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Spatial Decision-Support System for Electrical Distribution Grids

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DECLARATION

I, Esra'a Hasan Asad Asad the undersigned, declare that this thesis and the work presented in it are my own and has been generated by me as the result of my own original research, which has been done after registration for Master's degree in Computer Science at Arab American University.

I also certify that I have complied with all applicable university instructions, decisions, and laws and with recognized scientific and ethical standards, including scientific trust, and accept responsibility for the conduct of the procedures in accordance with the University's Committee if it turns out otherwise.

Signature: ……………………

Date: 5/10/2020

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To whom he lightens my life and by his existence my life becomes more beautiful, to my (lovely husband "Mohammad").

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Abstract

This thesis expresses a suggested model for Spatial Decision Support System (SDSS) to demonstrate the distribution of electric system as geometric network in Geographic Information System (GIS). Spatial data of the Qabatya city as the suggested study area was collected, Digitized and prepared for GIS geodatabase and analysis. A geometric network was applied after collecting and preparing geometric and attributes data connected to the relevant geometric layers. In order to present, analyze and make smart decisions, relevant layers were created to express the complex electric system components. Medium and low voltage networks were considered, transformers and feeders were also taken into account. Cables were digitized and relevant attributes were added just as material and cross section area, length was calculated geometrically counting on the spatial abilities of GIS, and the resistance was calculated mathematically. The consumers' meters were considered and their updated data about the electrical consumptions were exported from the municipality special system. Electric theories and equations were used and implemented to calculate daily and hourly power consumption where they helped to calculate the electric current for each consumer's meter. Geometric network analysis tools and methods were used to examine and present the flow direction of the electric current.

In order to calculate the technical losses for each cable at any phase according to its properties, resistance, length and electric current, the geometric network including all the

calculated results was designed and built using a hierarchical tree structure model using Oracle database to store exported data and SQL queries to calculate the current and technical losses using backward and forward approach to express the electric flow and its distribution in the network. The results were also presented in special website programmed using java programming language. The results were exported to attribute table that was joined to the spatial data. This enrichment data helped to present them spatially on the map by producing semantic maps using graduated color sympology for the electric current for each cable. In order to help the decision maker, the network was separated and each phase was presented individually. Satisfying results were presented for the electric network and the voltage vs. length, phases were highlighted for each cable and each phase

A 3D model was created, designed and presented to give a virtual really image of the system in the study area to help the decision makers to understand, watch the results of the reality and to be able to manage it smartly and making right and effective decisions.

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List of Abbreviations

Abbreviations	Explanations
GIS	Geographic Information Systems
SDSS	Spatial Decision-Support System
UML	Unified Modeling Language
D_C_R	Daily Consumption Rate
P=H_C_R	Hourly Consumption Rate
I	Electric current
cosϴ	Power’s Factor
LV_Line	Low voltage cables
R	Resistance
L	Cables length
Plosses	Power loss in each cable
P_source	Pole source of line feature class
P_ destination	Pole destination of line feature class
H_T_S	Hierarchal Tree Structure

Chapter One: Introduction

Electricity is the nerve of modern life, and people depend on it in all its aspects. Actually, it is important in our houses, businesses, hospitals, factories and companies. In other words it is an essential ingredient of a comfortable life, and like any other component in our life, electricity is exposed to damages and faults which cause power cuts and power losses. Additionally, when electric loads instantaneously exceed the thresholds allowed, the electric supply is subject to temporal disconnections that disturb the rhythm of life, in general.

Qabatya city in Palestine is about 6 km to the south of the city of Jenin and is considered one of the largest population groupings in the province of Jenin. This research study aims to manage the electricity network smartly by using the geographic information systems to support decision-making. As well as network analysis to know the routes of electricity lines and to identify the electricity sources inside this town.

GIS one of the most important technologies that help in managing and planning of geometric networks in general and electrical systems specifically in order to increase the efficiency of their usage by the capability of considering the spatial location and obtaining different types of statistics, data, charts and analyses to make the appropriate decisions for the decision makers and managements by using different work approaches.

The basic advantage of the GIS is the spatial analysis capability, where analysis processes consider elements that exist within the specific temporal and spatial frame. This helped to eliminate the problems that were encountered in the traditional linear maps used to store and display such spatial information, where the spatial data elements on these maps are recorded either as points or as lines or shapes based on a local or a geographic coordinate system and the altitudes from sea level.

