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# Selection of Sub-Station site for Greater NOIDA India by Analytical Hierarchy Process (AHP)

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**ABSTRACT**

Electric distribution sub-stations have an important role in energy distribution management. The sub-stations transfer energy from 400V to 20000V in centre of consumption. More decision in utilizing of this sub-station is basically assert on one attribute and most of time some important aspects may be forget. In this paper, the analysis is done by using Analytical Heirachy Process (AHP) method (taking four basic attributes involving Load forecast, Land availability, Cost of land and closeness to load centre) for selecting the best suitable location for placement of sub-station so, an example of a place Greater NOIDA, India, is taken which will grow into metropolis by 2021 as presented in a survey. The place comprises all the major power consuming sectors viz. residential, commercial and industrial. As in this study, the intention is to optimize the position of sub-station for construction of a new sub-station. As to conclude of this study the decision will help the electric managers and designers to be able to get multi aspects of decision making and improve the design, locations and grid reconstruction of the distribution sub-stations.



## Introduction

An electric transmission network is a multi-billion dollar investment in infrastructure that evolves and expands over decades as new generation is constructed and old generation is retired, and as the patterns and density of electric loads increase and alter with urban and suburban land developments. Planning for India's transmission grid should be driven by a range of requirements: enabling and maintaining overall grid reliability; relieving congestion on transmission lines; providing economic benefits through open access to transmission services and wholesale market operations; and facilitating achievement of regional and national energy and environmental policy goals. The decision of the location of sub-stations is a crucial aspect of the distribution system planning, with a strong impact on the investment and operation costs. The location of a sub-station site depends upon several factors, such as the voltage levels, voltage regulation, sub-station costs, primary feeders, distribution transformers, and subtransmission costs, etc. In general, some considerations that should be taken into account for the selection of the location for a distribution sub-station, such as [1], [2]:

• The sub-station must be as close as possible to the load center of its respected service area, in order to reduce the product of the load and the distance from the sub-station. Proper voltage regulation can be obtained without taking extensive measures.

• Provide proper access for incoming subtransmission lines and outgoing primary feeders and also allow for the future growth.

• Provide enough space for the sub-station expansion in future.

• Comply with land use regulations, local ordinances, and neighbors.

• Reduce the number of customers affected by any service discontinuity.

• Other considerations, such as emergency, adapatability etc.

Several methodologies have been proposed in the literature for the solution of the electric distribution sub-station location problem. In an optimization approach based on the well known Dijskstra's minimum path algorithm and Ford and Fulkerson's transportation algorithm are applied [3],[4],[5]. A branch-and-bound model is proposed for the selection of the sub-station location in [6]. An iterative optimization procedure is proposed, using successive linearizations as well as heuristic relaxation and bounding procedures [7]. In general, different mathematical programming formulations and techniques have been proposed and applied to the selection of location of electrical distribution sub-stations [8]–[10]. However, most of these deterministic methodologies are based on the analysis of a constant load level, normally assumed as the maximum load level.

The location and capacity of the sub-stations are important in choosing the suitable position. Depending on intensity of this sub-station and high investment, decision making around these sub-station repositioning has high significance, on the other hand time extension will change the condition and in the best premier design after some changes in consumer volume and location the status should be reviewed. These systems are suitable for approximate reasoning, especially for the system with a mathematical model that is difficult to develop. Fuzzy logic allows decision making with estimated values under incomplete or uncertain information [11].

According to the work by K.K.Li and T.S. Chung [14] genetic algorithm have been used to find the optimum location of sub-station to meet the load demands of 13 load points whose coordinates and MVA demands are given. Similar kind of work has been carried out by Belgin Turkay and Taylan Artac [12] and J.F.Gomez et.al.,[13]. In all the above cases planning of laying the feeders or distribution planning has been done either by man machine interface or heuristic algorithm. In [15] and [16] the potential of the GA's is shown in comparison with classical optimization techniques to solve the planning problem in a very complete and detailed formulation considering the

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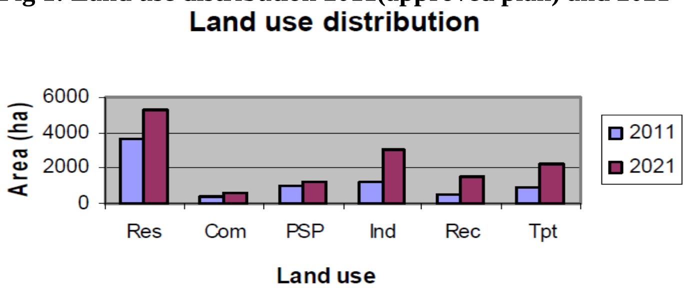
nonlinearity of the cost function, the limits of the voltage magnitudes and a term in the objective function to take into account the reliability of the system, reporting significant improvements in the solution times. An integer variable coding scheme was used to facilitate the consideration of different conductor sizes and sub-station sizes also new genetic operators were proposed to improve the performance of the algorithm.

