جامعة الملك فهد للبترول والمعادن
King Fahd University of Petroleum & Minerals

الشركة السعودية للكهرباء
Saudi Electricity Company

OPTIMUM SITE SELECTION OF TRANSFORMER SITES IN PLOT PLANS

(SAUDI ELECTRICITY COMPANY)

(Final Paper)

By
Hadi Y. Al-Kanani
ID # 901369

For
CRP 514: Introduction to GIS
Term 041 – 11th Offer

Course Instructor:
Dr. Baqer Al-Ramadan

January 02, 2005

ABSTRACT

Saudi Electricity Company (SEC) devotes a great deal of its activities for planning purposes of its resources. This includes the proper forecasting of the electrical network to be used for electrifying new residential, commercial, agricultural, and industrial areas. Using Municipality maps, SEC has a method of determining the required network (cables and equipment) needed to electrify a certain plot plan. The primary objective of this paper is to explain the potential application of a certain process (optimum transformer sites selection in plot plans) that can be simulated by a Geographic Information System (GIS) in order to use resources more effectively and efficiently.

There are certain criteria that are followed to obtain the transformers sites in plot plans. These include the area of the parcels in the plot plan and the distance between the source (the transformer) and each parcel. SEC has been using a manual method to accomplish this process that takes a lot of time and effort from the design engineer. SEC has a premature experience with GIS that started long back but did not payoff yet because of the insufficient support for the system. However, SEC is currently conducting a pilot project for part of its franchise area in Dammam using Star GIS. The system will be linked to a Work Management System (WMS) to formulate a comprehensive system that can be used to perform all functions of Engineering, Construction, Operation, and Maintenance of SEC electric network. However, this report will highlight all aspects about the process of transformers sites selection that can be modeled by the GIS system. It will explain the GIS assistance highlighting all the potential capabilities of the system to provide the necessary tools to accomplish the task of modeling.

INTRODUCTION

The fast and large growth of residential and commercial Plot Plans in the Eastern Province of Saudi Arabia necessitates the least cost and timely electrification of Plot Plans. Saudi Electricity Company (SEC) main objective is to deliver power to its customers with safe, reliable and minimum cost. A systematic procedure has been developed and implemented to achieve the mentioned objective. The backbone tool incorporated in this procedure is SEC method for optimum site selection of transformers which is the main and decisive factor in the economical electrification of plot plans.

The number of Plot Plans being received by SEC is increasing rapidly. It is estimated that approximately 200 Plot Plans on average are being studied every year in Dammam area. The average number of lots (lands/parcels) per Plot Plan is about 300 lots. Supplying power to these Plot Plans on time, in the most efficient way required effective planning procedure and implantation. SEC has been applying a manual method for transformer sites selection in new plot plans. It is the Engineer responsibility to make the most economical design with the least quantities needed to fulfill the Plot Plan requirement of electric power in the most reliable way. The design of the electrical network for power supply to residential and commercial customers in a new area (Plot Plans) must obey certain criteria and limitations to be followed. Engineers take long time to study and allocate the proper number of transformers required to electrify each plot plan. Because of this and other reasons, another way has to be developed in order to utilize the existing resources.

The objective of this term paper is to offer a proposal that can be later developed to simulate the process of selecting the optimum number and sites of transformers by a GIS model. This GIS model shall be able to automate the tedious existing manual method of performing the sites selection. This will lead to better utilization of resources, allocation of funds and eventually providing customers with power reliably in the most economical way. Accomplishing this model will save great deal of efforts and time to reach to the same results. Eventually, this will lead to the most optimal and most economical design of the entire electrical network of SEC.

This report will give a background and a brief history of SEC practices about electrification of new Plot Plans in Dammam area. Problem of optimizing the electrification of Plot Plans will be defined. Also, it will define and explain SEC process of transformers sites selection in new plot plans. For the purpose of illustration, an example will be shown using the case of Saudi Aramco Plot Plan # 1/367 located in Doha Area in Dhahran. SEC experience with GIS will be highlighted. Explanation of how GIS can help formulating and solving the problem in question will be presented. Finally, results and recommendations are communicated.