One of the most important problems of using such maps is the inability of determining of the logical relationship of the elements in the map. Also, the changing of any element of the spatial data does not lead to any impact or effect on any other element logically associated with. Another constraint is due to the different times the spatial data were collected in. Therefore, the GIS is considered one of the most important modern technologies used in information fields that provides a complete analysis of the management of land use, public services, infrastructure, etc., whether these pieces of data are descriptive, numerical or cartographic graphical data. GIS integrate spatial geographic features with alphabetic databases adding topology and cartographically relationships that leads to great abilities of multidisciplinary measurements, analysis and management to describe the site and its characteristics using advanced programming to produce improved visualization and sympology.

1.1 Motivation

In order to develop the disciplines that support the development process and not to duplicate existing researches, the importance of this research has been studied for solving the electricity problems that the Palestinian society is suffering from such as lack of network robust management. The orientation of this study will be to use new GIS technology which is of great benefit in improving the management of the network and its various resources, as well as the ability to link data sets with each other with geographic locations, facilitating data sharing and communication between different departments and the ability to support decision making, which contributes to improving the electricity sector in Palestine and the possibility of keeping pace with development and progress Worldwide.

Most of the information related to electricity is of a spatial and temporal dimension, so there is a wide possibility to make radical changes in the methods of collection, documentation, storage, management and maintenance of these data, which helps to benefit from them and increase their effectiveness in terms of quantity and quality, and this is what distinguishes GIS, where it will help us in specific spatial and temporal analysis, which would also lead to make smart decisions supported by knowledge and data.

Therefore, this thesis aims at enabling electricity distribution companies to detect the spatial location of grid problems and to specify their amounts and severity. This should provide an effective and smart decision support system for the decision-makers to be able to analyze the performance, specify the exact reasons for these problems, and to come to the best possible practices to deal with them and best solutions.

1.2 Research Problem

The problems of the management of the electricity network, the management of the distribution of electrical loads and power cuts constituted a headache for some of the electrical networks operators for decades, especially when the demand for electricity increases due for example to increased use of air-conditioning.

Qabatya town is an example of the above mentioned situation. It has an increasing number of factories and quarries. Additionally, citizens use air conditioners increasingly. Therefore, the electrical loads are dramatically increasing due to the large consumption of electricity. The electrical network in different areas of Qabatya town suffers from occasional sudden power cuts, due to the high electrical loads that exceed the maximum network capacity. In addition to that, the fluctuations in electrical potential sometimes damage electrical devices and appliances causing financial losses, disruption of citizens' lives, and large losses to electrical consumers.

Also, there are many lines in the town of Qabatya suffering from high loads due to operating the air conditioners at peak time which causes great problems, so this region needs to increase the electrical network capacity to cover all its needs, in addition to the citizen’s responsibility of optimizing the energy consumption.

Regarding the electricity theft problem, the municipality of Qabatya declared that this problem is not local and exists in all cities, and that it is fighting this phenomenon by all the available means.

After communicating with the electricity network engineer in Qabatya [1], he explained that the electrical grid in Qabatya suffers from several technical and management problems such as:

- Qabatya electric grid suffers from high technical losses between 15 to 20 %
- The voltage fluctuations exceed the universal level of +/- 5% from the source with poor power factor on the low voltage grid especially in stone factories due to non-compliance to install capacitor banks.
- Part of this losses caused by inadequate design of the low voltage network and due to overloaded feeders leads to voltage drop in the network.
- There are many of remote control, SMS, GSM and SCADA connected for controlling, protection and management of the network. But the problem is there is no platform or software environment to link between all of these programs and databases to serve the engineers for planning and administrate the network .
- Lack of the spatial data for the prepaid smart meters of consumers in database of

subscribers and this leads to inability to monitor the geographical location of the consumers by x and y coordinates then ca not remotely control using the GIS.

This unacceptable status of the present electrical grid in Qabatya with the absence of GIS in distribution management motivates toward.

The question we face as mentioned above, are there any effective techniques capable of solving this type of problem in electricity networks??

We suppose that the GIS techniques can decrease these problems, this will be studied and proven in our research.

1.3 Contribution

The aim of this thesis is to achieve several key contributions:

- Building a research framework in Electrical Distribution system based on Spatial Decision Support System using GIS in order to build a common multidisciplinary work to develop Electrical distribution systems for improving the efficiency of the electricity grid.
- The proposed research aims to represent the components of the electricity network geographically, especially the medium and low-voltage poles, and cables, the identification of transformers, feeders and their types, in addition to that consumers with their types and behaviors and connected to any feeder specially at any phase.
- Although the lack of possibility to get the hourly electric current, we contributed to find a way to calculate the electric current at any point in the network, whether it is a line or a pole, specifically at any phase network from historical data for the meters
- Electrical equations and analysis techniques were implemented in GIS to model a decision support system for Electrical Distribution Grids by using a hierarchical tree structure

model using Oracle database to store exported data and SQL queries for calculating the electrical current and present it spatially separated for each phase to help managing smartly the electric distribution

- Finally, the Feeders are geographically positioned and able to show the effect of its operation or not on the network, considering the electricity properties and physics parameters to model and estimate predict electricity losses.