MCDM is a modeling and methodological tool for dealing with complex engineering problems. Decision makers face many problems with incomplete and vague information in MCDM problems since the characteristics of these problems often require this kind of information. In this research Analytical Hierarchy Process (AHP) technique is used because, it gives them better performance for particular applications. An example of a well developing metropolis Greater NOIDA is taken which presently has an industrial and residential suburb of Delhi and will grow into a metropolis by 2021. It will become a self contained industrial city with complimentary business, trade and commerce, residential, recreational and institutional activities.

The land allotted for various activities in this developing city is following:

**Fig 1: Land use distribution 2011(approved plan) and 2021**




Res: Residential, Com: Commercial, PSP: Pb. & Semi Pb., Industial, Recreational, Transportation

The major consumption of power is from three sectors namely Residential, commercial and Industrial. These three areas are considered for finding out the best location of the sub-station. In the present work Analytical Hierarchy process (AHP) is used for ranking the best location of sub-station taking four major influencing factors: Load forecast, Land availability, Cost of land and closeness to load centre.

**Load forecast**: Load forecasts can be divided into three categories: short-term forecasts which are usually from one hour to one week, medium forecasts which are usually from a week to a year, and long-term forecasts which are longer than a year. The forecasts for different time horizons are important for different operations within a utility company. The natures of these forecasts are different as well. For example, for a particular region, it is possible to predict the next day load with an accuracy of approximately 1-3%. However, it is impossible to predict the next year peak load with the similar accuracy since accurate long-term weather forecasts are not available. For the next year peak forecast, it is possible to provide the probability distribution of the load based on historical weather observations. It is also possible, according to the industry practice, to predict the so-called weather normalized load, which would take place for average annual peak weather conditions or worse than average peak weather conditions for a given area. Weather normalized load is the load calculated for the so-called normal weather conditions which are the average of the weather characteristics for the peak historical loads over a certain period of time. The duration of this period varies from one utility to another.

**Land availability:** With scarce land availability there is a growing need for reduction of land use for setting up of transmission systems, particularly in Metros, hilly and other urban areas. Power Grid has established State-of-the-art Gas Insulated Substations (GIS), which requires less space (about 80% reduction) i.e. 5-6 acres as compared to conventional substation which generally requires 30-40 acres area. POWERGRID has already commissioned 400/220kV GIS at Maharanibagh in Delhi, Kayankulam in Kerala. Presently GIS are being implemented at many such locations (Gurgaon, Navi Mumbai, Koteswar etc). The performance is very satisfactory.

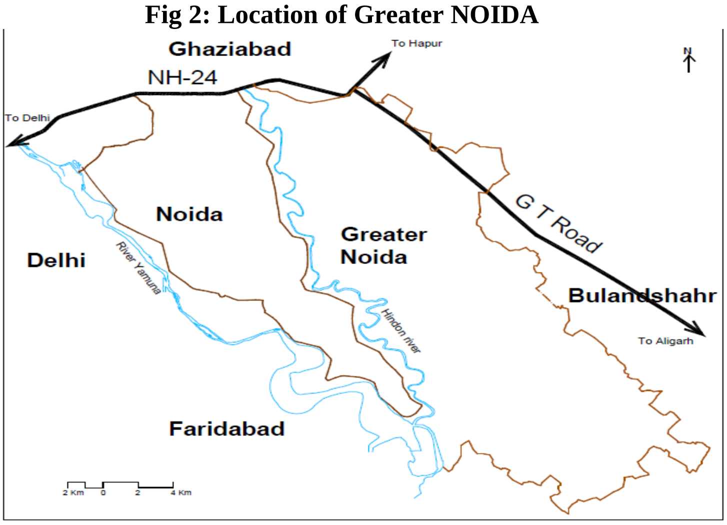
**Cost of Land**: Many factors influence land value. The common saying is that real estate is all about location, location, location. Location is important, but there are other considerations also which influence the cost.

**Closeness to load centre**: The site should be near the load center keeping in view the future load growth. In a State that is continuing to develop and grow there is an increasing demand for electricity across the power network. As homes continue to use more power and industry, communities and businesses continue to grow, more substations will be required. Zone substations are likely to be in close proximity to suburban areas as these particular substations convert the power to the lower voltages necessary for transfer through to homes or offices.

**Problem definition:**

In this project a well developing area and studied around location is chosen. A group of team has investigated the area of Greater NOIDA and its surrounding places. Personal interview was done on the questionnaires prepared for the proposed work.

