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GIS Utilization for Redistributing the Electricity Network Power on Rural Areas

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Abstract
The electrical networks in rural area have being distributed in randomly way, this lead to the problems of: high cost, losses in power, and difficult access. Geographic information system (GIS) is the most successful package for solving the problems that related by spatial data and analysis. This paper presents REG (Redistributed of Electrical network based-on GIS). Samraa city in Iraq is selected to collect spatial data for the current situation of electricity distribution. REG have been applied to solve the problem of electrical network distribution, it uses the factors: save cost, Efficiency, and accessibility. Which make benefits of the mentioned factors as: save cost (19.2%), accessibility (95%), save power (14%).
Keywords: Electric network distribution, GIS network, power loses.

1. Introduction

Delivery of electrical power from the source to the consumer in rural areas is a radial way, because energizing lands absence of some obstructions with the passage of time, the growed consumer and distributed randomly depend on the ownership of land and possibility of extending the power overhead lines, In particular electricity network random appeared from wire and poles and unequal distribution of electrical transformers which led to emergence of a number of problems: existence of a large amount of electrical materials (poles, wires, transformers ...... etc.) compared to the number of users, loss of electrical power, existence of illegal consumers, difficulty in determining the faults, overlap of some paths with trees planted, and the lack of accurate statistical data and database of both components of network or consumers.

1.1. Electrical power transfer

Transfer of electrical power from power plants to the final consumer is not an easy job, distance and topography have an impact to choose lines and appropriate network as needed. Use overhead lines and underground cables in transfer electrical power from power plants and transformer stations via different efforts until it reaches consumption areas. In Iraq the most electrical network used overhead lines. The general directorates for transfer of electrical energy transported power from (power plants) through transfer stations by high-voltage lines and turn it into a super effort 33 kVA and 11 kVA. Department of operation controlled over amount of electrical power through national control center. These lines represent the backbone of electrical network in Iraq. There are two transfer stations (effort kVA 400 - effort kVA 132), also two types of power transmission lines (kVA 400 effort and effort kVA 132). kVA is kilo-volt-ampere; kVA is a unit of apparent power, which is electrical power unit. 1 kilo-volt-ampere is equal to 1000 volt-ampere.

kWh Kilowatt-hour, is an energy unit (symbol kWh).One kilowatt-hour is defined as the energy consumed by power consumption of 1kWh during 1 hour: 1 kWh = 1kWh · 1h.

The distribution of long lines practically in line (11kVA) High Transfer (H/L) and line (220V) Low Transfer (L/T), in the extended rural areas for long distances for feeding loads widespread over wide areas. Thus, the distribution lines of line (11kVA) and line (220 V) rural areas to a large extent developed radial usually extend over long distances. Since power lost in the distribution lines can be considered to be entirely due to copper losses, it can be calculated using Equation (1) (E. Benedict& T. Collins& D. Gotham& S. Hofman.1992) .

$$P=I^2R \qquad \text{Eqn. (1).}$$

In our study calculate the loses in length wires of line (220V).

1.2. Geographic information system

Geographic Information Systems (GIS) has characteristic of intuitive display, supervision and simulating platform (Yuncheng Zhou & Wei Zheng & Tongyu Xu & Lisi Fu. 2010), such analytical functions usually present the best solutions to the users of GIS. Integration of these analyses with high visualization capabilities lead GIS to be widely used in decision making process (M. Alivand & A.A. Alesheikh & M.R. Malek. 2008).

1.2.1. Topology

Topology is a mathematical approach that allows us to structure data based on the principles of feature adjacency and feature connectivity. It is in fact the mathematical method used to define spatial relationships. Without a topologic data structure in a vector based GIS most data manipulation and analysis functions would not be practical or feasible (David J. Buckley. 1997).

1.2.2. Network Data Models

A network is referred to as a pure network if only its topology and connectivity are considered. If a network is characterized by its topology and flow characteristics (such as capacity constraints, path choice and link cost functions) it referred to as a flow network. A transportation network is a flow network representing the movement of people, vehicles or goods (Manfred M. Fischer.2003).