1.4 Document Structure

This thesis is represented in six chapters and a conclusions. In the first chapter we list the introduction, motivation, research problem and the main contributions.

Chapter two describes the state of art where the electrical distribution grid and Geographic information systems for electric networks is identified, the development of electrical distribution grid is reviewed, and the most related work is listed. In section two listed and detailed the objectives of this thesis.

The third chapter is about methodology which is composed of many sections: the first section describes Geographic Information system and its definition. The second section illustrates the Electrical distribution grids and its components, then the Electrical losses types and its meanings, especially the technical loss which is explained in its subsection and how to use electricity equations to calculate the technical loss in the network. The third section is to explain the spatial decision support system. Fourth section is about Geographic Information system and how it is used as a tool for SDSS. The next section, is to explain Electrical System Geodatabase in details. The Geometric Network and its component were defined, how to model Electrical Geometric Network and how to manage the electric geometric network by network analysis tools are illustrated in the fifth section . In section 6 is about modelling our approach for SDSS for Electrical distribution grids.

The fourth chapter presents the Software modeling by using object oriented UML, in the next sections to illustrates the main UML diagrams of the suggested SDSS to presents the scenarios that describe the flow of the events in the system.

The fifth chapter illustrates the system implementation parts, study area, data collection and preparing, used tools, additionally it presents the building of Geometric network, the next sections for calculating electric current and losses using hierarchal tree, codes and results. The last not least is how we build 3D Model for Qabatya electrical distributed network.

Testing and validating our SDSS results is illustrated in chapter six. Finally, the thesis conclusion and future work.

Chapter Two: Background

This chapter introduces the field of Electrical Distribution Grids and some of its traditional components. In addition, it lists the most related work in the field of Electrical Distribution Grids management and other studies that discusses the importance of Geographic Information Systems in government's utility applications especially the electricity field. We also describe Spatial Decision-Support System (SDSS). We finally describe Geographic Information Systems (GIS), its definition, and illustrate it as a Decision Support System.

2.1 Literature review

Over the centuries, electricity networks and distribution systems have suffered many problems, as mentioned previously. For example: Environmental impacts of power generation, infrastructure ageing, technical losses of electricity ,equipment overloading, increased demand for power quality and Reliability, low measurement efficiency, and power theft resulting in significant business and economic losses[2][3]. Some research adopted traditional methods to solve problems of electricity networks.

In [4], researchers used dynamical approach of the Crucitti-Latora-Marchiori (CLM) model to solve the overload of substation in the North American power grid where they studied the damage caused by the loss of individual nodes and after complex analysis the results showed that the power grid in theory and experimentation is extremely strong in cases of random failure. However they found potential damage to the network, such as limited disturbances in the efficiency of the transmission of the power grid, and that the efficiency of the network may be reduced by 25% due to the loss of any high-load and high quality transmission substation.

Others used flow entropy to measure total heterogeneity in the distribution of energy flow. The aim of this study was to analyze the causes of power outages in power transmission networks by constructing the dynamic model of relay failure in the electrical power system to identify important nodes or branches of the system which is of fundamental importance in terms of system weakness and to determine the load flow of power grids, DC power flow approximation was used to determine the load flow but the problem was that the errors of the flow of DC power reached 10% [5].

Due to the complexities and problems faced by developers and researchers in the use of traditional methods for the management of electricity grids and control all its components and analysis of the problems that occur in it. The use of geographic information systems (GIS) technologies has become very important because of its great facilities in managing and analyzing such types of networks.

The main reasons for the success of GIS performance and the analysis of spatial data structure and ensuring high accuracy in making improvements is the modeling of the topology of the electric power system and its proper construction as in [6].

GIS helps manage distribution networks by planning the electrical and consumer network database, which contributes to improved load management, reduced losses, and better revenue, as research findings [7] have shown the importance of GIS as an excellent decision-making tool to improve the distribution of electricity in Nigeria.

Moirangthem, J., Krishnanand, et al [8] integrate automation of a non-iterative power-flow with Geographic Information System (GIS). Their method is called Holomorphic Embedded Power Flow (HEPF). Theirs method produce a power-flow service over a communication network. Their proposed method is candidate for near real-time updates of the electrical states of a power system. The system was a very good method for electrical network but they didn't use the capabilities of the geometric network for electrical network in GIS which is provided in order to the analysis that they use a spatial analysis as provided in our work.