**Fig 2: Location of Greater NOIDA**




As a strict proven matter in electric distribution engineering the major consumption of power is from industrial, commercial and residential area. we know that whatever we move sub-station to centre of consumption the voltage drop will be lower than before and power loss also will amend but simultaneously related to increasing of number of sub-station the total cost will increase and also the beauty of network will change. So the important questions are:

• What are the weights of any criteria?
• How and how much we can extend this strategy?
• How can be chose the best option?

Depending on improvement of four criteria we needed to present a strategy to enable compromise between these criteria to choose best alternative for positioning of sub-stations.

**Proposed methodology**

***Analytical Hierarchy process (AHP)***

The Analytic Hierarchy Process (AHP) is an approach that is well suitable for dealing with complex systems related to making a choice from among several alternatives and which provides a comparison of the considered options. The AHP is based on the subdivision of the problem in a hierarchical form. The AHP helps the analysts to organize the critical aspects of a problem into a hierarchical structure. By reducing complex decisions to a series of simple comparisons and rankings, then synthesizing the results, the AHP not only helps the analysts to arrive at the best decision, but also provides a clear rationale for the choices made. The objective of using an analytic hierarchy process (AHP) is to identify the preferred alternative and also determine a ranking of the alternatives when all the decision criteria are considered simultaneously.

Briefly, the step-by-step procedure in using AHP is the following:

1. Describe decision criteria in the form of a hierarchy of objectives. The hierarchy is structured on different levels: from the top (i.e. the goal) through intermediate levels (criteria and sub-criteria on which subsequent levels depend) to the lowest level (i.e. the alternatives);
2. The weight of the criteria, sub-criteria and alternatives as a function of their importance for the corresponding element of the higher level. For this purpose, AHP uses simple pairwise comparisons to determine weights and ratings so that the analyst can concentrate on just two factors at one time.
3. After the judgment matrix has been developed, a priority vector to weight the elements of the matrix is calculated. This is the normalized eigenvector of the matrix.

The use of AHP instead of another multi-criteria technique is due to the following reasons:

1. Quantitative and qualitative criteria can be included in the decision making.
2. A large quantity of criteria can be considered.
3. A flexible hierarchy can be constructed according to the problem.

**Solution methodology:**

Based on the algorithm first the hierarchy is developed keeping criteria and decision alternatives.

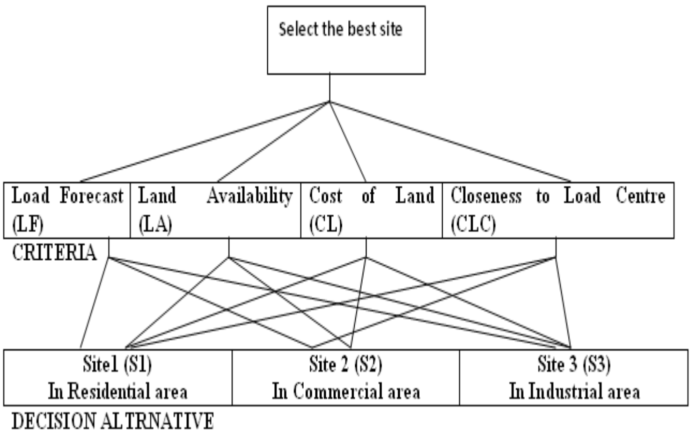



**Fig 3: Hierarchy developed for the problem**

The Hierarchy developed is applied with the algorithm of AHP for finding out the best suitable location for the sub-station.

**Algorithm application and result analysis:**

**Nine point scale chosen for pairwise comparison matrix**

| Alternative | Numerical Rating |
|---|---|
| Extremely Preferred | 9 |
| Very Strongly Preferred | 7 |
| Strongly Preferred | 5 |
| Moderately Preferred | 3 |
| Equally Preferred | 1 |

**Load forecast**

**Pairwise comparison matrix**

| | S-1 | S-2 | S-3 |
|---|---|---|---|
| S-1 | 1 | 1/3 | 1/7 |
| S-2 | 3 | 1 | 1/5 |
| S-3 | 7 | 5 | 1 |

**Normalized matrix**

| | S-1 | S-2 | S-3 |
|---|---|---|---|
| S-1 | 1/11 | 1/19 | 35/329 |
| S-2 | 3/11 | 3/19 | 35/235 |
| S-3 | 7/11 | 15/19 | 35/47 |

**Priority Vector**

| | |
|---|---|
| S-1 | (1/11+1/19+35/329)/3 = 0.0833 |
| S-2 | (3/11+3/19+35/235)/3 = 0.1931 |
| S-3 | (7/11+15/19+35/47)/3 = 0.7235 |

