Fuzzy Based Distribution Planning Technique

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Abstract: **A fuzzy logic based distribution planning technique is proposed in this paper. In this paper a proposal for a method for locating an optimum site for a substation which has the minimum distance from the various load points is given further the conductor layout to connect the various load points using the fuzzy logic technique is suggested in this paper. By combining the GA and the fuzzy logic technique it is possible to optimize the locations of substation and the conductor layout. Cost associated with conductor layout as well as the capacity of the substations and the distance of the load point from the substation has been considered while determining the optimal conductor layout.**

The results of the discussed techniques will lead to a configuration of substation that will minimize substation construction cost. It will further lower long range distribution expenses as it will lead to optimum feeder path.

The algorithm and simulation is carried out in MATLAB environment. The application of the proposed methodology to a case study is presented. The technique thus developed helps in better project management and plays a vital part in helping deliver corporate strategy.

Key words: Power distribution planning, fuzzy logic technique, optimization methods.

I. INTRODUCTION

Decision making features occurs in all the fields of the human activities such as scientific and technological and affects every sphere of the life. Engineering design, which entails sizing, dimensioning, and detailed element planning is also not exempt from its influence.

Basically we have been following traditional search technique for solving non linear equations. Normally, any engineering problem will have large number of solutions out of which some of are feasible and some are infeasible. The designer's task is to get the best solution out of the feasible solutions. The complete set of feasible solutions constitutes feasible design space and the progress towards the optimal design involves some kind of search with in the space (combinatorial optimization). The search is of two kinds, namely deterministic and stochastic.

In the case deterministic search, algorithms such as steepest gradient methods are employed (using gradient concept), where as in stochastic search, random variables are introduced. Whether search is deterministic or stochastic, it is possible to improve the reliability. Algorithm varies according to the transition rule used to improve the result.

Non traditional search and optimization methods have become popular in engineering optimization problems in recent past. These algorithms include:

1. Simulated annealing.
2. Ant colony optimization.
3. Random cost.
4. Evolution strategy.
5. Genetic Algorithm.
6. Cellular automata.

Genetic algorithms are good at taking larger, potentially huge, search spaces and navigating them looking for optimal combinations of things and solutions which we might not find in a life time.

Genetic algorithms are very different from the most of the traditional optimization methods. Genetic algorithms need design space to be converted into genetic space. So, genetic algorithms work with a coding of variables. The advantage of working with a coding variable space is that coding discretizes the search space even though the function may be continuous. A more striking difference between genetic algorithms and most of the traditional optimization methods is that GA uses a population of points at one time in the contrast to the single point approach by traditional optimization methods. This means that GA processes a number of designs at the same time. As we have seen earlier, to improve the search direction in the traditional optimization techniques, transition rules are used and they are deterministic in nature but GA uses randomized operators. Random operators improve the search space in an adaptive manner.

Three most important aspects of using GA are:

1. Definition of objective function.
2. Definition and implementation of genetic representation.
3. Definition and implementation of genetic operators.

Once these three have been defined, the GA should work fairly well beyond doubt. We can, by different variations, improve the performance, find multiple optima or parallelize the algorithms.

Genetic algorithm has been used in case of distribution planning. Since the expenditure of network expansion in distribution system is very large, planners have been trying their best seeking efficient methods to solve the problem of distribution planning. The problem of distribution planning involves optimum locations of substation and sizes of feeders to meet the requirement of load demands under various constrains such as substation and feeders capacity and network configuration. The available literature consists of work of only few researchers on the field of distribution planning. Most of them are based on mathematical programming such as transportation, transshipment algorithms [8, 9], mixed integer programming [10], dynamic programming [11] etc. Unfortunately only near optimal solutions have been obtained by these mathematical programming methods because almost every method has made some approximations on the model of distribution planning, moreover these methods are often complicated and time consuming.