1.2.3. Digitization

Digitizing in GIS is the process of "tracing", in a geographically correct way, information from images/maps. The process of georeferencing relies on the coordination of points on the scanned image (data to be georeferenced) with points on a geographically referenced data (data to which the image will be georeferenced). By "linking" points on the image with those same locations in the geographically referenced data you will create a polynomial transformation that converts the location of the entire image to the correct geographic location. We can call the linked points on each data layer control points (www.s4.brown.edu 16/10/2013, 11.05pm). GIS can represent data in three basic data models (vector data, raster data, and triangulated data) a geodatabase implements the vector data representing features as (lines, Points, and polygons). Line represent any object that have length but no area such as (Streets, Rivers, Bounders……etc.). Points represent any objects that don't have length and area or it's small in map scale such as (building, pole, check point, tree, etc.). Polygons represent areas such as (states, counties, census tracts, sales territories, soil units, parcels, and land-use zones).

2. System Overview

This paper illustrates how Re-distributed electricity network to the consumers point is considered as a systematic way and in terms of (save cost, efficiency and accessibility) using GIS ability and verification for: saved electrical materials that can be dispensed in the network, limited illegitimate and transitive consumers on the network, reduced lengths electrical overhead lines that reduces the cost and the loss of electrical power, make electrical lines path with roads and cause rapid troubleshooting, avoid natural and artificial impediments, and create a database and digital maps for all the electrical network components and consumers Figure 1.

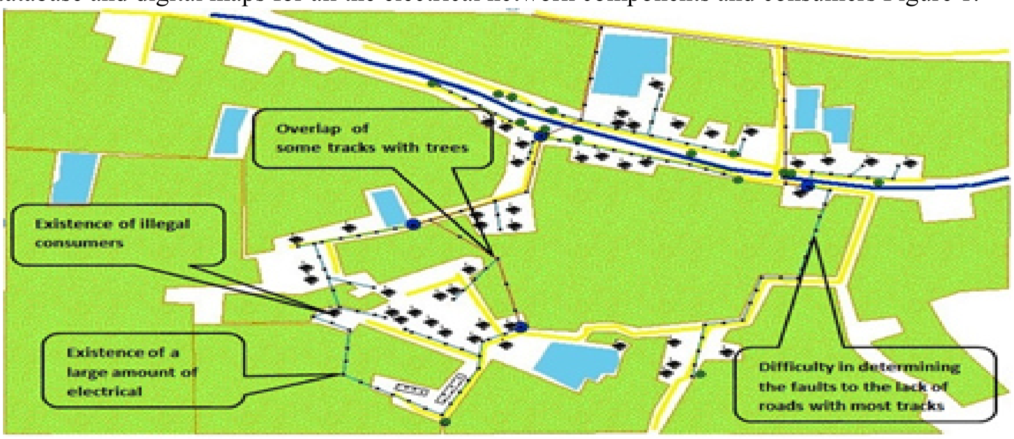


Figure 1. Shows the diagnosis of the problem in electrical network.

2.1. Base Map

Since maps identify what is at a location, user can point at a location on a map and learn the name of the place or object and any other descriptive attributes of feature (Michael Zeiler.2010). In this research we select a random zone from Sammara city rural areas; it's bounded between **(34.078992E, 44.055010 N, 34.071861S, 44.043053W)**. It is through satellite images, which were used in the application (ArcGIS 9.3) to digitize all features (streets, houses, trees, buildings, natural and artificial impediments, rivers etc.) of the region and also a network of electric power lines are physically located in the region Figure 2.

