Available online at www.elixirpublishers.com (Elixir International Journal)

Electrical Engineering

Elixir Elec. Engg. 62 (2013) 17464-17468

ISSN: 2229-712X

Evaluation of substation location using geographical information system: A case study

Shabbiruddin[1,*], Amitava Ray[2], Karma Sonam Sherpa[1] and Sandeep Chakravorty[3]

[1]Department of Electrical & Electronics Engineering, Sikkim Manipal Institute of Technology, Sikkim, India.
[2]Department of Mechanical Engineering, National Institute of Technology, Silchar, India.
[3]Department of Electrical Engineering, Baddi University of Emerging Science and Technology, H.P., India.

ARTICLE INFO

Article history:
Received: 16 July 2013;
Received in revised form:
20 August 2013;
Accepted: 31 August 2013;

Keywords
Sting,
Cluster,
Feeder.

ABSTRACT

This paper deals with the development of technique for planning the location of a substation. In this work, we propose a STatistical INformation Grid based (STING) approach for distribution of load points with suitable allocation of substation. A real- life data, that is, the power map of Bihar is taken for the planning purpose. At present there are six substations located in Bihar. Google Earth is used for finding the location (latitude and longitude) of the demand sites. By implementing STING algorithm and simulating it in MatLab we have determined five substations that can feed the entire Bihar area with minimum distribution losses. The substations determined by STING algorithm are centrally located for a particular area (cluster). The methodology will be a very useful tool for power distribution planners.

Introduction

Distribution system planning basically involves the optimization of both locations and sizes of a new substation and feeders to meet expected demand while satisfying specified constraints, e.g. substation capacity, feeder thermal capacity and voltage drop. The optimal distribution system planning is considered a complex problem due to the number of variables for a network configuration which is, in practice, related to geographical characteristics. There are a lot of parameters that are included in future network design and also in determining of substation location and capacity and also feeder routing. It is usually done using heuristic rules which are based on knowledge of distribution engineers in this design. Most of these designs have been done to reduce investment and optimize power loss. In general, the decisions in the planning of power distribution system includes that the location of substations, allocation of load and allocation of substation capacity is optimum. Few researchers have worked on the field of distribution planning [1], [2] so as to determine the optimum location of substation[3]. In the work done by K.K.Li and T.S. Chung [4] 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 [5], work has also been carried out by J.F.Gomez *et.al.* [6]. A complete survey [2] of the proposed techniques for the solution of the planning problem of primary distribution circuits can be found. In all the above cases planning of laying the feeders or distribution planning has been done either by man machine interface or heuristic algorithm. Most of the work done by the researchers are based on mathematical programming such as transportation, transshipment algorithms [7], [8] mixed integer programming , dynamic programming etc. The location of the substation feeding the various load points can be determined by means of STING (STatistical INformation Grid-based clustering method) [9], [10] which efficiently process many common "region oriented" queries on a set of points. Heuristic search methods have been developed [11], 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 [11] and [12], the comparison with classical optimization techniques to solve the planning problem in a very complete and detailed formulation considering the nonlinearity of the cost function is discussed. Clustering provides a method that shows how to group data points that populate some multidimensional space into a specific number of different clusters [13]. Clustering can also be thought of as a form of data compression, where a large number of samples are converted into a small number of representative prototypes or clusters [14], [15]. There has been a lot of research in the area of locating substations near the higher demand density [16], [17]. Optimum location of substations can be examined through the integration of spatial modeling and GIS [18], [19]. The integration of mathematical model with GIS is done and ways are found through which GIS can further assist in analyzing such a problem by making use of demand density according to the population volume as a proxy to the attributes being developed with network analyst [20], [21]. GIS ability as spatial data processing and analyses tools available can be used to manage a wide range of information [22]. The integration has the potential to become a powerful analytical toolbox enabling regional and social scientists to gain fundamental insight into the nature of spatial structures of regional development.

Problem definition:

Every consumer in a utility system should be supplied from the nearest substation. Supplying each consumer from the nearest substation, i.e., distribution-delivery distance must be as short as possible, which reduces the feeder cost, electric-power loss costs and service-interruption exposure.

