Software Development for Optimum Allocation of Power System Elements Based on Genetic Algorithm

SHAHRAM JAVADI
Islamic Azad University – Central Tehran Branch
Electrical Engineering Department
Moshanir Power Electric Company
IRAN

Abstract: In this paper, a software is developed in order to evaluate optimum allocation of any power system elements such as power plant, substation and capacitors. This software is based on genetic algorithm and use heuristic rules in order to get more applicable. This software is currently using to find substation allocation in optimum point regarding to their place and size. 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: Power System, Expert system, Genetic Algorithm, Substation Placement, Optimization

1. 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 done 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 by genetic algorithm which is a powerful method nowadays.

2. Genetic Algorithm

Genetic Algorithm (GA) is a kind of search and optimized algorithm that have been produced from simulating biologic heredities and long evolutionary processes of creatures. It stimulates the mechanism of "survival competitions; the superior survive while the inferior are eliminated, the fittest survive." The mechanism searches after the optimal subject by means of a successive iterative algorithm. Ever since the late 80s, GA, as a new cross discipline which has drawn people's attention, has already shown its increasing vitality in many fields.

GA stimulates reproduction, mating, and dissociation in natural selection and natural heredity procedures. Each possible solution to problems is taken as an individual among population, and each individual is coded as character string; each individual is evaluated in response to predefined objective functions and a flexibility value given. Three of its elemental operators are ***selection,*** ***crossing,*** and ***mutagenesis***.

Its main features are as follows:

(1) GA is to acquire the optimal solution or quasi-optimal ones through a generational search rather than a one-point search.

(2) GA is capable of global optimum searching.

(3) GA is a parallel process to population change, and provides intrinsic parallelism.

(4) The processed object of GA is the individuals whose parameter set are coded rather than the parameters themselves, and this very feature enables GA to be used extensively.

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.

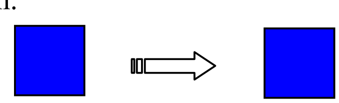


Figure1. Elite children generation

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

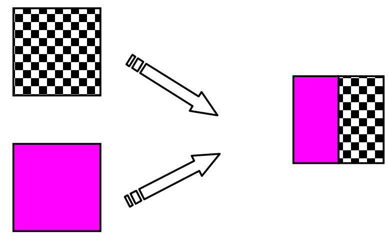


Figure2. Crossover children generation

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

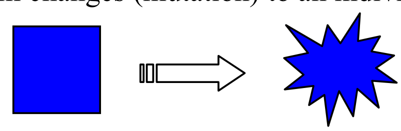


Figure3. Mutation children generation

3. Problem Definition

A reliable distribution network needs a good design which is based on heuristic rules related to engineering knowledge.

An expert system is shown in figure 4 for designing a distribution network:

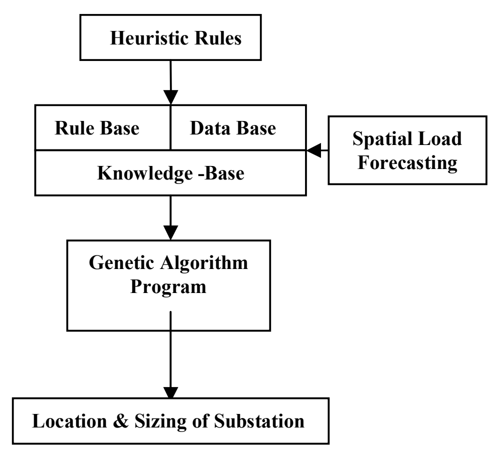


Figure4. Expert system

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 should be connected.
- Minimum distance from substation is considered as constrain in this paper.