There has become an urgent need to use geographic information systems applications as they are important in assisting with accurate and comprehensive knowledge about urban 3D space for simulation and analysis in the areas of urban and environmental planning, city management and disaster management. The authors in [9] took advantage of geospatial techniques in their study to conduct a functional classification of land use, developing an address-based geographic database in northern Nazimabad, examining actual design versus implementation strategies for some basic facilities and proposing reconsideration and redistribution factors. The maps prepared during their research may serve as an effective analytical and planning tool for policymakers, emergency response and facility management, and they have also developed a GIS-based electricity load analysis model to improve energy load and suggest factors for reallocating resources.

The authors in [10] used the CityGML Utility ADE Network as a suitable data model for the features of the underground utility network and related city objects above the surface of the Earth. Check how to currently store and use Utility Network data in a database, and how to utilize the data in the database to perform some routing analyses., the authors followed the 3D data modeling approach for the integrated management of underground utility networks and related above-ground city objects. This approach consists of first manipulating the utility data structure contained in the ETL Engine for commonly used feature processing software to make the data compatible with the ADE CityGML Utility Network data model. After that, workspaces concerned with storing CityGML data are created in the 3D city database, which has been expanded to manage network utility data as well. The study demonstrated the suitability of the extended 3DCityDB for performing graph-based topographic operations with the PostgreSQL pgRouting extension. Finally, they showcased the results in ArcGIS. Through it became easy to find the things of a broken or broken city in the event of a strike on the benefit, but the condition for carrying out such graphical analyzes is the formulation of topological relationships between network elements which requires more other types of relationships new queries and vice versa.

I.HIJAZI et al in [11] showed the importance of CityGML UtilityNetworkADE in meeting the requirements of modern urban complex facilities and needs of network infrastructure. Where their study proved that the UtilityNetworkADE is capable of linking different network systems, providing an integrated view to understand the relation to city entities. Several examples are discussed on the various network data models and utility network problems and applications that can be found between city settings such as electricity planning and simulation. they used use cases to define requirements to evaluate specific network data models where there was a need to link networks with other types of networks, intranets, and city entities,, the researchers discussed the importance of the model in determining the effects of maintenance operations performed on specific facilities on other types of networks and will allow them to plan the network in conjunction with other city entities, as a change in land use can affect energy demand in public utility network systems. In addition, they saw that their model would help to see the full picture of the network, and use it to plan future demand and maintenance and enhance management, yet they concluded that the model still needs further development which includes:(Connectivity rules, application-specific extensions, reference network objects, and connection to the CityGML EnergyADE and to sensors).

G.Custodio et al [12] implemented an advanced GIS _based planning tool, named OpenGIS, to assess the impacts of distributed energy resources on distribution networks, and to investigate potential solutions for thermal and voltage problems, and to help accelerating the transition to Smart Grids. The integration of OpenDSS, QGIS, and AIMMS along with a friendly GUI created with Qt Designer allows results to be analyzed spatially, simplifying the identification of voltage and thermal problems.

S.Nawaz-ul-Huda et al [13] designed a model using GIS to manage electricity production and consumption in a transparent manner and they presented a case for a GIS modeling for Spatial Electricity Management System in Karachi in Pakistan so as to help circumvent the electricity theft and mal-distribution problems in the city. The researchers clarified in this paper that the use of geographic information systems helped in drawing maps of the electrical network and building a consumer database, which led to improved load management, reduced losses, improved revenue generation, and possibly better relationships with the consumer.

Parkpoom et al [14] used a conceptual design model of GIS-based power network in Thailand. Power transformers have been mapped using GIS and its applications. Researchers used the capabilities of GIS and the system ability to manipulate geo-reference data. The proposed method allows power system planners to work on the real system by relating the output to the location of electrical wires and feeders. They use the GIS and GPS capabilities to obtain data of poles and electricity cables. They used the obtained data to build an electricity network using GIS that enhances and affects the performance.

Many researchers have tried to address some of these problems using different techniques (The most important was GIS). The researchers confirmed that the integration of geo-information systems into electrical power systems is critical to any fast-growing developing country with a large population, GIS and their applications play an important role in the planning, analysis and control of the modern energy system [2]. In addition it provides the ability to predict loads at the long-term, load flow and short circuit analysis. [3] they used Global positioning system, remote high-resolution images, and Geographic information systems to improve planning, maintenance and management standards in distribution systems, GIS also helped them perform different types of analysis such as load analysis and site analysis like the location of each pole, location of each consumer, and network analysis. This is what we have demonstrated in our thesis, in addition to our ability to manage every component and element of the electricity network not only the locations of each consumer, cable and pole, but we have been able through our work to focus on network details such as medium voltage and low voltage networks, transformers, feeders and all the 3-phases networks, this is what distinguishes us from others, ability to identify type of problem, etc.