BACKGROUND

Saudi Electricity Company- Eastern Region Branch (SEC-ERB) is the largest Power Generating Electric Branch among all SEC Branches in Saudi Arabia. SEC-ERB consists of four operating areas: Dammam Operating Area (DOA), Hasa Operating Area (HOA), Northern (Jubail) Operating Area

(NOA), and Fourth (Skaka) Operating Area (FOA). DOA is the highest populated area and customers are increasing rapidly every year. Moreover, the number of newly developed Plot Plans is increasing accordingly.

Fifteen years ago, there was no electrification network planning, instead distribution substations locations (insets for transformers) in the Plot Plan were taken via negotiation with local authority (Amara & Municipality). However, the allocated insets were always less than what was required which led to deficiencies in power supply to customers. Improper planning resulted in a very costly electrification projects, high maintenance cost, and low quality service.

In 1986, the local authority of the Eastern Province decided that each new Plot Plan should be sent to utility companies (Electricity, Water & Sewage, Telephone, Etc…) to study for their service requirements before the final approval of the Plot Plan.

Electricity is generated in Power Plants located usually in remote areas (sea sites) at 13.8KV voltage level. Then, it will be stepped up to a high level voltage (380KV, 230KV, 132KV, or 115KV) in order to be transmitted through Transmission Lines (TL) to residential areas or cities. This power will be transformed to a lower voltage level (69KV) via Bulk Supply Points Substations (BSP). From the BSP, it will be distributed to Grid Stations (G/S) in which the voltage will be stepped down to 13.8KV. This 13.8KV power will be distributed through Medium Voltage cables (MV Network) to smaller substations (S/S) that will transform the voltage to distribution level voltage of 220/127V. This is the voltage that will be used by end customers for their equipment (DEG-2 1997).

The usual voltage level that feeds the Plot Plan with power is the 13.8KV voltage through primary cables (3x300mm2 AL XLPE) connecting the S/Ss of the Plot Plan to the source of supply. Secondary cables (4x300mm2 AL XLPE) will be extended from the S/Ss to a distribution panel called Minipillar (MP). This MP will supply power through service cables (4x70mm2 AL XLPE) to Kilo Watt Hour Meters (KWH Meter). This KWH Meter is the source of power given by SEC to the customer. It is the interface point between SEC and the customer to measure the consumption and produce bills accordingly (DEG-2 1997).

PROBLEM DEFINITION

Any plot plan consists of a number of lots that form blocks with streets between them. The planning engineer responsibility is to make the most economical design with the least quantities needed to fulfill the plot plan requirement of electric power in the most reliable way. The most important factor is to install the least (optimum) number of transformers in the most appropriate sites in the plot plan. However, to do this, certain criteria and limitations must be followed and obeyed. These are demand load (required electric power) of each lot (customer) in the plot plan for, the electric ratings of equipment to be used, and the voltage drop (distance from source to customers). For these reasons, the following objectives shall be achieved:

- Individual demand load shall be met
- Voltage drops are within allowable limits

- Equipment ratings shall not be exceeded

The individual demand load can be obtained from a predetermined values issued by the Ministry of Water and Electricity. These values (Appendix-A) show numerous values of demand load equivalent to area of each lot. From the plot plan approved municipality drawing, total covered area (TCA) of each customer will be calculated by checking the allowable construction area and maximum number of stories (usually set by Municipality). Then, the Ministry tables will be used to decide upon the demand load per customer. Also, Additional calculation shall be made to find out the demand load for a group of customers (DEG-1 1997).

The distance between the source of power supply and the customer shall always be designed in a way that the customer receives the minimum power needed at nominal voltage to operate his load. This means that voltage must not be less than 95% of its nominal value (SEC standard). That means that Voltage Drop (VD) shall not exceed 5% of the nominal supply voltage in order to deliver reliable power to customers at all times. Using the voltage drop limitation, the maximum distance to feed the furthest customer from a transformer can be calculated (DEG-2 1997).