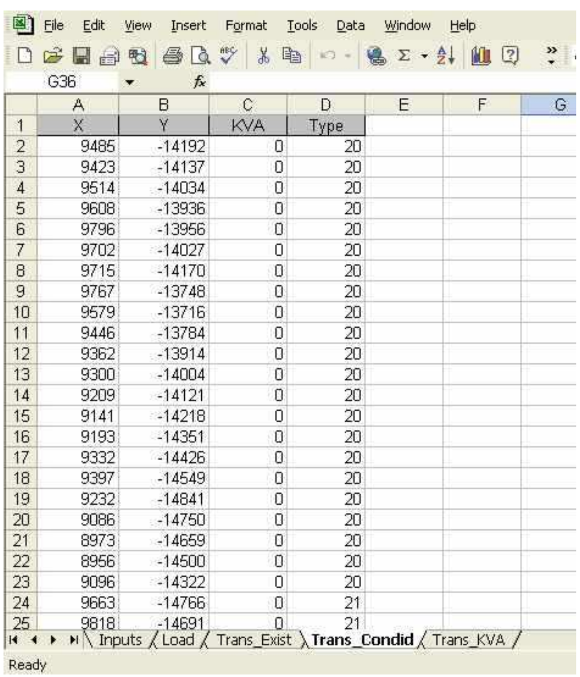
B. Allocation Algorithm

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:

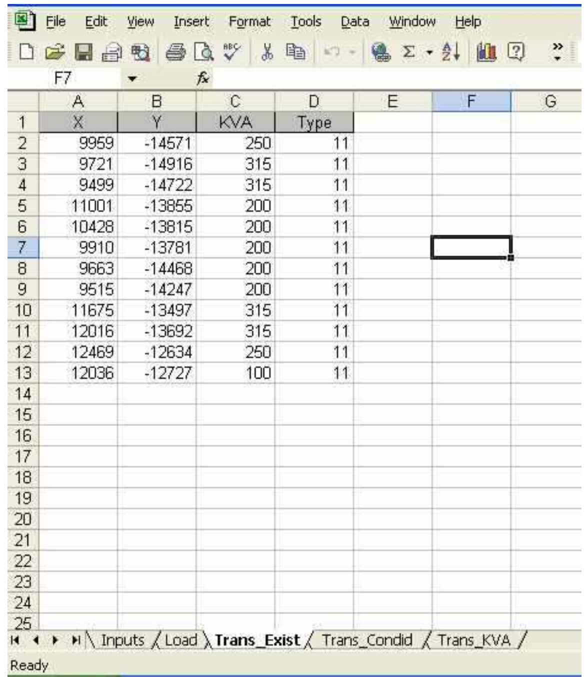
Step 1:

Firstly we choose all candidate locations and enter to the software with an unknown capacity. The existing substations can be left with their capacity. After running the program, their locations will not be changed (Fig 5, Fig6).



	A	B	C	D
1	X	Y	KVA	Type
2	9485	-14192	0	20
3	9423	-14137	0	20
4	9514	-14034	0	20
5	9608	-13936	0	20
6	9796	-13956	0	20
7	9702	-14027	0	20
8	9715	-14170	0	20
9	9767	-13748	0	20
10	9579	-13716	0	20
11	9446	-13784	0	20
12	9362	-13914	0	20
13	9300	-14004	0	20
14	9209	-14121	0	20
15	9141	-14218	0	20
16	9193	-14351	0	20
17	9332	-14426	0	20
18	9397	-14549	0	20
19	9232	-14841	0	20
20	9086	-14750	0	20
21	8973	-14659	0	20
22	8956	-14500	0	20
23	9096	-14322	0	20
24	9663	-14766	0	21
25	9818	-14691	0	21