In the work done by K.K.Li and T.S. Chung [3] genetic algorithm have been used to find the optimum location of substation to meet the load demands of 13 load points whose coordinates and MVA demands are given. Similar work has been carried out by Belgin Turkay and Taylan Artac [1] , work has also been carried out by J.F.Gomez *et.al.*,[2]. In all the above cases planning of laying the feeders or distribution planning has been done either by man machine interface or heuristic algorithm. The papers further don't give any option of the second, third or further optimum location of a substation which may be needed in real life scenario because it may not be feasible to construct the substation in the location obtained due to various constraints. During such cases we should explore the possibilities of the second, third and so on optimum locations.

A complete survey for the solution of the planning problem of primary distribution circuits can be found in [15] and [16]. Initially methods were mainly based upon the generation and evaluation of possible solutions, oriented to small size problems, and requiring important efforts for the production of the alternatives to be evaluated. Among these the heuristic zone valuation and the generation of service areas methods may be mentioned. They rely completely upon the experience of the planning engineer and have the disadvantage that the best alternative may not be considered.

The planning problem of primary distribution networks has been basically stated as a classical mixed integer linear programming problem, where an objective function that includes both the investment and the operation cost of the network, is minimized subject to technical constraints related with the characteristics of the electric service [17]. This formulation includes binary variables linked to the fixed costs associated to some of the decision variables as well as linear approximations to represent the variable costs. Stated as such the classical branch and bound techniques [17] have a natural application. Although the continuous research and improvement of these techniques keeps them as an alternative always to be considered, the linear approximations as well as the combinatorial complexity of the problem question their application to electric systems of real dimensions due to the requirements of excessive computing resources. This is the main reason for the application of alternative approaches, such as those classified as metaheuristic methods that are able to locate good solutions with reduced computational effort.

In order to reduce the computation requirements of the branch and bound optimization technique, the identification of the set of variables that affects most of the results was proposed in order to reduce the complexity of the mathematical model [16] however a linear approximation of the variable costs is required and excessive solution times are reported as the number of binary variables increases.

Heuristic search methods have been developed [17], [18], showing faster performance than the conventional optimization techniques but with some limitations in the goodness of the solutions to the problem that are obtained.

In [20] an open loop planning procedure is proposed where an expert system based upon the use of geographical information is applied to automate the selection of the primary and secondary circuit routes. GA's have also been applied to the solution of this problem, reducing the solution time and enhancing the obtained results [15],[18],[21],[22],[23]. In [22] a solution methodology based upon a GA is proposed for the design of primary distribution circuits considering multiple system expansion stages, where a special coding procedure is proposed to reduce the number of unfeasible solutions evaluated by the algorithm. These methodologies have been improved significantly. An evolutionary programming algorithm is presented in [25], considering the uncertainties of the possible scenarios. In [16] and [24] the potential of the GA is shown in comparison with classical optimization techniques to solve the planning problem. An integer variable coding scheme was used to facilitate the consideration of different conductor sizes and substation sizes also new genetic operators were proposed to improve the performance of the algorithm. In [26] the approach is expanded to consider the multiple development stages as well as multiple objectives. In [31] an evolutionary approach is applied to the design of a medium voltage network using a detailed model of the network.

Going through the literature survey, here in this paper we suggest a method where we can have the optimum location of all the substations required to meet the load points. Here the optimum location as well as the load distribution is done plainly by using the GA technique and no necessary assumption is made further we suggest the conductor layout to connect the various load points using the fuzzy logic technique. We can further have the second, third and so on optimum location of the various substations which may be necessary because many a times it's not possible to have the substation in the first optimum location due to some constraints.

II. PROPOSED METHODOLOGY

Let us have a system where thirteen load points are present which are to be fed from two substations depending on the capacity and the load demands. The layout of feeders for feeding the thirteen load points depends on the following factors:

i). Substation Capacity
ii). Load demands
iii). Distance of the load from the substation
iv). Expenditure incurred in laying the feeder

Substation location has been obtained by the use of genetic algorithm. In case its not feasible to have the substation at the optimum location obtained by the use of genetic algorithm, the second optimum location is considered which too is obtained by the use of genetic algorithm. The distribution layout is done using fuzzy logic rules. The pictorial representation of the problem is as shown in fig 1.

