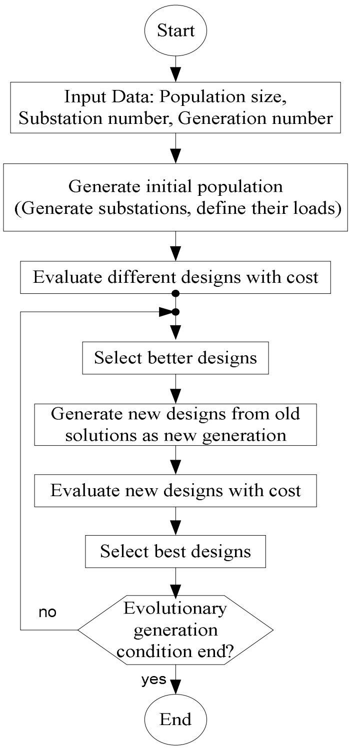

Fig.1 General steps of Genetic Algorithm

GA consists of an initial set of random solutions called populations. Each individual in the population is called a chromosome, which is a string of symbols and represents a solution to the problem. The chromosomes evolve through successive iterations, called generations [6]. The method to coding the problem and making the chromosomes and population is one of the most important steps of algorithm because it constructs stochastic network model. The encoding should consider the distribution network radiality. During each generation, with using some measure of fitness, the chromosomes are evaluated. The fitness function must reflect both the desired and the unwanted properties of a solution, rewarding the former and strongly penalizing the latter [7]. The fitness function consists of checking the voltage and current constraints to select the suitable conductor and calculate the network cost. The next generation is created by offsprings resulted from two chromosomes, from the current generation, merged together either crossover or mutation operator. A new generation is formed by selecting some of the parents (reproduction) and offspring according to the fitness values and by rejecting others to keep the population size constant [8, 9].
Crossover is the main genetic operator. It combines two chromosomes features to generate an offspring. In this algorithm the crossover is achieved by choosing a random cut point and combining the segments of one parent to the left of the cut point with the segment of the other parent to the right, generating an offspring. Contrary, a high crossover rate increases the computation time greatly and results in wasting a lot of time in exploring unfavorable regions of the solution space.
Mutation is a background operator that produces instinctive random changes in various chromosomes. Mutation plays a crucial role because it recovers some lost genetic materials, which is missed by cross over or reproduction, decreasing the error in finding the global optimum.
Elitism operator in this algorithm ensures that the best result will never be lost. Therefore, this operator can avoid trapping in local optimal positions by storing the best result in each step and send it directly to the next generation [9].
Selection is done with tournament selection. Since the distribution system solution space is fairly large, tournament selection has been used in special way. Selection is based on the results value. Therefore, the results with higher value have better chance to stay in the population for next generation. In this step unacceptable answers (with unacceptable costs) are deleted.

Branch Exchange Technique

Branch Exchange (BE) technique is a knowledge based method which uses heuristic methods to solve optimization problems [4]. General flowchart of proposed algorithm is shown in Fig.2.

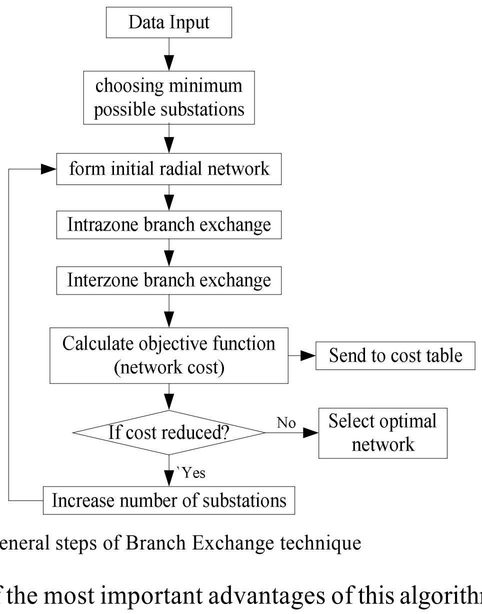

Fig.2 General steps of Branch Exchange technique

One of the most important advantages of this algorithm is its independency to the operator input and then operator tact. In similar algorithms, always some information such as probable substation location is proposed by the operator, however in this algorithm, all the parameters are specified optimally by the algorithm [10].
In this algorithm, the program starts designing the network with minimum number of feasible substations and finds the

optimal place and optimal capacity of substations [11].
This is approached by finding the average capacity of the network for specified number of substations. Then sweeping the geographical map from a start point and calculating the summation of the load in front till the summation becomes near to the average capacity which is settled. At this time the zone is closed and the substation is located at the load gravity center and the capacity is determined by the loads fed in the zone considering operational factors of transformer.
After this step, in which the zones and substation capacity and location are specified, the algorithm designs the network. At the end of each optimal design, the total network cost is calculated and saved and another step with increasing the substation numbers is started. In this case, the number of substations which were selected for designing increased and all the design procedure is done one more time for the new number of substations. Thus, expansion of MV network would be tested with this algorithm. Till the objective function (cost) allowed, the MV network could be expanded [5].
The design procedure after defining the number of substations, locations and capacities of them and zones continues from a set of initial radial networks. These initial networks are formed by constructing the distribution network spanning trees. The root of each tree is a substation node [5].
As shown in Fig.2 the next phases of the algorithm is intrazone branch exchange and interzone branch exchange. In intrazone branch exchange the configuration of a distribution network is changed by exchanging the branch in each zone [5, 10]. In interzone branch exchange nodes are exchanged between two adjacent distribution zones. Interzone branch exchanges determine the optimum service area of each distribution substation [5, 10].
The branch exchange technique basically converts a radial network into a meshed network by connecting the tie lines. The radial structure is restored again by opening some other lines of the network to minimize the objective function. The exact form of the objective function is dependent upon the purpose of planning.