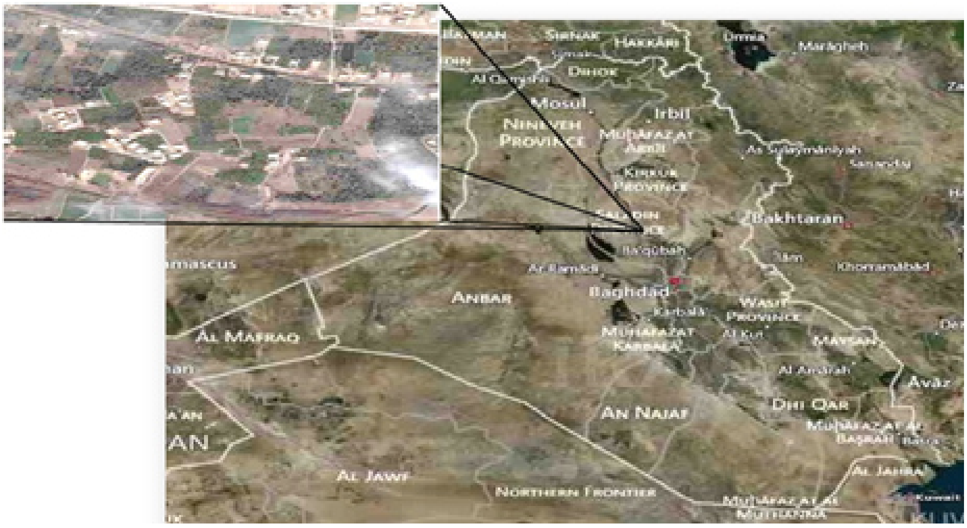


Figure. 2: Shows the satellite image of the area.

2.2. Data Collection

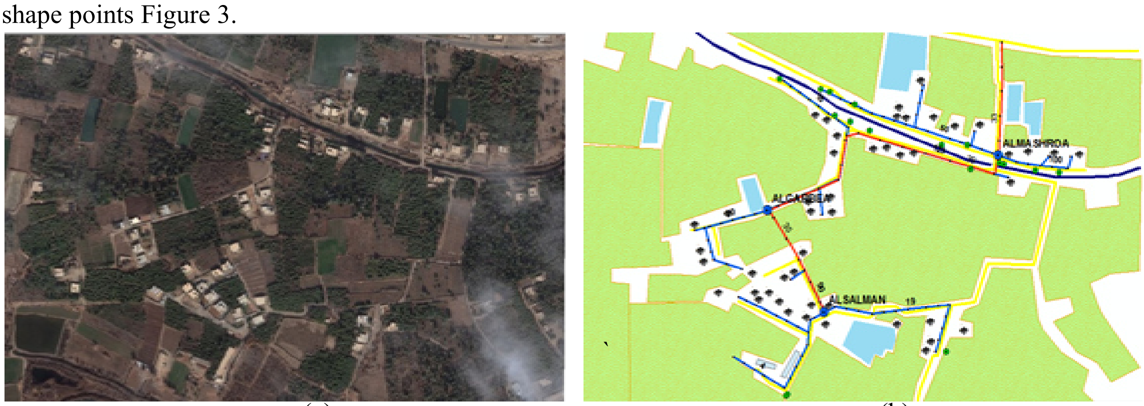
There were two sources to collect data:-

The first through visited site and specified the beginning paths of lines, electrical transformers location, collected of specific data points of consumption (type, owner, amount of consumption, permitting use of the network). Which determine: poles data (location, type, length), wires data (type, length, diameters) that use in the effort lines (11kVA) and effort lines (220v), and transformers data (location, type, absorptive capacity depend on type of unit of consumption (kWh)), as well as the prices of these materials in local markets and cost work.

The second through processed satellite images by (Arc Map 9.3) to obtain the streets paths, consumers geographically distributed, and all natural or artificial impediments (rivers, trees, buildings ... etc.) that cannot be path of transmission line.

2.3. Digitization

Digitization means to convert analog maps into digital form such as lines, polygons and points. In this research, HT/LT line has been represented with red and blue line respectively. Transformers have been mapped with blue color points and Poles with black color points. Trees, farms and fish ponds have been represented through polygons. River represented with bold blue line. Streets represented with yellow lines. Homes represented black shape points Figure 3.



(a) (b)

Figure.3: (a) Shows Satellites image (analog map); (b) Shows digital map

2.4. Layers of Data

A data layer consists of asset of logically related geographic features and their attributes (H.T Hassan & M. Faheem Akhtar.2012).We create a nine layers represented most features and components of electrical network: Image satellite of search area(base map), path of lines effort (11kVA) and names of each line, path of lines effort (220 V), poles, houses, river, streets, trees, farms and fish ponds).

3. System methodology

The problem was resolved through balance between three important factors:

1- *Save cost*, by saving the largest number of electrical materials in the existing network without affecting the efficiency and accessibility. Which is calculated from the difference between the actual network cost and the proposed network cost, the greater saved cost difference was a positive factor.
2- *Efficiency*, through the selection of fair distribution for electrical transformers and not exceed lengths paths between the source and the consumer, take into consideration the cost and accessibility. And calculate the loss of power in grid through the wire resistance at long distances.
3- *Accessibility* means to make path of network lines with the roads in nearest point with reduced cost and increasing Efficiency.