Figure5. Candidate Substations sheet

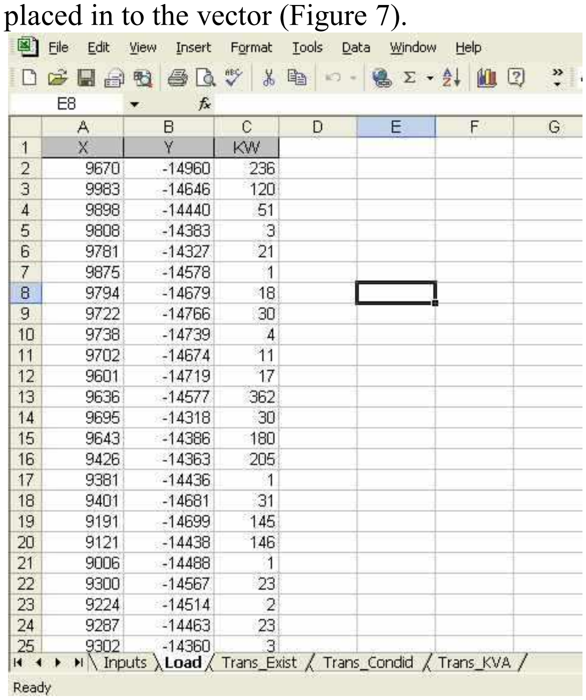


	A	B	C	D
1	X	Y	KVA	Type
2	9959	-14571	250	11
3	9721	-14916	315	11
4	9499	-14722	315	11
5	11001	-13855	200	11
6	10428	-13815	200	11
7	9910	-13781	200	11
8	9663	-14468	200	11
9	9515	-14247	200	11
10	11675	-13497	315	11
11	12016	-13692	315	11
12	12469	-12634	250	11
13	12036	-12727	100	11

Figure6. Existence Substations sheet

Step 2:

All load values and places of their center are placed in to the vector (Figure 7).

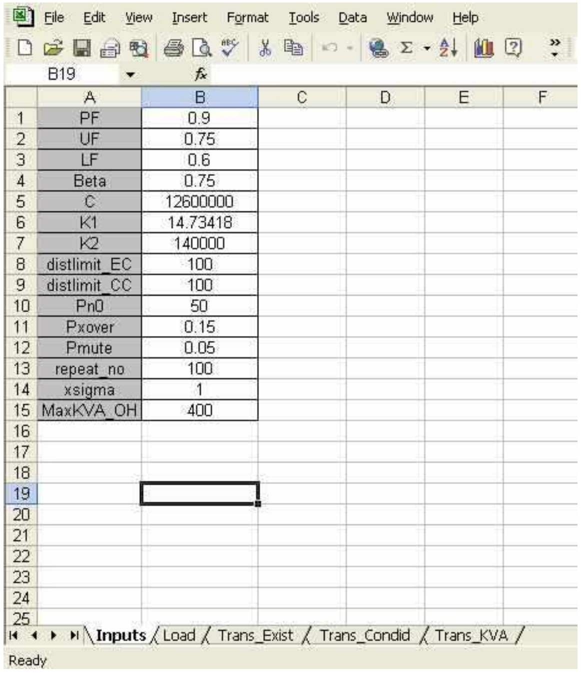


	A	B	C
1	X	Y	KW
2	9670	-14960	236
3	9983	-14646	120
4	9898	-14440	51
5	9808	-14383	3
6	9781	-14327	21
7	9875	-14578	1
8	9794	-14679	18
9	9722	-14766	30
10	9738	-14739	4
11	9702	-14674	11
12	9601	-14719	17
13	9636	-14577	362
14	9695	-14318	30
15	9643	-14386	180
16	9426	-14363	205
17	9381	-14436	1
18	9401	-14681	31
19	9191	-14699	145
20	9121	-14438	146
21	9006	-14488	1
22	9300	-14567	23
23	9224	-14514	2
24	9287	-14463	23
25	9302	-14360	3

Figure7. Load sheet

Step 3:

All coefficients of algorithm and constants of projects are placed in an input sheet. User can modify or change all this parameters easily (Figure 8).