A. Khattak et al [15] clarified that the using GIS and GPS techniques that provides high accuracy in mapping the electrical, analyze and find optimal solutions to electricity problems. They used this techniques to map the 11 kV feeders and to carry out the load flow analysis in SynerGEE Electric software. Results show voltage drop and annual energy loss using Bifurcation and load shifting techniques, moreover, a single feeder can be optimized in various ways to determine the best ideal method, which can be beneficial to the distribution network.

GIS importance is also coming from the increased controllability of the electrical system and its ability to identify the location of malfunctions on the map, its ability to manage interruptions and analyzing user’s requests and behavior, the determination of the best location of the network components, which is essential for the success of the smart grid [16].

The paper discusses the subject of the smart grid and its importance and impact in the development of the energy sector in India into a secure, adaptable, effective and sustainable energy system within a specified time frame. A system has been proposed that provides a reliable and competitive energy to meet the needs and aspirations of all the citizens through the active participation of all stakeholders, and the innovative technologies and policies owners. The smart grid helps reducing greenhouse gases, filling electricity shortages, and reducing the economic and the environmental losses, etc. Authors explains the importance of the GIS in managing the smart grid by building a powerful and appropriate model for network work methods by understanding the relationships between the network, the surroundings, the planning capability, and the data management and analysis [16].

Author’s in [17] redesign the distribution network of Milano based on geographic information system (GIS) and a cascading of MILP (Mixed-Integer Linear Programming) approach. The purpose of this work is to propose a procedure for testing a real large-scale distribution subsystem of Milano .they use geographically referenced data to determine the optimum shape of electricity distribution network, and perform computational measurements on it. They use GIS that maintains, creates or removes cable routes, taking into account electric power cable joints. Considering that joints, results in a more effective topology and profit optimization. They focused more on the whole shape of the electrical distribution network ignoring the details of the network elements such as consumers and all component of the low voltages network that our proposed system focus on it.

In [18], the authors provide a developed geographic information system (GIS) for the integration of solar energy into energy planning in a wide area of Province of Frosinone in central Italy. They chose this area because of the weak active performance of existing buildings and the climatic characteristics of the area). The model that has been put to use equations and the (raster data grid) as tools to analyze the many quantitative assessments needed at the planning stage. This model has specialized only in solar energy data where it aims to comprehensively analyze the different energy production scenarios in the Province of Frosinone.

The data was submitted on the basis of: The availability of land, and the high land production potential classification from RES, taking into account the restrictions listed in the Italian code to limit the spread of solar power plants on lands dedicated for use, for example, placing solar power plants at a distance of at least 2 km and not exceeding 10% of the land area. The main agricultural land was excluded in order to avoid the loss fertile land and was limited to the available space available for the production of solar energy on grassland and heterogeneous agricultural land. After study and analysis using GIS, they found that the actual available land to utilize is located in the valley areas of the province and is often close to the cities. Thus, the installation of solar power plants will allow the rehabilitation of these areas and these stations will be close to urban areas where the demand on energy is high on energy [18].

The Integration of the renewable energy sources where the active productivity of these sources should be assessed, the technology has been taken into account, thus, in the proposed model different data on buildings have been included (such as the classification of surfaces types i.e. tapered, flat, inclined, etc.) and the theoretical characteristics of the solar panels; This classification process helped them to assess the area by the occurrence of solar radiation, a three-dimensional model was produced for the buildings identified by the examined database. The obstacles they faced at this stage are that they could not obtain the data of the inclination of roof directly through the model because the gutters and the roof surfaces are not able to be assessed. There are also obstacles that reduce the useable space for installing solar panels such as windows, chimneys, stair cases, etc.… [18]

Authors in [19] discussed the problems of power cuts that make tremendous negative economic results over a long period of time, particularly when the affected province contains many commercial units, this problem has made the authors think about building a web-based system for smart cities able to: Connect to web sensors that collect power cuts data, also connect to web services that provide an estimate of economy losses (ELES), processing their spatial database over the web, and finally provide data for real-time power cuts and the E.L.E in real-time by creating and sharing web map services (through WMS). This spatial Web service has provided this tool to support the decision-making in emergency management in responding to crisis in the energy sector in real time by helping to prioritize the restoration of processes in electrical facilities to reduce the economic effects of power cuts, helping to improve decision-making and planning, and enabling real-time monitoring, supporting operational decisions, solving critical problems, and creating new and innovative experiences in smart electrical facilities and smart cities making these cities more flexible. The disadvantages of this system are using of (ArcGIS for Server) which is an expensive program. Moreover, this system needs to make flexible and upgradable. Another disadvantage is the usage of the simple E.L. calculation models.