RESULTS

Two computer programs on the basis of proposed optimization algorithms have been obtained by MATLAB m-files with more than 7000 rows. These programs were applied for three real cases that have different load configurations and the results were satisfactory in all of them. One of these networks, named Shahrake-Refah at the suburb of Karaj, is chosen to present in this paper because of its small dimensions and explicit structure. Geographical dimensions of this area are about 250m×340m. There are 674 residential consumers with the total load of about 825 kW.
The optimization process for distribution network of this area continued for genetic algorithm about 48 hours and for branch exchange technique about 10 minutes, with a Pentium IV-3.0 GHz personal computer. The geographical map of pilot area, load and suggested substations for both algorithms, GA and BE, are illustrated in Fig.3 and Fig.4.

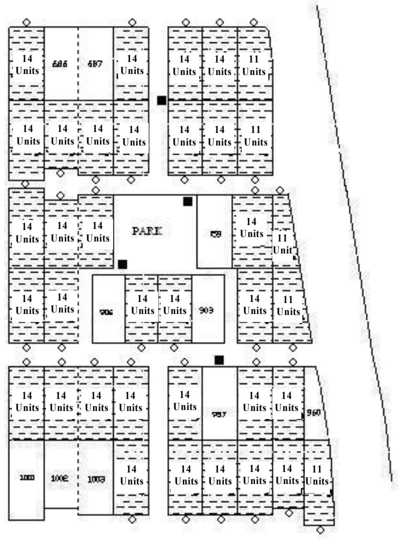

Fig.3 Geographical map, load positions and optimal substation location with GA (square is for optimal substation location and circle is for load positions)

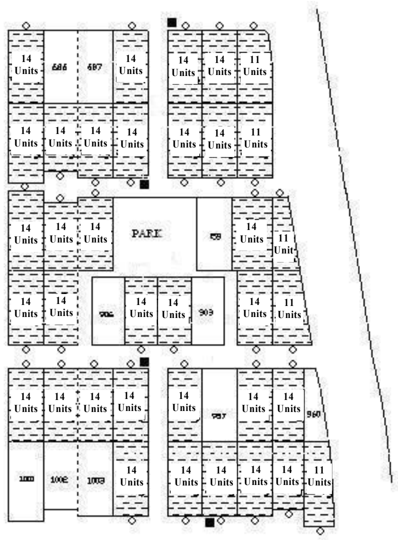

Fig.4 Geographical map, load positions and optimal substation location with BE (square is for optimal substation location and circle is for load positrons)

Trend of network costs during the optimization process with each of the optimization algorithms is shown in Fig.5 and Fig.6. As shown in Fig.5 and Fig.6, expanding MV network has an optimum point which both algorithms are convergent at that point. It means that designing the sample area with 4 substations is the optimum solution whereas the arrangement of the network shown in the Fig.3 and Fig.4 are different in two algorithms; thus, the network costs are different. It is clear from the lower network cost in BE algorithm that the network structure and the substation locations are better in this algorithm. This advantage is because the algorithm is based on the distribution network structure and approved by network topology, however the GA is a stochastic algorithm which could reach the optimal solution; however, it is hard to guide the solution with fitness value, encoding data and constraints to a technical distribution network. Table.1 illustrates comparison between these two algorithms.

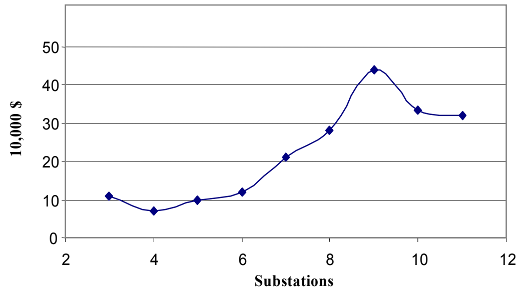

Fig.5 Expanding MV network trend according to network cost with GA

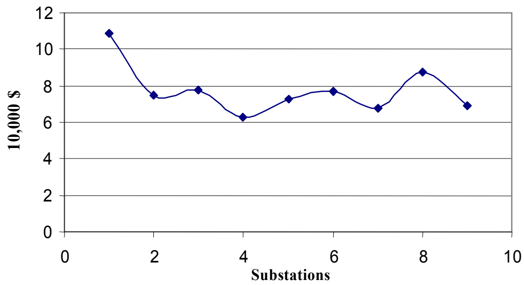

Fig.6 Expanding MV network trend according to network cost with BE

TABLE.1. COMPARISON GA AND BE METHODS

	Running time	Flexibility	Constraints management	Non linear model	Local optimization trap	practical network topology	Large system
BE	+	+	+	+	-	+	+
GA	-	+	+	+	+	-	-

CONCLUSION

Two optimization algorithms, genetic algorithm and branch exchange, have been proposed in this paper which could design an optimal distribution network according to the municipal map of a selected area.

The prominent difference between the proposed algorithms can be explained as: GA is an evolutionary stochastic algorithm; however, BE is a knowledge based algorithm. Both algorithms are co-optimizing of the size and location of substations and the size and configuration of feeders. Computer program outputs in a real case for both algorithms have been presented and discussed. As it is pointed out the potential of these tools for the optimum design of distribution networks and their convergence to an optimal point is highlighted.

It seems that using mixed method (which is the combination of knowledge based methods that uses heuristic techniques depending on technical specification of the problem and evolutionary techniques which is based on imitation of physical, biological and neurological processes present in nature) to gather their combined strengths will obtain better results. If the strength of BE algorithm in designing technical distribution network with optimal topology is combined with the strength of GA algorithm in finding the optimal solution and avoiding the local optimum, the optimization process will be improved completely and better network achieved.

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