Then, we calculated the data of: length, types of wire, number of poles and electrical transformers of network in the search area, shows table (1).

Table 1. Quantity of material network.

Item	Transformers	wires (220V)	wires (11kVA)	poles
Description	250kVA	Aluminum 35mm	Aluminum 50mm	Iron rolled
Number	4	4 line	3 line	144
Length	-	11404 meter	2856 meter	11 meter

First step: spatial data analysis tools and buffering tool are used to determine the impediments as (trees, houses, streets, rivers, ponds and other buildings) Figure 4.

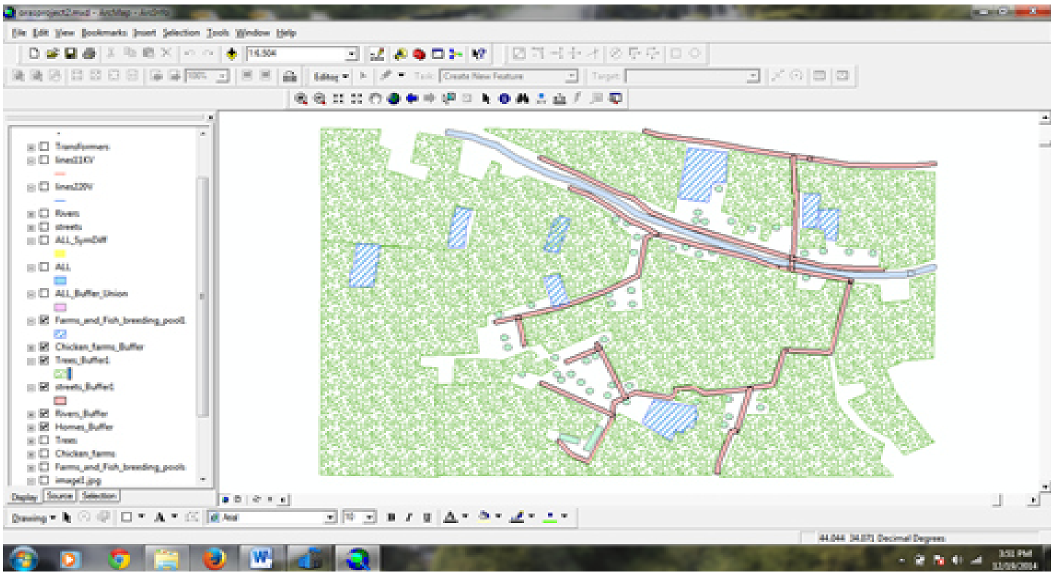


Figure.4: Shows buffer of each features.

The union operation applied on all buffers. This union subtracted from the cover layer, cover layer its polygon coverage all study zone, which produces the available area of work (without impediments) Figure 5.

