A Knowledge Based Expert System to Optimum Design of Distribution System

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Abstract **--In this paper, an expert system is developed in order to evaluate optimum number and capacity of distribution substation and also their loads value connected to it.**
The proposed method uses some heuristic rules to evaluate optimum number and capacity of substations. The mathematical model of problem which uses minimum investment costs and power loss, obtains the goal. A genetic algorithm which is an effective tool in non-linear and discrete functions optimization is used. Finally, the proposed method is applied on a typical network and the results are obtained.

Keywords**--Distribution system, Expert system, Genetic Algorithm, Substation Placement, Optimization**

I. INTRODUCTION

Regarding to high application of loads in distribution networks, there are a lot of parameter that is included in future network design and also in determining of substation location and capacity and also feeder routs. It is usually using heuristic rules which are based on knowledge of distribution engineers in this design. Most of this design has done to reduce investment and optimize power loss [1].
A new model for optimum location and determination of substation size and its feeders in a distribution network is brought in [2].
In this model, both linear and non linear loads are intended.
In other methods, location and capacity of substations are determined intelligently and it doesn't need to some candidate location at the first. [3]
These methods are not usually applied, because finding the candidate location of a substation is a difficult job.
Using of GIS system in addition to spatial load forecasting and adequate mathematical models, is so useful for finding substation location. [4]
At the first step, all locations which can not be used for substation are determined by operators and then, location and capacity of remained substations are determined regarding to constrain and using a special methodology [5].
In this article, location of substation is based on GIS and spatial load forecasting, and optimization of cost function, which is a discrete and nonlinear function is done be genetic algorithm which is a powerful method nowadays.

II. EXPERT SYSTEM DESIGN

A reliable distribution network needs a good design which is based on heuristic rules related to engineering knowledge.
An expert system is shown in "Fig.1" for designing a distribution network:

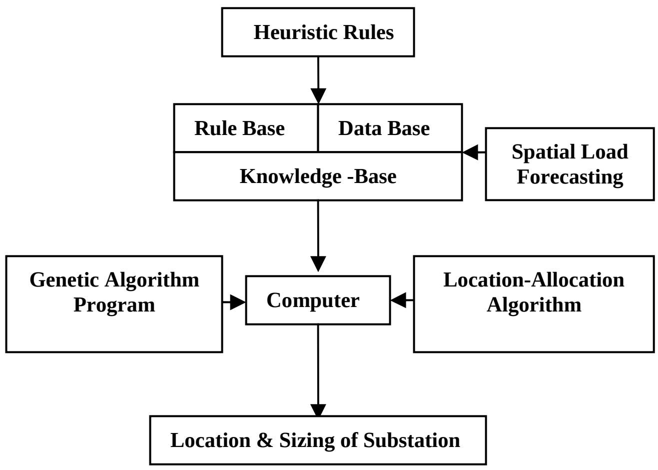

Fig. 1. Expert system

Designing of this system is based on engineer's knowledge, data base and primary rules which are a set of heuristic rules and also result of spatial load forecasting is added to it.
All data are edited and entered to computer and then modeled by mentioned algorithm. The part of this process which is needed to optimize a nonlinear and multivariable function is done by genetic algorithm. Finally, location

and capacity of substations and all connected loads are given to user as output.
This expert system has the following features:

- The cost function is assumed as the goal function.
- Optimization is done by the genetic algorithm.
- Substation location and size determination is done simultaneity.
- It is possible to edit location of candidate substations.
- It can be to convert the large size blocks to smaller sizes in order to design private substation.
- The results are applicable.

A. heuristic rules

There are several parameters which effect on network designing. So in order to obtain an optimum response and also coverage the problem, it must be used a series of heuristic rules. In our problem, we also use such that rules as follow:

- All loads must be connected to nearest substation.
- Voltage deviation must be in allowable range.
- All loads must be feeded.
- Load which is connected to a substation must be placed in rated power of substation.
- Minimum distance from substation is loom in this paper.

B. Allocation Algorithm

As it is mentioned before, it can be specified candidate points in expert system.
In one case, we can choose all blocks as candidate points. Regarding to pervious mentioned heuristic rules, this algorithm involve following steps:

Step 1:
All substation capacities are 50 KVA.