	A	B
1	PF	0.9
2	UF	0.75
3	LF	0.6
4	Beta	0.75
5	C	12600000
6	K1	14.73418
7	K2	140000
8	distlimit_EC	100
9	distlimit_CC	100
10	Pn0	50
11	Pxover	0.15
12	Pmute	0.05
13	repeat_no	100
14	xsigma	1
15	MaxKVA_OH	400

Figure8. Constants sheet

Step 4:
Each load is connected to the nearest substation. A distance constrain (100m) between each two substation is assumed. If this distance is less than 100m, the substation with lower connected load is dismissed.
Step 5:
All first population is determined randomly regarding to their capacity and also specified place. In this case study the number pf it is considered as 50.
Step 6:
After running the algorithm and creating some additional chromosomes using various GA operands, the five best chromosomes are selected for the next iteration.
Step 7:
This step (step 6) is repeated and in each iteration the cost function is calculated until to find the best chromosome with the minimum cost.
Step 8:
All steps 5-7 are repeated with a reduced number of total substations until its minimum required number.
Step 9:
Find the minimum value of costs which is saved in step 8 and it is considered as final answer.

4. Formulation of Problem

In step 7, 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:

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

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.

5. Software Features

The software which is developed for this simulation has the following features:

- Genetic Algorithm Based in Optimization
- High speed in Calculations
- Filtering of Excess Candidate Substations in Pre-calculation
  - Regarding to Substation Distance Limitation
  - Regarding to Total Connected Load Limitation
- Separate Capability for Exist and Candid Substations
- Separate Capability for Overhead and Ground Substations
- Separate Capability for Different Zones of City
- Various Parameters are considered in Cost Function
  - Substation Parameters
  - Feeder Parameters
- User friendly input/output format
  - Excel sheets for inputs
  - GIS Based for outputs

6. Results

The proposed algorithm in this paper is tested on city of BAM which is destroyed in irritant earth quick in 2003 in the middle of Iran.

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

Also all possible location for substations is marked in the map as candidate substations which are shown in figure 9.

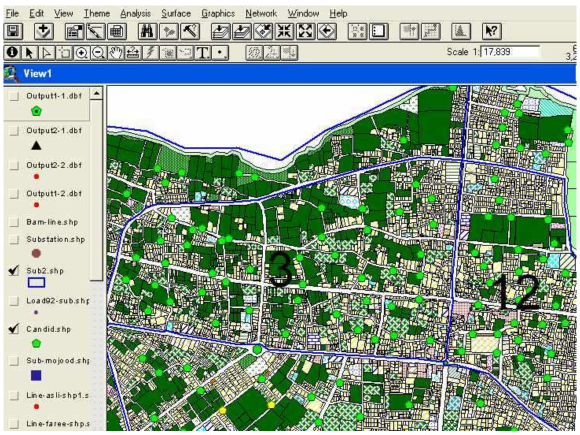


Figure9. Candidate locations for substations

After running the algorithm and calculating location and size of substations, they are placed on a geographic map by Arc view which is geographic managing software. The results are shown in figure 10.

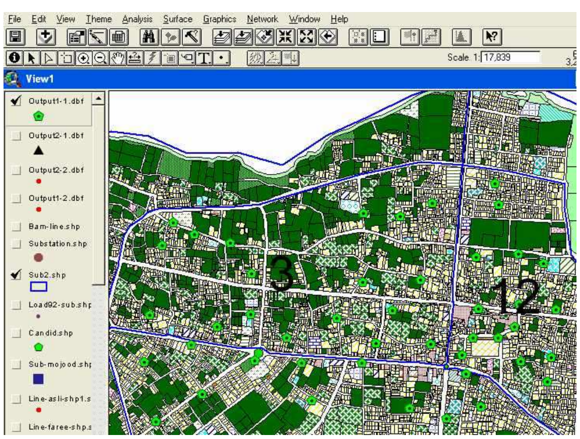


Figure10.
Substation location and size on the geographic map

In addition all connected load to a specific substation are highlighted around their substation in GIS map as in figure 11.