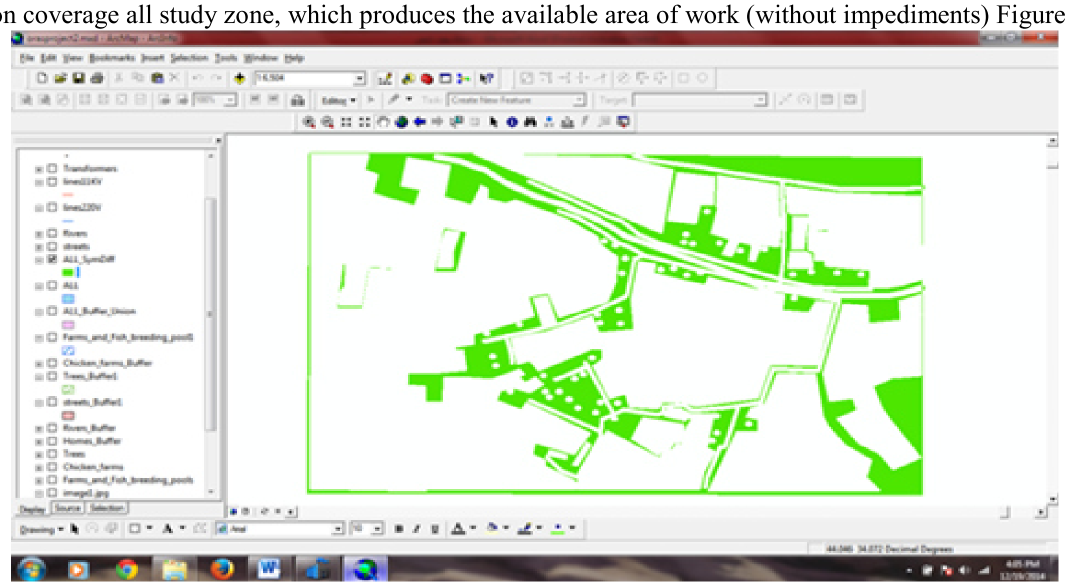


Figure 5: Shows the areas that permissible extend paths in it.

Second step: we calculate ability of transformers respect to the number of consumers. There was four transformers three phase of each, the capacity of each transformer (**250kVA**) that is equal (**200kWh**) to each phase,(1kVA=0.8kWh)[www.electrical-engineering-portal.com 12/25/2014-12:14 pm].

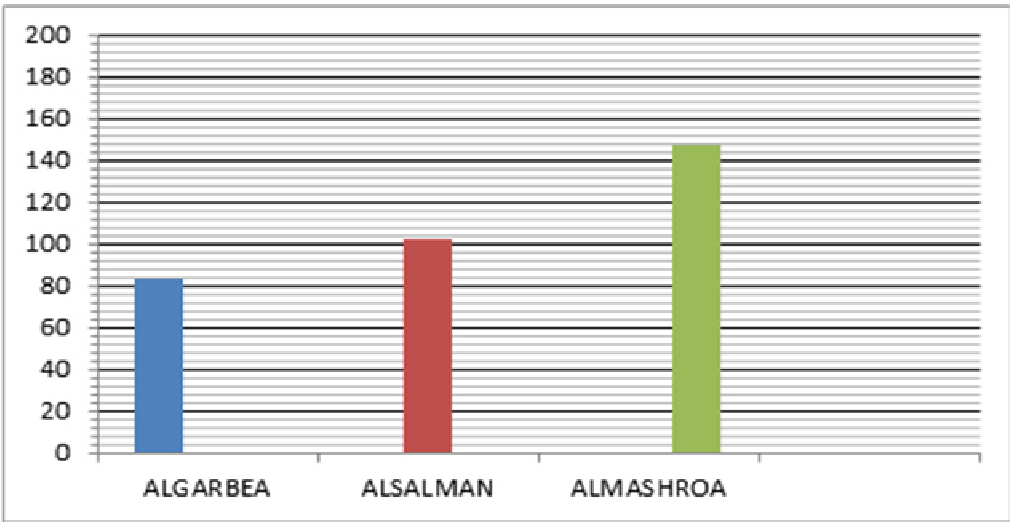
Note: all consumers use three phase.

The consumers are as following Table (2):-

Table 2. Shows consumption rate of consumers point

Consumers point type	Home	Water Pump	Poultry field
Number	**47**	**17**	**2**
Maximum consumption rate of each phase, kWh.	**5**	**6.21**	**25**
Sum consumption rate, kWh	**235**	**105.6**	**50**

Total consumption in actual network is equal to (**390.6 kWh**), and the max load per phase to four transformers is equal (**4 * 200 = 800kWh**), if we subtracted rate of actual consumption from the four transformers capacity (**800-390.6 = 409.4kWh**). That means that we have excess capacity (**409.4kWh**), we dispensed with one transformer and saved our excess capacity (209.4kWh) this equal to 34.9% of three transformers, thereby saved 25% of number of transformers. Section (1) shows the loads per phase of three transformers in the case of dispensed one transformed.



Section 1: Shows the distribution of loads on the three transformers by kWh.

The location of a transformes is selected to cover the maximum number of consumers, without lossing of power. the distance from the farthest consumer to transfrom is not morethan 700m. Choose the appropriate location for the transformer been through a tool (buffer & near), (Figure 6) Shows a new place for transformer number (26) and other transformers cover all consumers at half the allowable distance between the consumer and transformed (350m).