Step 2:
All load values and places of their center are placed in to the vector.

Step 3:
A 50 KVA substation is assumed for each load center.

Step 4:
A distance constrain (100m) between each two substation is assumed. If this distance is less than 100m, the smaller substation is dismissed. In this step, a maximum number of substations which can feed the area are obtained.

Step 5:
In this step, the value of load is checked which has not been more than value of substation capacity. If this occurred, the capacity of substation will be increased one size bigger.

Step 6:
Step 5 is repeated until each substation can feed its connected load.

Step7:
Each Unconnected load is connected to a substation randomly and first generation is obtained with this method.

Step 8:
Capacity of substation is increased until there is no problem for connected loads.

Step 9:
Minimize the cost function and save its value.

Step 10:
Maximum number of substation which is obtained in step 4 is decreased by one.

Step 11:
All step 4-10 are repeated until *NTmax*=1.

Step 12:
Find the minimum value saved in step 9 and it specify the response.

III. FORMULATION OF PROBLEM

In step 9, cost function must be minimized such that all casts including construction and power loss will be minimized.
In this paper the mathematical model is as below:

$$MinCF = \sum_{i=1}^{N_S}\left[INS_i + C\left(Pc_i + B^2 Pcun_i\right) + K\sum_{j=1}^{L} d_j p_j\right]$$

Which:

N_S : Total number of substation
INS_i: construction cost of i^th transformer
p_{ci} : Fe losses of i^th transformer
p_{cuni} : Cu losses of i^th transformer
B: loading percentage
d_j : Distance between j^th load and its connected substation
Pj: Average of j^th load (KW)
L: Number of branches between substation and related loads.
C, k: converting factor form kW to cost.

IV. OPTIMIZATION METHOD USING GENETIC ALGORITHM [6]

The genetic algorithm is a method for solving optimization problems that is based on “natural selection”. The process that derives biological evolution. Unlike many Conventional optimization methods, which are generally Single path searching algorithms, Genetic algorithm starts searching from several points and “evolves” to ward an optimal solution.
In the beginning, the first population included several individuals is created. These individuals are then evaluated by the target fitness function. Throughout successive generations, the populations are created using three methods:

i) Elite selection
ii) Crossover

iii) Mutation

A. INITIAL POPULATION

The primary population is a collection of a specific number of individuals created randomly: the larger the number of individuals, the bigger the probability of finding optimum value.

On the other hand, large number of individuals would result in long and unsuitable response time as well as huge amount of mathematical computations. In our problem, the populations are 1-by-n matrices, in which n represents the location of suggested switching devices.

B.CREATING THE NEXT GENERATION

At each stage, the genetic algorithm uses the current population to create the children that makes up the next generation. The algorithm selects a group of individuals in the current population, called parents, who contribute their genes (the entries of their vectors) to their children.

The algorithm selects individuals that have better fitness values of parents.

Totally, three types of children are generated:

i) Elite children are the individuals with the best fitness values that are directly passed to the next generation.

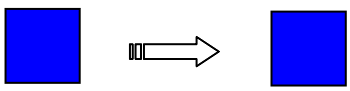

Fig. 2. Elite children generation

ii) Crossover children are generated by combining the vectors of a pair of parents.

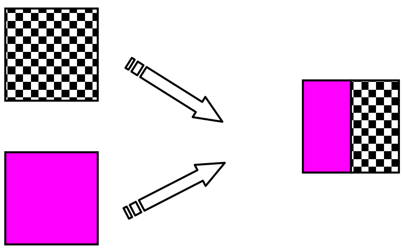

Fig. 3. Crossover children generation

iii) Mutation children are generated by exerting random changes (mutation) to an individual.

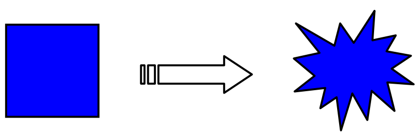

Fig. 4. Mutation children generation

V. CASE STUDY AND ANALYSIS

The proposed algorithm in this paper is tested on one of northern city in Iran which includes different usages.

The load centers and load values are computed by spatial load forecasting method before evaluating size and location of substations.