In their study, J.Acostaet al [20] focused on technical losses and how it can be defined and minimized based on measured data and modeling energy systems in IPSA. Their developed methodology was to identify the losses in the low-voltage network with limited data available, they proposed interventions in order to improve the overall efficiency of the distribution of power across Scottish and Southern Electricity Networks and reduced the respective cost (6%) to the customers.

V.Telukunta et al [21] studied the technical losses in distribution networks for 11kV Hosakote agriculture distribution feeder in Chamundeswari Electricity Supply Corporation Mysuru area Karnataka, India. The proposed methodology was to collect the proper technical data of the network, loss evaluation and finally loss reduction, they used GIS for mapping the data, and for measurements, used two approaches for reducing the technical losses in the electrical network. Replacing the inefficient irrigation pump sets and 11kV network reconfiguration by using particle swarm optimization technique. Their study results showed that the reason for high technical losses in the network was all substandard pump sets and 90 percentage of pump sets are re-wounded at least ones and overloading some of DTR's.

[22] Discusses the problem of congestion of the electrical network resulting from the complications that leads to many problems including unexpected electrical power cuts. Network congestion is a condition or situation in which power transfer restrictions (placed by engineers and specialists) to reduce the flow, transfer or productivity below the levels required by market participants or government policy. Increasing of DER (Distributed Energy Resources), shall increase the restrictions thus increasing the congestion problem. This research illustrated the importance of GIS in helping to manage the smart grid by placing its major components such as batteries more properly, and also by providing a model for improving network operations by balancing the supply and demand for electricity, so that the proposed model helps companies in decision-making by identifying the potential congestion areas and identifying areas priorities where additional actions are needed (priority can be

given to areas where potential demand to charge batteries) and to detect areas where the DERs may provide a general benefit.

In some studies, the orientation was towards critical and repeated electricity problems such as commercial losses in electrical distribution system over the years in an attempt to solve them in several ways. Some applications and devices capable of detecting electric theft were designed and implemented on GIS, for example, [23] authors used a robber detection device that helped detect the thefts, some of it was by consumers illegally using bypass ways, this has been applied by Microcontroller to calculate the difference in input and output voltage, if there are differences, a message of theft is sent through the Global System of Mobile Telephoning, while the reliability of the identification of data sources through the use of the and the functions of the software may be subject to failures was one of the dilemmas encountered in their study.

Others [24] discussed the problem of loss of electricity may be technical as problems in the wiring or parts of the electricity network or non-technical such as thefts, MATLAB techniques have been used for analysis, loss assessment and solutions, but it turns out that if it was the data was detailed or accurate more precisely in particular both technical and non-technical losses which is not exist in general then the results will be more accurate and reliable.

Au et al [25] calculate technical losses depended on feeder load factor and feeder characteristics, such as feeder length, peak demand to installed capacity ratio, and load distribution profile along feeder. They used the energy distribution along each network component to calculate the percentage technical losses for the whole network. Requires minimum component and data but it is give an accurate results which is good advantage of this study.

Others [26], focused in calculating the low voltage losses in Britain. They aims to reduce the whole network losses. Losses calculations is affected by the configuration, interactions with other incentives and the cost-effectiveness of possible actions. They try to build a real model of the network and this was one of the difficulties that they face they present at the end of the papers some measures for losses reduction.

CONCLUTION

This chapter discussed the term of GIS as one of the best technologies that facilitate data management, and its importance and abilities to support spatial decisions because it consideration for geographic data, location and spatial distribution. These abilities are very important and effective for managing electrical distribution grids, many researches and works were listed to highlight the importance of the suggested subject and specifically the suggested work in this thesis work.

Chapter Three: Needs Analysis

To achieve the objectives of the proposed thesis, several main stages were followed: beginning with describing the need assessment methodology that we will follow it : the first one is the Geographic Information system and its capabilities to support spatial decision through managing electrical distribution grids and its components, solve problems that may faces such as electrical losses and it's to use electricity equations to calculate the technical loss in the network depending on hierarchical tree that structured using geometric network components.

3.1 GEOGRAPHIC INFORMATION SYSTEM

3.1.1 Geographic Information system (GIS) definition

Geographic information systems in general is an information system that depends on geographical data, these systems allow to store, configure and formed this information, and therefore it will works by processing and visualizing the data. [27].