Tele:
E-mail addresses: shabbiruddin85@yahoo.com

There is a need to find the optimum substation location using some methodology. The technique should be flexible for the best alignment of substations. Loads are allocated to a given substation according to the distance from substation to load points, substation available capacity and also technical characteristics of the electric distribution network. The main objective is to meet demand with the minimum transportation cost, defined by the sum of the product of the loads by its distance to the substation. This cost must be optimized for all substations in the area and using this method cost can be reduced considerably as there is less transmission cost considering the minimum transmission length of each load point from the substation. This substation location planning takes in consideration to protect the surrounding habitat.

Propose Methodology

Architecture of STING clustering algorithm

The spatial area is divided into rectangular cells. Levels of cells correspond to different levels of resolution and these cells form a hierarchical structure. Each cell at a high level is partitioned to form a number of cells of the next lower level. Statistical information of each cell is calculated and stored beforehand and is used to answer queries. For each cell, we have attribute-dependent and attribute-independent parameters. The attribute independent parameter is:

$$n = \sum_{0}^{i} n_i$$

n=number of objects (points) in this cell

We assume that the attribute-dependent parameters have numerical values for each object. We have the following five parameters for each cell for ***each*** numerical attribute:

m=mean of all values in this cell

$$m = \frac{\sum_{0}^{i} m_i}{n}$$

s =standard deviation of all values of the attribute in this cell

$$s = \sqrt{\frac{\left(s_i^2 + m_i^2\right) n_i}{n}}$$

min = the minimum value of the attribute in this cell, *max* = the maximum value of the attribute in this cell. *Distribution* = the type of distribution that the attribute value in this cell follows. The value of *distribution* could be either assigned by the user if the distribution type is known before hand.

Data and Analysis

The area of Bihar on which the work is done is shown in fig 1.

Using Google Earth Platform the snapshot of area of Bihar can be taken. Which is actually the demand site of the whole region. The view can be seen in fig 2

The substations presently in function is marked with the help of Matlab platform. Presently six substations are functioning at the transmission level in the area. The existing substations are marked and shown in fig 3

Using the Google Earth platform, coordinates for all the existing load points in Bihar were generated and applied with MatLab software to plot them in 2D plane taking x axis as the longitude and Y axis as latitude. The latitude and longitude of each 76 load points are shown in Appendix. According to latitude and longitude all the load points are plotted and shown in fig 4.

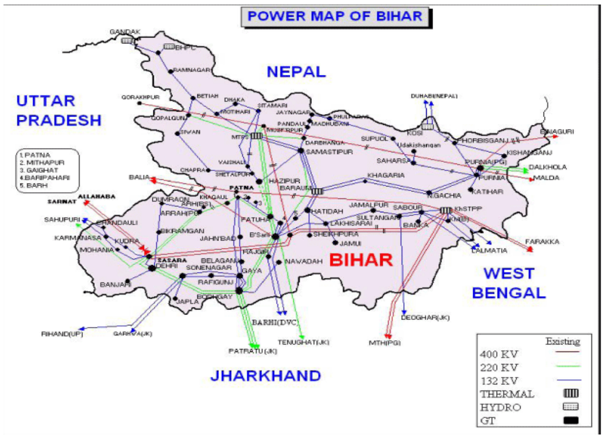

Fig 1: Map of Bihar showing the location of loads points and the existing substation locations