Load blocks and necessary value for each of them are shown in "fig.5".

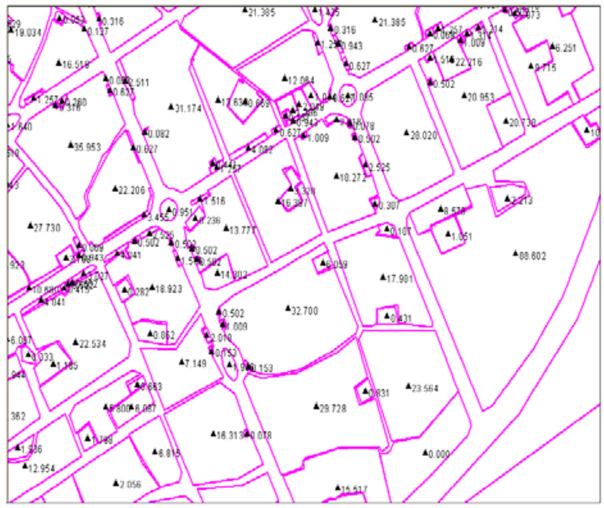

Fig. 5. Load blocks and necessary **kW**

All necessary data for load forecasting program and proposed algorithm which is based on genetic algorithm are modeled in software and optimum response is obtained which is shown in "fig.6".

As it is shown in "fig.6" capacity of substation and related and also number of them foe feeding the case are specified. It is also specified that each load is feeding from which substation.

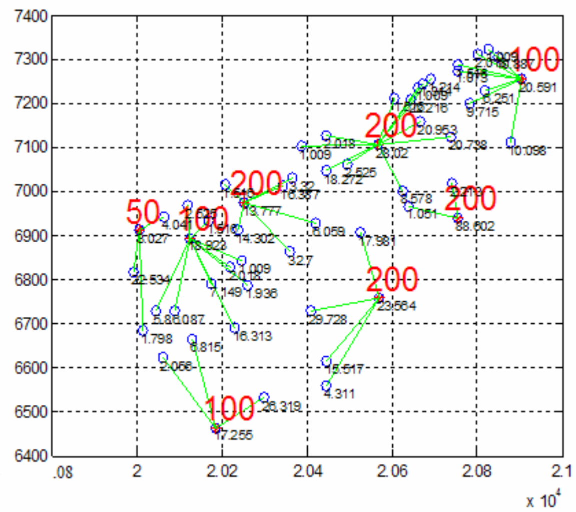

Fig.6 .output of design program

All output information is transferred on a geographic map by a GIS based interface. It is shown in "fig.7".

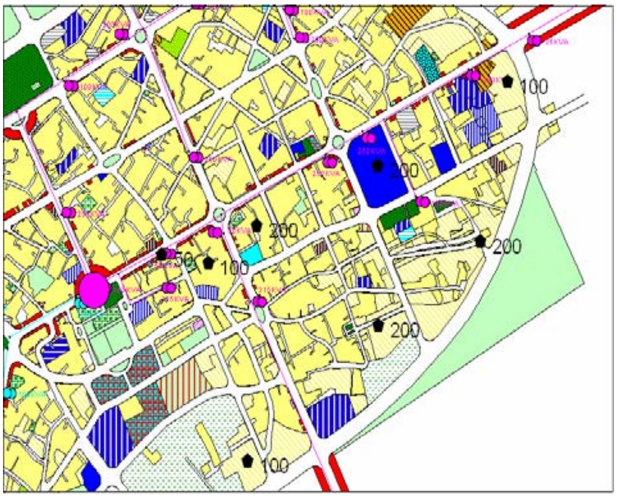

Fig. 7. Substation location and sizing on the geographic map

VI. CONCLUSION

In this paper a new method is presented for finding optimum size and location of distribution substation by genetic algorithm.
In this method, location of distribution substation is evaluated first.
Using genetic algorithm, optimum solution is evaluated regarding to all constraints such as allowable voltage drop and also allowable substation connecting load.
The proposed algorithm is tested on a specified area and its advantage is shown in results.

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VIII. ACKNOWLEDGMENT

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IX. BIOGRAPHIES

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