After formulating the limits of the maximum individual/ group demand and maximum distances to feed the lots, LT distribution can start the by allocating a S/S in the load center of a partial area of the plot plan and usually place the 1^{st} S/S in the services lots. From this S/S extend a 4x300mm2 cable by the shortest distance to a place a MP between 2 lots that can feed the maximum number of lots as per the reference table. After finishing from distributing the MPs with the maximum feed, start distributing for the next maximum feed and continue the same way until the 1st S/S. Then, based on the 1st S/S, choose another S/S site to continue feeding the lots that were not fed from the 1st S/S. Continue doing the same process until you finish allocating S/S sites for the whole plot plan .

For any utility company, there exist standards for the equipment to be used for any particular task, which will limit the design to the specifications of these equipments. This is usually to avoid the labor, maintenance and operation costs associated in having various types of equipment. In SEC, the equipment ratings shown in Table-1 are standard types that are used for supplying power to customers. It is to be noted from the table that the MV cable is a 3x300mm2 cable that is connecting the proposed S/Ss in the Plot Plan with each other and with the source coming from outside. The MV cable will carry the Total Demand Load of the Plot Plan. The S/S rating is 500KVA, which is the total capacity and has 8 outgoing LV cables. The maximum load on an LV cable is 130KVA with a VD of 3.5% to the MP. It has 6 outgoing service cables. Finally, the KWH Meter is interface point with the customer lot which represents the customer load (DEG-2 1997).

.

TECHNICAL DATA OF ELECTRIC COMPONENTS			
COMPONENT	# OF CKTS (EA)	MAX. LOAD (KVA)	MAX. V.D. (%)
MV Cable	NA	TDL	NA
Substation	8 / 14	500 / 1000	NA
LV Cable	NA	130	3.5
Minipillar	6	130	NA
Service Cable	NA	56	1.5
KWH Meter	1	DL	NA

Table 1: Technical data of electric network equipment

It is required to find out the optimal quantities of equipment and cables to be used in electrifying the Plot Plan. In the following paragraphs, the process procedure is explained:

1. From the new plot plan drawing received form Municipality, we get the information about the percentage covered area of lot that is to be constructed, the number of stories, and the use of each lot either residential, commercial or others.

2. Divide the plot plan into groups of similar lots according to lot area categorizing the big lots with same area as one group, small lots as one group, and commercial lots with same area as another group …etc.

3. Calculate the Total covered area (TCA) for each category according to Equation-1 below. Also, from Ministry table (see Appendix-A), get the ICMD equivalent to the corresponding TCA of each category of lots. Use this information to formulate a reference table (see Appendix-B) for the maximum length and load that can be supplied power from S/S's circuits or MP,s circuits. This can be done using equation-3 and equation-4 formulas for diversified load and VD calculations.

TCA = No. of Stories * % covered Area of lot * Area (Equation-1)

ICMD (diversified) = (No. of Customers * ICMD per Cust.) / DvF (Equation-2)

From S/S to MP (4x300mm2 cable):

VD= (ICMD (diversified) * Length) / 3238 (Equation-3)

From MP to KWH Meter (4x70mm2 cable):

VD= (ICMD per Customer * Length) / 920 (Equation-4)

4. After making all calculation and formulating the reference table, we will know the maximum number of customers that can be fed from each circuit and the maximum distance a MP can be placed from the S/S.

5. After formulating the table, we can start the LT distribution by allocating a S/S in the load center of a partial area of the plot plan and usually place the 1st S/S in the services lots. From this S/S extend a 4x300mm2 cable by the shortest distance to a place a MP between 2 lots that can feed the maximum number of lots as per the reference table. After finishing from distributing the MPs with the maximum feed, start distributing for the next maximum feed and continue the same way until the 1st S/S. Then, based on the 1st S/S, choose another S/S site to continue feeding the lots that were not fed from the 1st S/S. Continue doing the same process until you finish allocating S/S sites for the whole plot plan (DEG-2 1997).