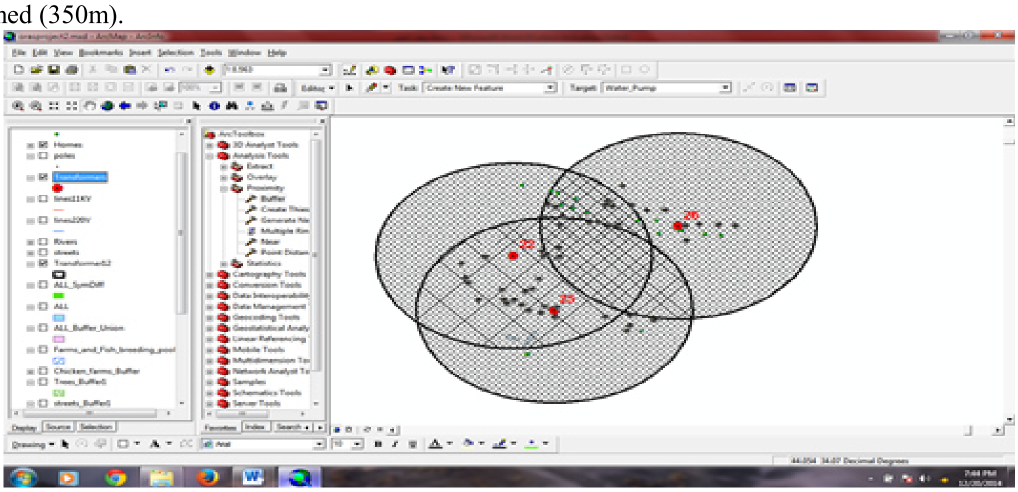


Figure 6. buffering of transformers

By used network analysis tools was Re-distribution line (11kVA) in Figure 7, depended on the factor (accessibility) and factor (save cost) shows the proposed path by system Figure 8.

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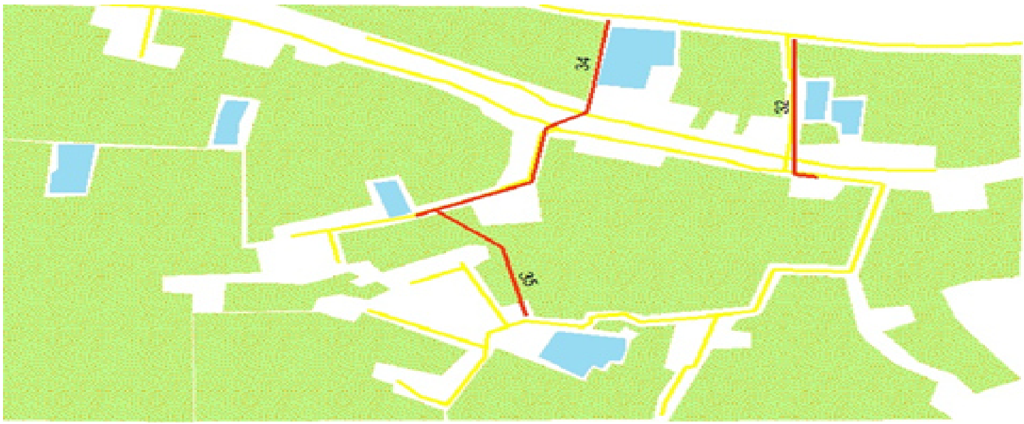


Figure 7. shows actual line (11kVA).