Fig 2: Demand sites in Bihar

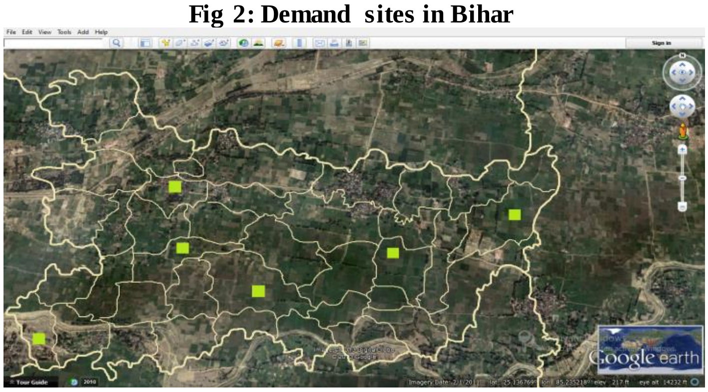

Fig 3 : Existing substations in Bihar

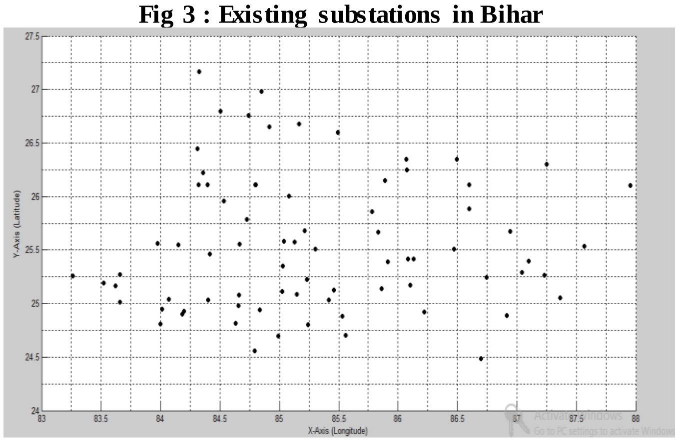

Fig 4: The 76 load points of Bihar in MatLab.

Clustering of data

Clustering was done in MatLab according to the STING algorithm and five different clusters were obtained which are represented with different colors. The clustering was done depending upon the density and minimum area containing a large number of load points, the same is shown in fig 5.

Appendix

Sl. No.	X co-ordinate (longitude in degrees)	Y co-ordinate (latitude in degrees)
1	84.182	24.901
2	84.013	24.945
3	83.661	25.012
4	83.263	25.258
5	83.623	25.166
6	83.523	25.189
7	84	24.808
8	83.661	25.268
9	84.399	25.033
10	84.631	24.814
11	84.99	24.694
12	84.792	24.559
13	85.561	24.704
14	85.244	24.802
15	85.533	24.883
16	85.023	25.116
17	84.836	24.942
18	84.655	24.978
19	84.659	25.081
20	85.418	25.034
21	85.459	25.125
22	85.032	25.35
23	84.667	25.557
24	84.415	25.463
25	85.232	25.228
26	85.15	25.084
27	86.221	24.922
28	86.103	25.172
29	85.861	25.142
30	86.745	25.244
31	86.915	24.885
32	86.7	24.483
33	87.363	25.054
34	87.234	25.263
35	87.045	25.291
36	87.249	26.3
37	86.084	25.419
38	85.914	25.392
39	85.306	25.508
40	85.127	25.578
41	85.039	25.579
42	83.977	25.564
43	84.149	25.551
44	87.566	25.537
45	87.956	26.106
46	87.1	25.4
47	86.471	25.512
48	86.6	25.883
49	86.601	26.108
50	86.943	25.676
51	86.133	25.416
52	85.835	25.665
53	85.781	25.862
54	85.89	26.149
55	86.072	26.249
56	86.071	26.346
57	84.071	25.041
58	86.496	26.348
59	85.216	25.683
60	85.081	26.003
61	84.727	25.784
62	84.535	25.96
63	84.357	26.219
64	84.312	26.448
65	85.495	26.598
66	85.167	26.678
67	84.916	26.65
68	84.742	26.758
69	84.503	26.799
70	84.197	24.926
71	84.85	26.983
72	84.325	27.164
73	84.32	26.11
74	84.395	26.11
75	84.8	26.11
76	84.803	26.11

These clusters efficiently include even those points in their respective areas which were not connected to the transmission system earlier making the transmission system better organized.