6. there are certain tips that must be taken into consideration to complete the process:

   - Try to allocate most of the S/Ss in the services (gardens, parking, …etc).
   - Avoid allocating a S/S site in the mosque (Royal Decree).
   - Minimize the use of direct cable 3x300mm2 and allow for the relax use of 4x70mm2 cable.
   - For TCA beyond the table limit, ICMD= 80 KVA (Demand Load of 152.4KVA) must be chosen as equivalent ICMD for that TCA.
   - Evaluate the final number of S/Ss by comparing the total capacity of the S/Ss to the total Demand Load of the plot plan based on number of lots.

Saudi Aramco Plot Plan # 1/367 located in Doha Area in Dhahran is taken as an example for the purpose of illustration. This residential Plot Plan consists of 187 lots (that is 187 customers). The allowable construction area is 60% of the lot area with a maximum of two stories per lot. These limitations are set by the Municipality and must be followed precisely as they play a decisive role in estimating the Demand Load of the lots/customers and hence the whole Plot Plan. To propose the S/S sites, the following steps will be followed:

1. From Municipality drawing of PP# 1/367, get the average area per lot which is found as 20X25 = 500 m2.

2. Calculate the Total covered area (TCA) as follows:

   TCA = 2 * 60 % * 500 = 600 m2

3. From Ministry table (see Appendix-A), get the ICMD equivalent to the corresponding TCA.

   ICMD (600m2) = 38.4 KVA

4. Use above data to formulate the reference table (see Appendix-B) for the maximum length and load that can be supplied power from S/S's circuits or MP,s circuits. This can be done using the equations-2, 3, & 4 mentioned previously for diversified load and VD calculations.
5. After making all calculation and formulating the reference table shown below (Table-2), we will know the maximum number of customers that can be fed from each circuit and the maximum distance a MP can be placed from the S/S.

			5%VD	**3.5% VD**				
TCA (m2)	No. of Cust. / ICMD (KVA) (diversified)		**1**	**2**	**3**	**4**	**5**	**6**
600	38.4	KVA	38.40	55.53	79.28	102.60	125.57	148.36
		L(m)	295	204	143	110	90	76

Table 2: Reference Table

6. After formulating the table, we can start the LT distribution by allocating a S/S in the load center of a partial area of the plot plan and usually place the 1st S/S in the services lots. From this S/S extend a 4x300mm2 cable by the shortest distance to a place a MP between 2 lots that can feed the maximum number of lots as per the reference table. After finishing from distributing the MPs with the maximum feed, start distributing for the next maximum feed and continue the same way until the 1st S/S. Then, based on the 1st S/S, choose another S/S site to continue feeding the lots that were not fed from the 1st S/S. Continue doing the same process until you finish allocating S/S sites for the whole plot plan. (See Appendix-C)

SEC EXPERIENCE WITH GIS

SEC started its first step with GIS almost 20 years ago. However, that start was very primitive and included only preparation of accurate digital maps for portions of SEC electric network in Dammam area. In fact that step was not successful and the project was terminated with no practical use or benefits. Recently, SEC initiated a pilot project to convert a selected area of Dammam into GIS maps that are linked with a Work Management System (WMS) containing all electric network databases. The project consists of data conversion from hardcopy maps into digital ones and functionality performance of SEC applications of Engineering, Construction, Operation, and Maintenance of electric network projects.

GIS has become an indispensable tool for many organizations. For example, GIS helps employees to perform their jobs and provide services to the public. Many advantages will be gained with this project. A major requirement in operating an electric distribution network is having accurate information. This inability to gain an accurate view of operations in the network had a negative impact on asset management. GIS can build a link between the distribution management system and their databases which will make old and new systems operate simultaneously doing the applications and function. Operations personnel can refer to the digital map, to plan maintenance and to design engineering changes to accommodate expansion and enhancements in the electric distribution network. New applications can also be considered for implementation at utility companies. These include a computer-aided dispatch system running off the GIS, which gets data from the WMS and outage management. Also, the Engineering Department can use off-the-shelf design package to run on top of the GIS. Other new automation technology can also be examined thanks to the enhanced system compatibility (Shaw 2004).