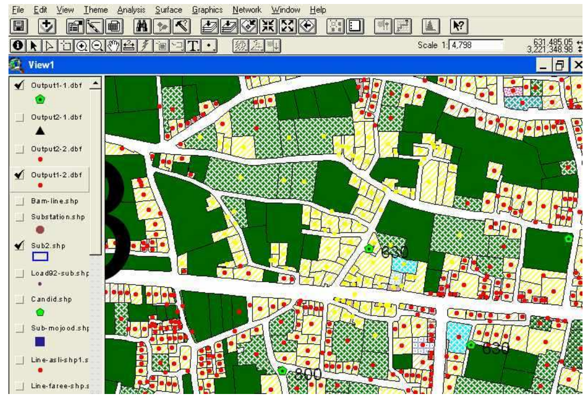


Figure11. Load connected to a specific substation after running the program

7. Conclusion

In this paper a new method is presented for finding optimum size and location of distribution substation by genetic algorithm and its software is developed.

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.

For the future research it is recommended to work more on cost function and add some additional parameters to cover executing problems. In addition it is suggested to expand more software features such as dividing Overhead trances and Ground trances and related flexibilities.

8. Acknowledgment

The author is grateful to Islamic AZAD University for all supports and also MOSHANIR, Power Electric Consultant Engineering Company for all cooperation.

References

[1] Yuan-Yihhsu, Jiann-Liang Distribution Planning Using A knowledge-based Expert system, IEEE Transaction on Power Delivery, Vol.5, No.3.July 1990, PP1514-1519

[2] Poonam Singh, Elham B. Makram, Warren P. Adams″ a New Technique for Optimal time-dynamic distribution and Feeder Planning″

Electric Power System research 17 (1998) pp. 197-204

[3] Dailtongwei, Yu Yixin, Huang chunhua, Wang chengshan, Ge shaoyun″ optimal planning of distribution substation locations and sizes. Molded and Algorithm IEEE TENCON'93 Beijing, pp 351-354

[4] ZHOU Quan, Sun Caixin, CHEN Guoqing, DENG Oun and Liaoruigin″ GIS Baled Distribution System Spatial Load Forecasting and the Optimal Planning of Substation Location and Capacity″ National Power Energy Conference 2002 IEEE Proceeding, pp 885-889

[5] Shan Jahiral Islem, Mohd Wazir Mustafa, Ismail Itasun″ Optimal Source Substation Location Selection in Radial Distribution Networks″ National Power Energy Conference 2004 proceedings Kuala Lumpur Malaysia, pp 278-283

[6] H. Najafi, Sh. Javadi ″Optimal location and Number of Automatic Switches in Distribution Networks ″ 4^{th} WSEAS National Power Engineering Systems Conference 2005 proceedings, Rio de Janiro, Brazil.

[7] Nikos E. Mastorakis, "Solving Differential Equations via Genetic Algorithms", Proceedings of the Circuits, Systems and Computers '96 (CSC'96), Piraeus, Greece, July 15-17, 1996, 3rd Volume: Appendix, pp.733-737

[8] Nikos E. Mastorakis, "Genetic Algorithms and Nelder-Mead Method for the Solution of Boundary Value problems with the Collocation Method", Proceedings of the 5th WSEAS Int. Conf. on SIMULATION, MODELING AND OPTIMIZATION, Corfu, Greece, August 17-19, 2005 (pp690-694)

[9] Nikos E. Mastorakis, "Unstable Ordinary Differential Equations: Solution via Genetic Algorithms and the method of Nelder-Mead", Proceedings of the 6th WSEAS International Conference on SYSTEMS THEORY and SCIENTIFIC COMPUTATION (ISTASC'06), Elounda, Ag.Nikolaos, Crete, Greece, August 18-20, 2006

[10] Nikos E. Mastorakis, "The Singular Value Decomposition (SVD) in Tensors (Multidimensional Arrays) as an Optimization Problem. Solution via Genetic Algorithms and method of Nelder-Mead", Proceedings of the 6th WSEAS International Conference on SYSTEMS THEORY and SCIENTIFIC COMPUTATION (ISTASC'06), Elounda, Ag.Nikolaos, Crete, Greece, August 18-20, 2006