**Land availability**

**Pairwise comparison matrix**

| | S-1 | S-2 | S-3 |
|---|---|---|---|
| S-1 | 1 | 1 | 1/5 |
| S-2 | 1 | 1 | 1/3 |
| S-3 | 5 | 3 | 1 |

**Normalized matrix**

| | S-1 | S-2 | S-3 |
|---|---|---|---|
| S-1 | 1/7 | 1/5 | 1/3 |
| S-2 | 1/7 | 1/5 | 5/9 |
| S-3 | 5/7 | 3/5 | 5/3 |

**Priority Vector**

| | |
|---|---|
| S-1 | (1/7+1/5+1/3)/3 = 0.2254 |
| S-2 | (1/7+1/5+5/9)/3 = 0.2994 |
| S-3 | (5/7+3/5+5/3)/3 = 0.9936 |

**Cost of land**

**Pairwise comparison matrix**

| | S-1 | S-2 | S-3 |
|---|---|---|---|
| S-1 | 1 | 3 | 1/3 |
| S-2 | 1/3 | 1 | 1/5 |
| S-3 | 3 | 5 | 1 |

**Normalized matrix**

| | S-1 | S-2 | S-3 |
|---|---|---|---|
| S-1 | 3/13 | 1/3 | 5/23 |
| S-2 | 1/13 | 1/9 | 3/23 |
| S-3 | 9/13 | 5/9 | 15/23 |

**Priority Vector**

| | |
|---|---|
| S-1 | (3/13+1/13+5/23)/3 = 0.1750 |
| S-2 | (1/13+1/9+3/23)/3 = 0.1061 |
| S-3 | (9/13+5/9+15/23)/3 = 0.6334 |

**Closeness to load centre**

**Pairwise comparison matrix**

| | S-1 | S-2 | S-3 |
|---|---|---|---|
| S-1 | 1 | 1/5 | 1/7 |
| S-2 | 5 | 1 | 1/5 |
| S-3 | 7 | 5 | 1 |

**Normalized matrix**

| | S-1 | S-2 | S-3 |
|---|---|---|---|
| S-1 | 1/13 | 1/31 | 35/329 |
| S-2 | 5/13 | 5/31 | 35/235 |
| S-3 | 7/13 | 25/31 | 35/47 |

**Priority Vector**

| | |
|---|---|
| S-1 | (1/13+1/31+35/329)/3 = 0.0718 |
| S-2 | (5/13+5/31+35/235)/3 = 0.2316 |
| S-3 | (7/13+25/31+35/47)/3 = 0.6965 |

**Criteria**

| |
|---|
| Load Forecast (LF) |
| Land Availability (LA) |
| Cost of Land (CL) |
| Closeness to Load Centre (CLC) |

**Pairwise comparison matrix**

| | LF | LA | CL | CLC |
|---|---|---|---|---|
| LF | 1 | 7 | 1/5 | 1/3 |
| LA | 1/7 | 1 | 3 | 1/5 |
| CL | 5 | 1/3 | 1 | 1/5 |
| CLC | 3 | 5 | 5 | 1 |

**Normalized matrix**

| | LF | LA | CL | CLC |
|---|---|---|---|---|
| LF | 7/64 | 21/40 | 1/46 | 5/26 |
| LA | 1/64 | 3/40 | 15/46 | 3/26 |
| CL | 35/64 | 1/40 | 5/46 | 3/26 |
| CLC | 21/64 | 3/20 | 25/46 | 15/26 |

**Priority Vector**

| | |
|---|---|
| LF | (7/64+21/40+1/46+5/26)/4 = 0.2121 |
| LA | (1/64+3/40+15/46+3/26)/4 = 0.1330 |
| CL | (35/46+1/40+5/46+3/26)/4 = 0.1989 |
| CLC | (21/64+3/20+25/46+15/26)/4 = 0.3996 |

**Priority Vector**

**Criteria [ 0.2121 0.1330 0.1989 0.3996 ]**

| | LF | LA | CL | CLC |
|---|---|---|---|---|
| S1 | 0.0833 | 0.2254 | 0.1750 | 0.0718 |
| S2 | 0.1931 | 0.2994 | 0.1061 | 0.2316 |
| S3 | 0.7235 | 0.9936 | 0.6334 | 0.6965 |

**Overall Priority**

| | |
|---|---|
| S1 | 0.1111 |
| S2 | 0.1944 |
| S3 | 0.6899 |

Industrial area appears to be the overall recommendation.

**Conclusion**

Multi-criteria decision making represents an interest area of research since most real-life problems have a set of conflict objectives. In this paper Analytical Hierarchy Process (AHP) technique is used in distribution electric network, considering to important criteria we arranged possible options to get better result in summation, then depending on the different factors influencing the location of sub-station the best suitable area is selected. Industrial area (S3) appears to be the most suitable area for the placement of sub-station in comparison to Residential (S1) & Commercial (S2). This is a proven technique of decision making in electric engineering in combination with basic of power electrical knowledge.

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