The GIS can help for tracking utility location-based spatial information related to a WMS. For GIS users to fully track equipment, they need access to the equipment specifications in the WMS. To avoid dual entry of large volumes of information in both systems, a link has to be developed between the systems to exchange the information. The biggest benefit of integrating the systems was in the work management side. All work orders can be developed in WMS can be tagged with a GIS location, typically a map page and a location ID. This makes it possible to better plan and schedule work by geographic area. It also allows the district to produce maps for failure analysis and required maintenance work (Shaw 2004).

GIS will save companies and public hundreds of hours through enhanced efficiency and service. GIS will increase the reliability of the base maps and data. It will increase the productivity of data collection and maintenance. It will make the data more accessible to the public by placing GIS on the Internet. This will also increase timeliness and production of mapping efforts. Internet access for the public will help free staff time to better serve the public. Also, Sister agencies will be better served by accessing the data. Putting a functional GIS system on Internet will greatly enhance accessibility to the public of the mapping and property data. This grant will fund Internet access to integrated map and property data usable through anyone's Internet browser. Internet access will help free staff time and provide better service to the public by allowing people to easily answer questions themselves. Other public agencies will be better served by Internet access to the data. The business community will have enhanced access to useful information, which can provide economic benefits to the community. Availability of the data to the public over the Internet will reduce the number automobile trips to the company offices for information (Hahne 2004).

As a potential application of GIS in utility companies, GIS can be developed to simulate a distribution substation design application to speed work flow. Engineers historically spent three months designing each substation. Engineers will develop a modular 3-D substation design application based on the CAD programming abilities. Output includes a cost estimate and a full set of construction drawings as well as material lists and purchase requisitions. Substation design times will be reduced from an average of three months to three hours.

Furthermore, the system can be utilized as a right-of-way application tool. An ultimate aim is making the system available to field personnel equipped with mobile computers and geographical positioning system (GPS) modules to enable them to quickly query where maintenance is required and determine the quickest route to get heavy equipment to the site. Information includes instantaneous access to environmental site constraints and landowner restrictions, weight and height limitations and preferred travel routes. GIS can also ties to engineering and procurement software, speeding up the process of getting engineered solutions to the site (Bush 1999).

GIS POTENTIAL FOR SITES SELECTION

The case of optimum site selection is a typical application of GIS that has been tackled by many professionals in fields of tourism, city planning, facilities planning. Dr. Al-Ramadhan case study of optimum tourism sites selection is one case in which certain criteria were set to allow GIS to choose the required sites according to these criteria (Al-Ramadhan 2003). However, throughout the search in the Internet, it is found that this issue has been either rarely tackled for electric transformers allocation in plot plans or it is part of a comprehensive GIS in which there is no substantial highlight on the issue. Considering the transformers sites selection process explained in the beginning of this report, GIS will be investigated for potential capabilities to automate, simulate and model the whole process of transformer distribution over the plot plan. The way GIS can be used to extract data about the lots areas to be used in calculating the demand load of each customer and the appropriate distance to feed them. After getting the criteria to distribute the transformers, the GIS system shall use certain logical expressions (based on fed information) to allocate the first transformer and distribute the electric cables up to the customers' lands. Then, it will continue the distribution process until feeding the whole plot plan.

In our investigation we will use ESRI product which is ArcGIS. It is known that any GIS software has the ability to read data from any given map. However, the size and type of data depends on the map format. In SEC, there are two types of maps; hardcopy and digital type. The digital maps are in the Microstation (.dgn) format.

We start by converting the dgn-formated map into ArcGIS by using the conversion tool. If ArcGIS is able to incorporate the map and read it, will automatically generate attribute tables for the map giving the area of all the parcels in the map. Additional table about the ICMDs (Ministry values table) has to be fed to the system and another map layer for the transformers has to be created. The transformers attributes (technical specifications and ratings) will also be entered into the system. If we were able to create the previously mentioned attributes, a link will be developed between the parcels areas and their corresponding ICMD.