GIS is the science that is concerned with collecting, processing and studying geographical information, and it depends on recognizing maps, aerial photograph, using tables, working to treat them, and making sure that they are completely correct, and free from any errors, so that they can be preserved, and used when needed, especially In cases where it is necessary to study it, or analyze it via computer, paper, or graphics [27].

Geographic information systems (GIS) have the ability to collect, input, process, store, retrieve, query, spatial and statistical analysis, and display and output spatial and descriptive information for specific purposes, and helps planning and decision-making [28].

GIS shows its importance in determining the coordinates of each component in the map (location) as well as the topology relationships between these components, will make this environment very effective and promising to make smart design and manage spatial decision support systems especially for the electrical grids.

3.2 Electrical Distribution Grids

It is a power distribution system consisting of cables/wires that deliver electrical energy from its start (connection or purchase) point to end users. Electricity distribution systems are primarily designed to meet consumer energy demands. This is done by taking energy from the main stations and connecting them to the different customer stations either by underground cables or lines above the ground. Because there is no free space, some cities and towns rely on underground cables and rural areas use air lines [29].

Usually, electricity is transmitted at a very high voltage through power lines spread across rural areas. The higher the voltage, the lower the current required for the same amount of electricity, and consequently the less electricity is lost. (The resistance to the current in the lines creates heat that causes some electricity to be lost)[30].

When electricity reaches the neighborhoods where customers reside, transformers convert high-voltage electricity to a lower voltage for distribution to homes and business centers [31].

The electrical network consists of the four major component [32]:

1. Generation station: It is the power plant where electrical energy is generated. There are a lot of types, sizes, voltage levels, and categories according to resources of electrical generators. [33].

2. Transmission and sub-transmission: It is the system that is used to transmit electrical power from the generation side to the distribution system. It normally operates at high and extra high voltage.
3. Distribution: It is the system that distributes electrical power received from the transmission and sub-transmission system to the electrical consumers. It normally operates on both medium and low voltage levels. This is the system that we concentrate our study at. It includes many components such as different types of electrical poles, wires, cables, switches, transformers and others.
4. Consumption: This part consists of all the electrical consumers. It is the core of the electric power system. All of the power system is built up to supply and satisfy the electrical needs of the consumers with adequate quality and quantity. Each consumer has different needs from the other, and the types of consumers are classified according to these needs, which may be residential, industrial, commercial, etc.

Figure [3.1] below shows a sketch of the electric power system with its four major components.

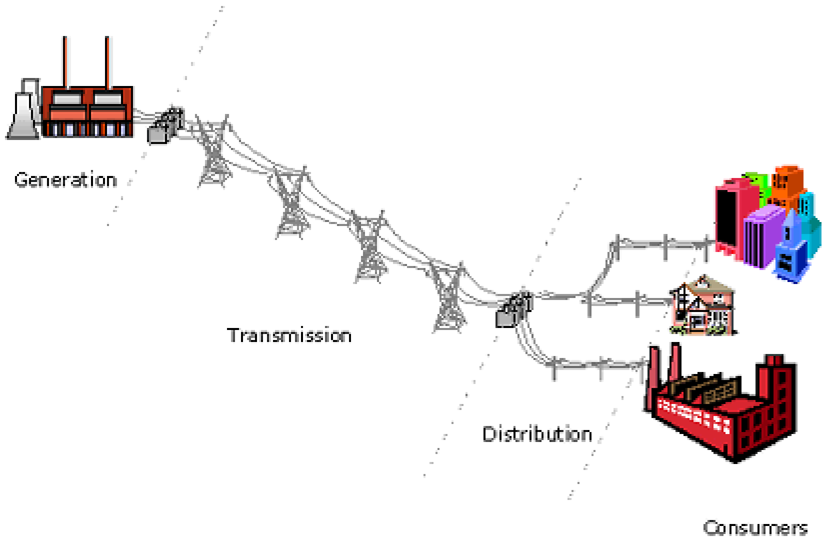


Figure 3. 1: the electrical network component [34].

3.2.1 LOSS DEFINITIONS IN Electrical DISTRIBUTION NETWORK

Electricity distribution grids suffer from the excessive growth in losses resulting from the loss of electrical energy, and this results in the loss of a large amount of allocated resources without utilization, which leads to an increase in the burdens on the electricity companies.

Electricity losses can be divided into [35]:

- Non-technical losses: often due to electrical current theft, non-payment of electricity bills by consumers and possible mistakes when accounting for electricity consumption
- Technical losses: These are losses caused by internal procedures of the energy system, such as energy lost through transmission lines, transformers, measurement systems, etc.