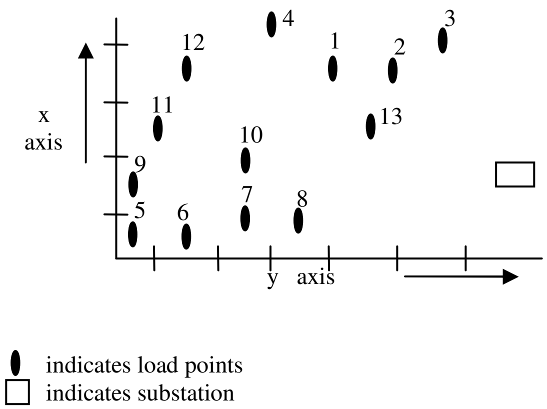

Fig 1 (Representation of the problem)

Load points	X coordinates	Y coordinates	Load demands in MVA
1	8	7	5
2	10	7	12
3	11	8	7
4	6	9	5
5	1	1	7
6	3	1	11
7	5	2	8
8	7	2	3
9	1	3	4
10	5	4	12
11	2	5	6
12	3	7	3
13	9	5	4

Table 1 (Showing the coordinates of the various load points with their respective load demands in MVA)

Let us assume thirteen load points with the above mentioned coordinates. GA technique has been used to obtain the optimum location. In the algorithm ten chromosomes are chosen of eight bit each and two points cross over is opted in this method. The first four bits of the chromosomes indicates the x coordinates of the substation and the next four bits indicates the y coordinates of the substation. The fitness function treated in the problem is the product of the distance of substation from the load point and the MVA rating of the individual load points. The Genetic algorithm iterations are repeated till the fitness value of the chromosomes match till 80% to 90%.

Now for the conductor layout a fuzzy system is developed. To determine whether node Y is to be connected to substation or to node X the following factors have been considered:

a). Distance of node Y from the substation and node X.

b). Cost incurred in laying the conductor from substation and node X.

The membership function of all the factors is of similar types we show one of such membership function as in fig 2.

dist_node$_Y$_sub

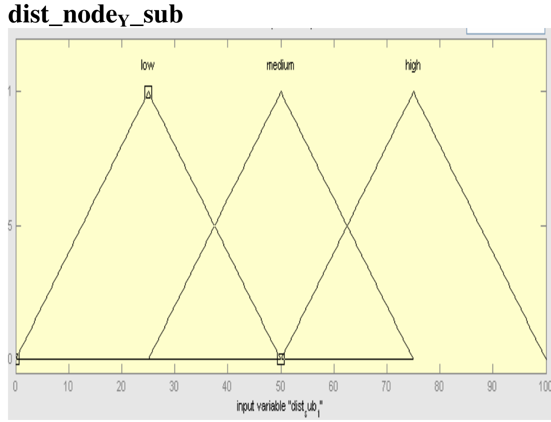

Fig 2 (Showing the membership function used for the distance of node Y from Substation)

We have similar such membership function for the distance of node Y from node X, for cost incurred in laying the conductor from node X and cost incurred in laying the conductor from substation.

Using these membership function and the rules stated below we decide as to whether node Y is to be connected to substation or to node X. The simulation has been carried out in matlab environment.

Here

dist_node$_Y$_sub indicate distance of node Y from substation.

dist_node$_Y$_node$_X$ indicate distance of node Y from node X

cost_node$_X$ indicate cost incurred in laying the conductor from node X

cost_sub indicate cost incurred in laying the conductor from substation

Fuzzy Rules:

		dist_node$_Y$_sub, cost_sub								
	Φ	00	01	02	10	11	12	20	21	22
dist_ node$_Y$_ node$_X$, cost_ node$_X$	00	Φ	NX	NX	NX	NX	NX	NX	NX	NX
	01	S	Φ	NX	S	NX	NX	NX	NX	NX
	02	S	S	Φ	S	S	NX	S	NX	NX
	10	S	NX	NX	Φ	NX	NX	NX	NX	NX
	11	S	S	NX	S	Φ	NX	S	NX	NX
	12	S	S	S	S	S	Φ	S	S	NX
	20	S	S	NX	S	NX	NX	Φ	NX	NX
	21	S	S	S	S	S	NX	S	Φ	NX
	22	S	S	S	S	S	S	S	S	Φ