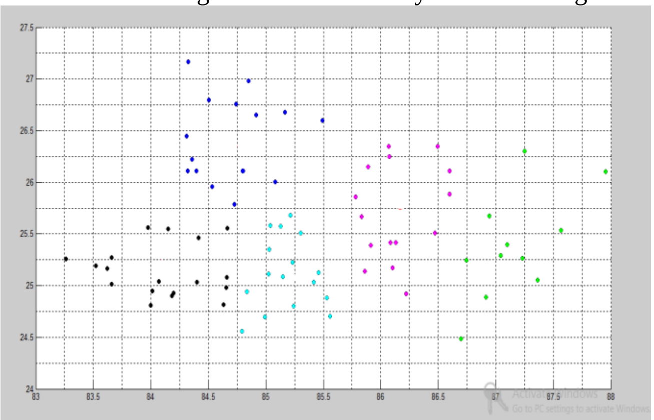

Fig 5: Clustered load points after applying STING algorithm

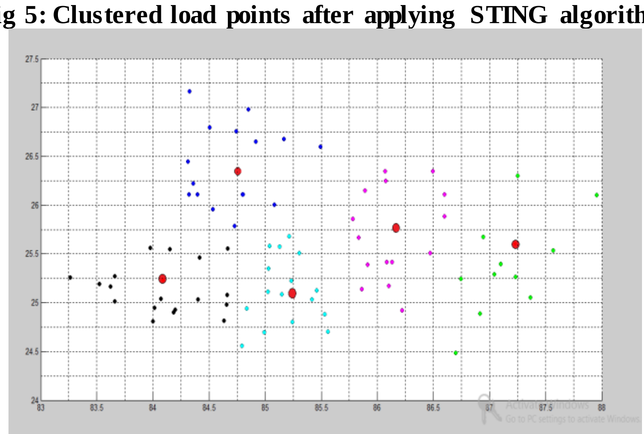

Fig 6: location of substations

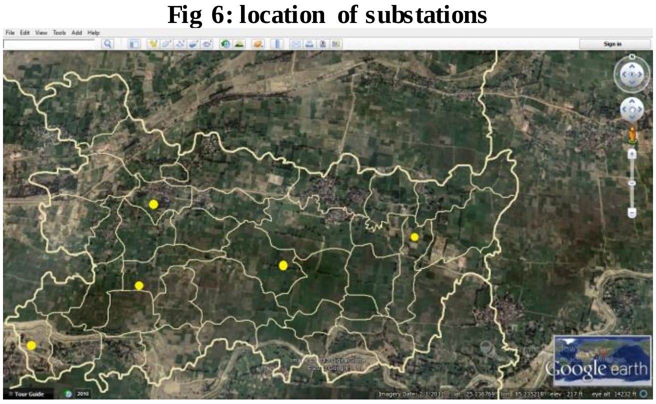

Fig 7: Substation locations proposed through STING

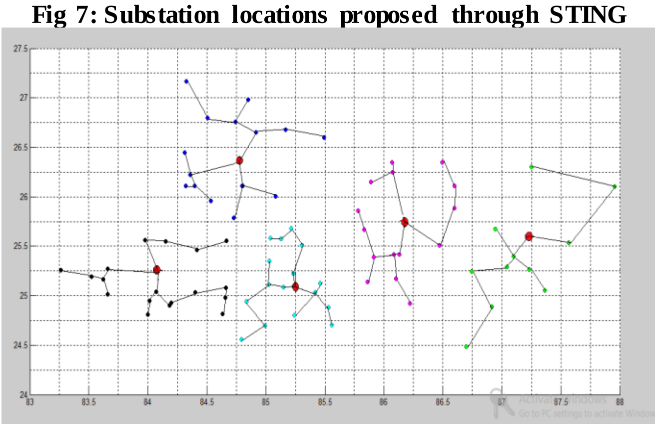

Fig 8: Generation of feeder system

Location of substations

In a Euclidean space, the members of a cluster can be averaged, and this average is called the centroid. Here the centroid method was used for locating the optimum location of the substations. In the result shown in fig 6 the red points represent the substation location. These substation locations are such that they are at a minimum distance from every load point. This ensures greater stability and efficiency. As every load point is at a minimum distance from the substation, the cost of transmission line will also be minimal.

Hence through STING algorithm the new substation locations along with the load points which it will feed were found out to be at: Dinara, Barauni, Nalanda, Ashapur and Murtiganj. The same areas are marked and shown in fig 7

Feeder system:

A feeder line is a peripheral route or branch in a network, which connects smaller or more remote nodes with a route or branch carrying heavier traffic. Feeder system helps in efficient transmission of power to all the load points. Hence forth 2 and 3 feeder systems are designed. The same is shown in fig 8. The present feeder routing is based on the minimum distance of the substation to the load points. Also the minimum distance one load points to other load points.

Conclusion

The STING clustering method used centroid method to find the optimum substation location. In this method the distance between each load point and substation is taken as minimum which reduces the transmission cost and also cuts down the power losses during transmission. The substation as the centroid of the cluster ensures increased stability and balance. The approach suggested has much less computational cost than other approaches and is simpler than all the existing methods. The technique is shown as a flexible and powerful tool for the distribution system planning engineers. Therefore, our proposed approach is very interesting not only considering the quality of the solutions, but mainly from the computational cost point of view. Results are very promising and encourage further research for the preliminary location of substations. The methodology allows a significant reduction of workload for engineers in charge of planning the electric power distribution network. Finally, we believe that the methodology proposed can be useful for any other facility location problems.