After that, equations and logical expressions have to be entered into the system to create the reference table in order to limit maximum demand and distance. However, the first transformer site has to be fed manually to the system to be used as a reference to other sites. The system will start connecting all the parcels within the allowable distance (along roads) taking into consideration the allowable ratings of equipments and maximum demands of groups of parcels. After finishing the first site, the system should choose another site with reference to the first one to feed neighboring unfed parcels. This will continue until the system finishes all the parcels.

CONCLUSIONS & RECOMMENDATIONS

SEC now is in the verge of saving time and efforts and eventually money by investing in a highly progressing area of work automation. GIS will facilitate the process of doing business and servicing customers. Unnecessary costs and imprecise data and drawings will be eliminated using GIS applications. However, effort must be made to convince management to invest in such system to ensure enough funds are available for successful implementation of GIS.

Clear understanding of users' functions and purpose must be the main focus of any good GIS system. Planning decisions require construction of precise GIS models for forecasting or selecting optimum sites. These models should be integrated into the planning process and to existing work management systems. These models have to be upgradeable.

In order to proceed with the previously discussed GIS simulation model of the process of optimum transformers sites selection, certain issues have to be addressed. Management and staff support for the incorporation of GIS technology has to be gained. Mutual understanding between the GIS vendor and the users has to be there to reach to a practical outcome.

REFERENCES

1. Al-Ramadhan, Baqer and Aina, Yousuf (2003), *GIS Application in Optimum Site Selection for Tourists Sites*: Texas State as a Case Study

2. William Shaw, We Energies; Bart Koenig, and Rich Inman (2004), *3 in 1 Merged Information Systems Maximize Efficiency*

3. Ray Hahne, and Roger Fletcher, (2004) *Chelan PUD Integrates GIS and Asset Management*. Transmission & Distribution, 56, 20-30.

4. Bush, Rick, (1999) *Five Utilities Lead the Way to the 21st Century*. Transmission & Distribution,

5. SEC Manual, 1994, DEG-1.

6. SEC Manual, 1994, DEG-2.

Appendix-A:

Ministry of Water & Electricity Table for Individual Customer Maximum Demand Load (ICMD)

TOTAL COVERED AREA-TCA (m^2)	RESID-(URBAN)		RESID-(RURAL)		COMM.(URBAN)		COMM.(RURAL)	
	ICMD (KVA)	ICMD/m2 (VA)	ICMD (KVA)	ICMD/m2 (VA)	ICMD (KVA)	ICMD/m2 (VA)	ICMD (KVA)	ICMD/m2 (VA)
100	9.80	98	8.1	81	10.8	108	8.6	86
150	13.70	91	11.2	75	15.2	101	11.9	79
200	17.00	85	14	70	18.8	94	15	75
250	20.30	81	16.5	66	22	88	18	72
300	23.10	77	18.9	63	25.5	85	20.4	68
350	25.90	74	21	60	28.7	82	24.5	70
400	29.20	73	22.8	57	31.2	78	25.2	63
450	31.50	70	24.8	55	34.7	77	27	60
500	33.50	67	27	54	37	74	29	58
600	38.40	64	30.6	51	42.6	71	33	55
700	42.70	61	32.9	47	47.6	68	37.1	53
800	46.40	58	36	45	52	65	40	50
900	50.40	56	39.6	44	55.8	62	43.2	48
1000	54.00	54	43	43	60	60	47	47
1100	58.30	53	46.2	42	64.9	59	49.5	45
1200	62.40	52	49.2	41	69.6	58	52.8	44
1300	67.20	52	52	40	72.8	56	57.2	44
1400	71.40	51	56	40	78.4	56	61.4	44
1500	75.00	50	60	40	82.5	55	66	44
1600	80.00	50	64	40	88	55	70.4	44

TCA = TOTAL LOT AREA X COVERAGE FACTOR (CvF) X NO OF FLOORS (F)

Appendix-B:

Reference Table

Use	Area (m2)	TCA (m2)	No. of Cust. / ICMD (KAV) (diversified)	5%VD	3.5% VD				
				1	**2**	**3**	**4**	**5**	**6**

Appendix-C:

Drawings of Aramco Plot Plan # 1/367

(See Attached Drawings)