Table 2 (Showing the fuzzy rules to determine the conductor layout)

0 indicate low 1 indicate medium and 2 represent high in the membership function shown in figure 2 above.
S and NX denote to which node Y can be connected based on the conditions as that of substation capacity, distance of node Y from the substation and node X and the cost incurred in laying the conductor from the substation and node X.
Φ denote that node Y can be connected to either substation or node X.
S denote that node Y can be connected to substation.
NX denote that node Y can be connected to node X.
Proceeding in the manner represented above when connection for node Z is to be decided we need to consider the following membership functions.
dist_node$_Z$_sub indicate the distance of node Z from substation.
dist_node$_Z$_node$_Y$ indicate the distance of node Z from node Y
dist_node$_z$_node$_X$ indicate the distance of node Z from node X
cost_sub indicate cost incurred in laying the conductor from substation
cost_node$_Y$ indicate cost incurred in laying the conductor from node Y
cost_node$_x$ indicate cost incurred in laying the conductor from node X
All the membership functions are of similar nature as shown in fig. 2.

The process is to be repeated for all other nodes that are to be connected. The number of input for each simulation keeps on increasing as for every node the number of options keeps on increasing.

III. Case Study

For the thirteen load point problem representation shown in Fig 1 a optimum location is obtained by the use of genetic algorithm whose flowchart is as shown.

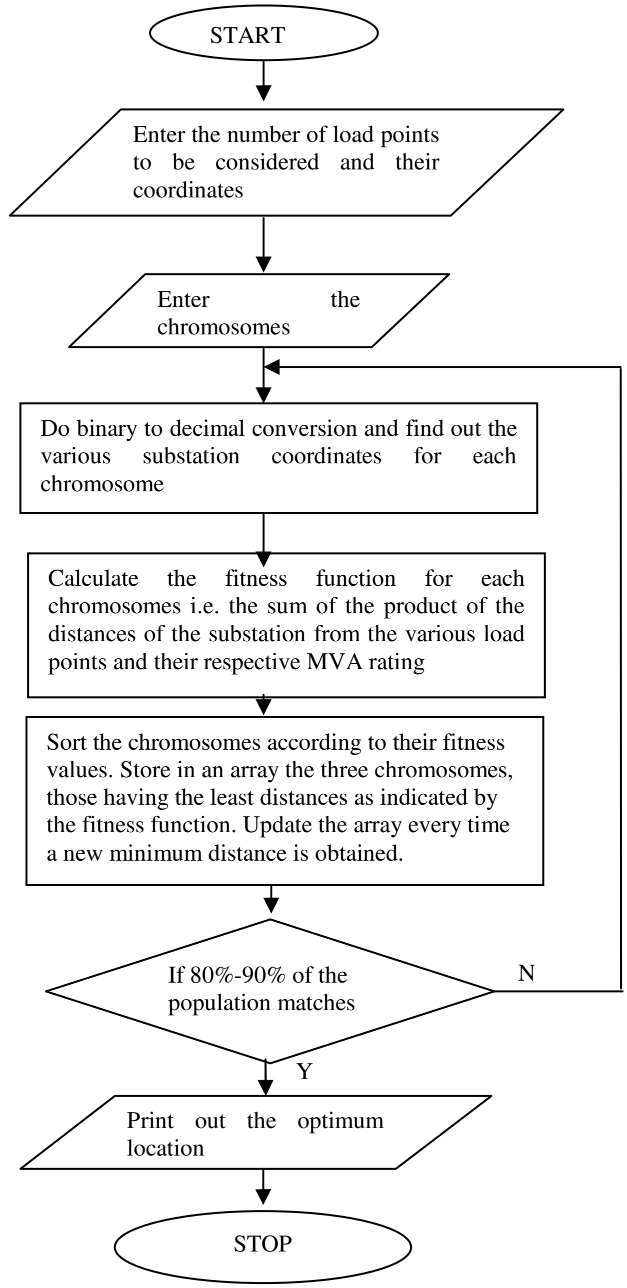

Fig 3 (Shows the flow chart of the program used)