Reference:

[1] Shabbiruddin, Sandeep chakravorty "Load Distribution Among Distribution Substation and Feeder Routing Using Fuzzy Clustering and Context Aware Decision Algorithm", Journal of Electrical Engineering, PP. 57-67. Volume-11 2011.

[2] N. G. Boulaxis and M. P. Papadopoulos, "Optimal feeder routing in distribution system planning using dynamic programming technique and GIS facilities, "IEEE Trans. PWRD 17, No. 1, pp. 242-247, January 2002.

[3] Sandeep Chakravorty, M.Thukral, "Choosing Distribution Sub Station Location Using Soft Computing Technique", Proceedings of International Conference on Advances in Computing, Communication and Control – 2009, pp. 53-55.Mumbai. India. 2009.

[4] K.K.Li and T.S.Chung, "Distribution Planning Using Rule Based Expert System Approach," IEEE International Conference on Electric Utility Deregulation and Power Technologies(DRPT 2004), April 2004.

[5] Belgin Turkay and Taylan Artac, "Optimal Distribution Network Design Using Genetic Algorithm," Electric Power Components and Systems, 33; 513-524, 2005

[6] J.F.Gomez et al., "Ant Colony System Algorithm for the Planning of Primary Distribution Circuits," IEEE Transactions on Power Systems, Vol. 19, No. 2, May 2004.

[7] Poonam Singh, Elham B. Makram, Warren P. Adams " A New Technique for Optimal time dynamic distribution and Feeder Planning" Electric Power System research pp.197-204. 1998

[8] J. L. Devore. "Probability and Statistics for Engineering and the Sciences", 3rd edition. Brooks/Cole Publishing Company, Pacific Grove, California, 1991.

[9] Wei Wang, Jiong Yang, and Richard Muntz, "STING : A Statistical Information Grid Approach to Spatial Data Mining" University of California, Los Angeles, 1997.

[10] R. Ng and J. Han. "Efficient and effective clustering method for spatial data mining". Int. Conf Very Large Databases, pp. 144- 155, Santiago, Chile, September 1994.

[11] S.K.Khator and L.C. Leung, "Power Distribution Planning: A review of models and issues," IEEE Trans. Power Syst., vol. 12, pp 1151-1159, Aug. 1997.

[12]Sandeep Chakravorty, M.Thukral "Optimal Allocation of Load Using Optimization Technique", Proceedings of International conference CISSE. Bridgeport.USA. pp. 435-437, 2007.

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

[14] Sandeep Chakravorty, Smarajit Ghosh, "An Improvised Method for Distribution of Loads and Configuration of Distribution Sub Station", International Journal of Engineering Research and Industrial Applications. Vol.2, No. II, pp. 269-280. 2009.

[15] Sulochana Baruah, Swati Raj, Shabbiruddin, Amitava Ray, Sandeep Chakravorty "Analysis of Influencing Factors for Costs on Substation Siting Based on DEMATEL Method", International Conference on Modelling, Optimisation and Computing (ICMOC 2012), Procedia Engineering, Science Direct, Volume 38, PP. 2564-2571, 2012.

[16] Abel, D., Taylor, K., and Kuo, D. "Integrating Modelling System for Environmental Managemental Information Systems", SIGMOD - Quarterly Publication of the Association for Computing Machinery Special Interest Group on Management of Data, 26(1): 5 - 10. 1997

[17] Bailey C.T "A review of statistical spatial analysis in geographical information systems", Book: Spatial Analysis and Fotheringham. S and Rogerson .P 2:13-40. 2001

[18] Rigaux P, Scholl M, Voisard A, "Spatial Databases With Applications to GIS", Academic Press a Hardcourt Science and Technology Company, San Francisco. 2002

[19] Jankowski, P., "Integrating geographical information systems and multiple criteria decision making methods", Int. J. Geo. Inf. Sys. 9(3), 251-273, 1995.

[20] Bennett, D.A. "A Framework for the Integration of Geographica Information Systems and Modelbase Management", International Journal of Geographical Information Science, 11(4): 337 - 357. 1997

[21] Goodchild, M.F., "A spatial analytical perspectives on geographic information systems "International Journal of Geogaphical Information Systems, 1, 327-334. 1987

[22] Openshaw, S., "A spatial analysis research agenda, Handling Geographical Information", Masser, I. and Blakemore, M.(Eds.), London: Longman.1991

[23] Miller H. J. and Shaw S. "Geographic Information Systems for Transportation Principles and Applications"., Oxford University Press. 2001