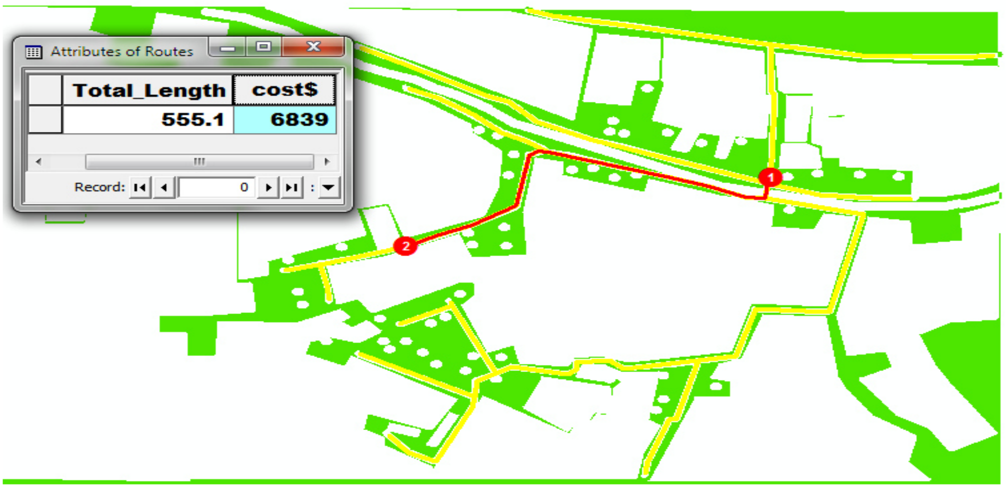
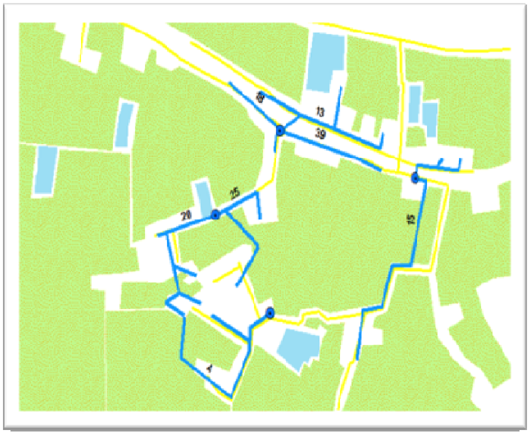


Figure 8: shows proposed line (11kVA).

(Figure 7) has two paths (32 and 34), path (34) extends without road area, side pond water and trees that leaded to difficulty in maintenance in case of faults. We dispensed line (34) and the line32 is source of effort (11kVA) for the region. In figure (9) the proposed path of the line (11kVA) extends with the roads and without any impediments along the increase (4%), depended on the perfect paths find operation in first step above. saved cost (17%) and accessibility (90%), as well as the benefit from the poles of lines (220V) or lines (11kVA) in proposed extended-line that are with it in the same path.

Figure.9: Shows proposed path line and transforms.

Lines (220V) were also changed, its path depending on the factor (accessibility, cost, and efficient) (figure 10-a) shows the current path, (figure 10-b) shows proposed path.



(a) (b)

Figure 10. a- Shows actual path of line (220V), b- Shows proposed path of line (220V).

The results of changed paths as in (Figure10-b) save cost (21%), length (10%) and accessibility (100%), while in the actual network accessibility (80%) (Figure10-a). The cost was calculated for all networks through (field calculator) tool as shown in (Figure 11).

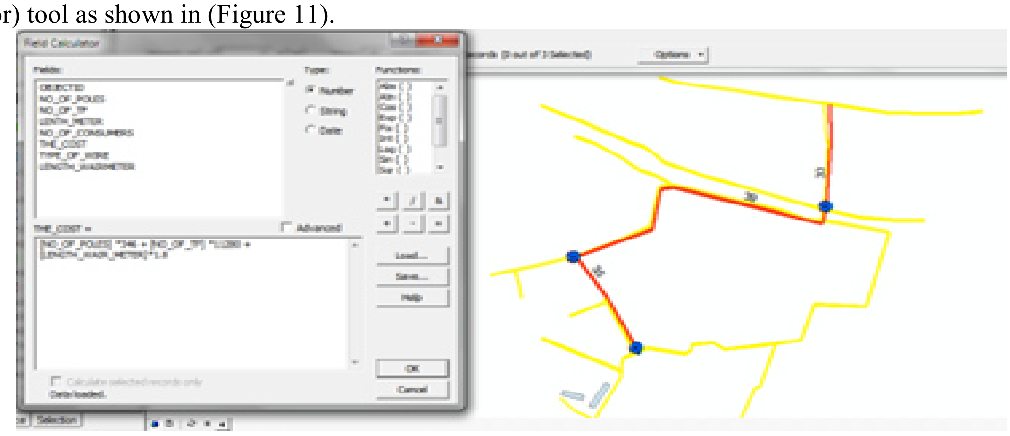
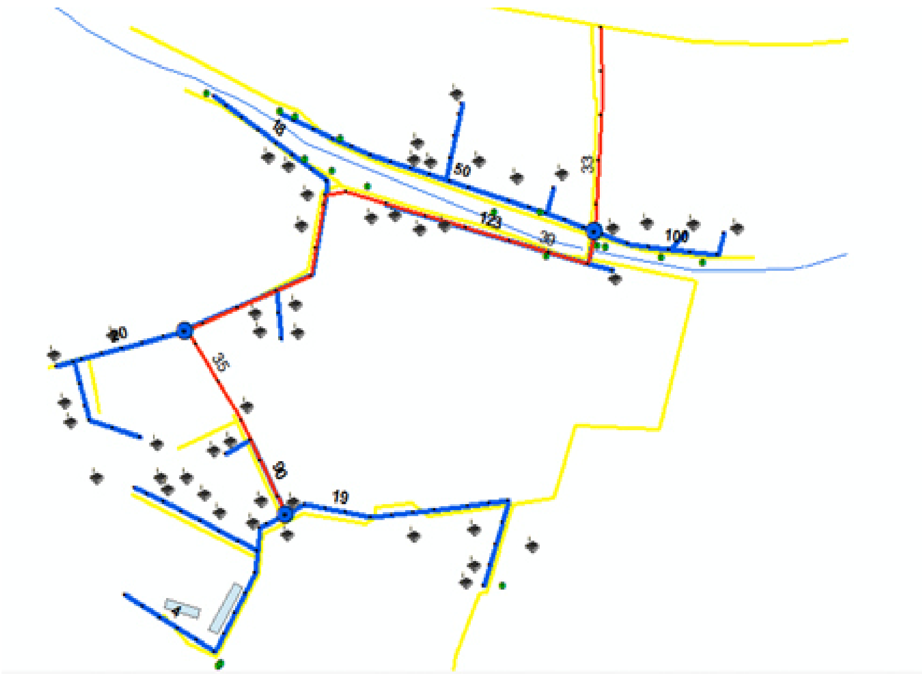