After running the program with the given coordinates of the load points and their respective load demands the optimum location that was obtained using the GA technique was coordinates (5 3). The result in tabular form is as shown

Load points	X coordinates	Y coordinates	Load demands in MVA	Dist. From Sub station
1	8	7	5	5
2	10	7	12	6.4
3	11	8	7	7.8
4	6	9	5	6
5	1	1	7	4.4
6	3	1	11	2.8
7	5	2	8	1
8	7	2	3	2.2
9	1	3	4	4
10	5	4	12	1
11	2	5	6	3.6
12	3	7	3	4.4
13	9	5	4	4.4

Table 3 (The result in tabulated form)

Let us assume the capacity of the first substation is 55 MVA and that of substation two is 30 MVA. Now to get the optimum location of the two substation we sort the result obtained in ascending order as per their distances from the location thus obtained (5 3) and in case the distance turns out to be same for two load points we give preference to the MVA rating.

Load points	X coordinates	Y coordinates	Load demands in MVA	Dist. From Sub station
7	5	2	8	1
10	5	4	12	1
8	7	2	3	2.2
6	3	1	11	2.8
11	2	5	6	3.6
9	1	3	4	4
12	3	7	3	4.4
13	9	5	4	4.4
5	1	1	7	4.4
1	8	7	5	5
4	6	9	5	6
2	10	7	12	6.4
3	11	8	7	7.8

Table 4 (The result sorted in ascending form)

As per the sorted list now we allot load points (7 10 8 6 11 9 12 5) to substation 1 and load points (13 1 4 2 3) to substation 2. Now with the allotted load points we again run the genetic algorithm to get the optimum location of substation one and two. The fitness function remains the same for choosing the location for the two substation i.e. product of load demand and distance from the substation.

We again precede taking ten chromosomes of eight bit each and two point crossover. The first four bit represents the x coordinate and the last four bit represents the y coordinate. Moving in the fashion of the flowchart given in fig 12. We get the location for substation 1 as (3 2) and that of substation 2 as (9 7). In case the optimum location cannot be met due to some constrains we can get the second or third optimum location whose values are stored in the arrays. By increasing the array size we can have the forth, fifth and so on optimum locations.

Applying the fuzzy rules we get the conductor layout as shown below.

Lets start of with substation 1 the node nearest to substation 1 is node 6, so first connect node 6 to substation 1, next nearest node to substation is node 7, using fuzzy rules stated above node 7 gets connected to substation and not to node 6 (here node X is node 6 and node Y is node 7). Proceeding in the manner we get the conductor layout is as shown.

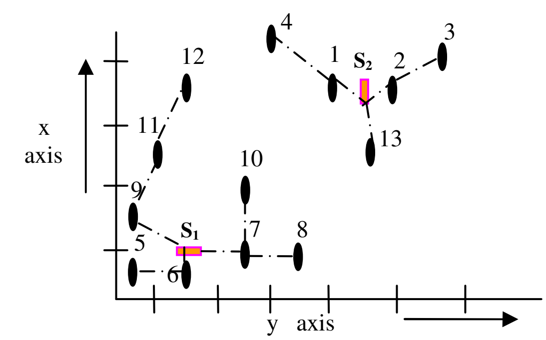

Fig 4 (Showing the final conductor layout from the substations)

IV. Conclusion

Using the method stated above we can have an optimum location of substation from where the distances of the various load points will be minimum and from where the cost incurred in meeting the load demands will be optimum as it depends on the factor distance × MVA demand of the load. The method gives an optimum conductor layout considering the factors such as:

i). The distance between two nodes.

ii).The cost involved in laying the conductor.

In this method first priority is given to cost incurred in laying the conductor and next to the distance. The method also helps us to have the second, third and so on optimum locations in case we have constrains with the first optimum location of a substation.

V. Discussion

The method thus suggested here may be further improved to make it more close to optimum. Some new methodologies for clustering the load points or for choosing the load points to be fed by a substation may be thought of. Here in the suggested method the fuzzy rules are to be referred every time a node needs to be connected to some new nodes or to a substation and the factors keeps on increasing with every new node. Further research for new methodology may overcome this drawback.

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