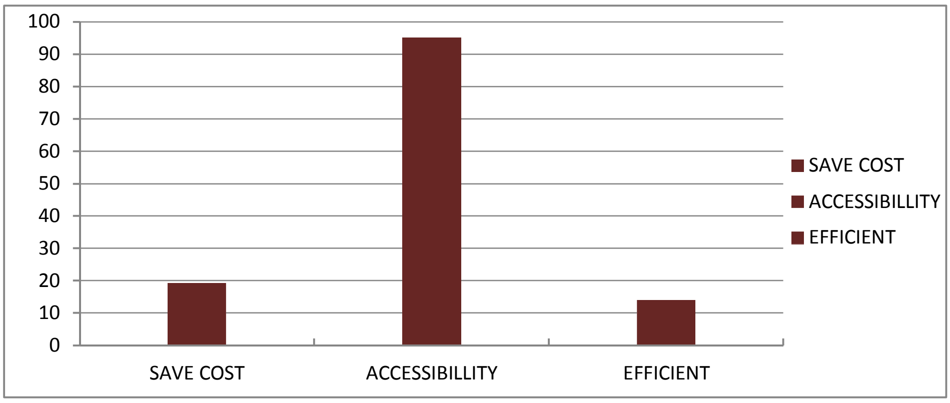
Figure 11. Shows how the calculation cost by used program (Arc Map).

4. Result



(Figure 12) shows the final distribution of the electricity network on consumers.

Figure 12. Shows the proposed network.
Section (2), the final results that have been obtained from the re-distribution of the network.



Section 2. Shows results by the percentage.

Through results in our study:-

1-*save cost (19.2%),* which represent what has been saved from the real cost of the actual network, these money is used to increase efficiency and accessibility.

2- *Increase accessibility (95%),* represent accessibility to all parts of network through the roads, which allows fast detect and repair faults which leads to reduced cost.

3-*Increase the efficiency by reduces loss of electric power (14%),* represents reduced lengths wire, and the distances between consumers and transferred to the nearest distance.

5. Conclusion

This paper solved the problems of electrical network distribution. It applied REG on a rural area, and affected of: save cost, efficiency, and accessibility. Table 3 shows the factors which should be taken (materials), the actual network, proposed network (output of REG), and the save (amount and percentage).

Table 3. Shows the save result.

No.	Materials	Actual network	Proposed network	save	Save in Percentage
1	Length path meter	3803	3567	236	**6.2%**
2	Length wires meter	14260	13277	983	**6.9%**
3	poles	144	118	26	**18%**
4	Transformer	4	3	1	**25%**
5	Cost $	107619.2	86893.4	20725.8	**19.2%**

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