The transmission and distribution of electricity across transmission lines and substations is usually accompanied by technical losses, mainly due to the resistance and iron core loss in the metal lines connecting the power plants to the end users. Incomplete infrastructure also weaken efficient network operations.

The high technical losses in electricity distribution grids are mainly due to the lack of rehabilitation of power lines, in addition to the insufficient number of substations, and more losses due to increased distances (technical losses are proportional to the distance covered by electricity) [36].

For this reason, the proposed system will study the technical loss of the electrical network by finding the relationship between the electrical current passing through the lines and the length and resistance of the cables, which is what GIS will offer us in its great ability to define and store the exact lengths of each cable. Once you draw any line (cable) using the ArcMap program, it will calculate the length in meters for this line very accurately and also by using the program tools, it will make it easier to perform the calculations and apply the equations, which will save effort and time, in addition to giving real results, more correct and accurate.

Below is a definition of terms in Electrical Distribution grids [37] that will considered to calculate the technical loss in the low voltage network:

- Electric current: a flowing electrical charge as or a stream of electrons traveling from one place to another through a conductor
- Ampere: a measurement unit of electric current intensity
- Electrical resistance: is a characteristic of electrical circuits, which is a part of the electrical circuit that converts electrical energy into thermal energy, where it is

defined as the ratio of voltage applied to the device or circuit divided by the electrical current flowing through a device or circuit, and this is also known Ohm's Law

- Ohm: It is a unit for measuring electrical resistance, symbolized by the symbol Ω.
- Electric Voltage: It has other names, such as the electric or driving force, which is the energy that is given to the electron to be able to move, and is symbolized by the symbol (V) and measured in units of volt (Volt).
- A prepayment meter: It is an electronic electrical device that measures the electrical energy consumed in the place in which the consumption is calculated, but differs from the regular electricity meter where it does not conduct electrical current unless it is pre-charged with the consumption value for a specified period of time

To calculate electrical Current at meters we will depend on these equations:

1. For Single phase:

$$I = P/V \qquad [1]$$

Where we have adopted the value of V= 220 volte

I is electric current

P=Hourly consumption rate.

2. For three phases:

$$P = \sqrt{3}\, V_{3\emptyset} * I * cos\vartheta \qquad [2]$$

So …

$$I = P/\sqrt{3}\, V3\varphi * cos\vartheta \qquad [3]$$

- And using formula for calculating the Electric Losses for each cable:

$$P_{losses} = I^2 * R \qquad [4]$$

$$\text{Where } R = L * R \qquad [5]$$

P_{losses} : is the power loss in each cable

R : is the cable resistance

L: is the cable length.

3.2.2 TECHNICAL LOSS DETECTION USING Hierarchal MODEL

Hierarchical tree depends on the principle of the hierarchy in the work, as it makes a sequence from the root, as this system begins to branch in the form of sections, and the principle of its work is based on accessing data in a sequential and branched manner, and it is either from the bottom up or from Top to bottom [38]. Figure [3.2] illustrate the hierarchal tree components.

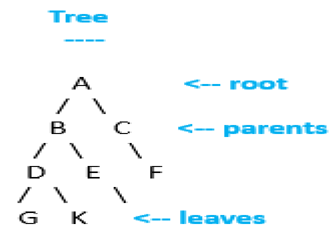


Figure 3. 2: The hierarchical tree components

Components of the hierarchical tree will explain as follow:

- Root: The highest element in the tree (at the top) as shown in the image above (which is A). The feeder are the root in our approach.
- Children: The element below any other element (B, C), we represented the poles as children of feeders.
- Parent: the element above a specific element (such as B is the parent of D, E). The poles is also represent the parent.
- Leaves: Items that do not have any children (such as K, F). The Leaves represent Meters in our case.
- To calculate the technical electricity loss, we will need to information's which are electric current and resistance for each cable.
- First, we had to calculate the electric current at each pole, and to get the current values, the data must be built in a hierarchical tree structure. As we do not have the current values initially, but we can know the electric current at the meters (which is leaves of our tree). From this information, we can use the hierarchical tree to calculate the current at any point in the network using the backward approach (bottom up).

- To do that we will add the parent for each meter, by using Geometric Networks, we have the ability to do that by selecting each meter on the map and then selecting the pole connected to it, then selecting the pole id and adding it in the column that we will add to the meter layer and call it the P_Source.
- Now that we have the parents of the meters, we will build the hierarchical tree structure in the LV_Line layer, and we will add four column which representing the root (Feeders), children, parents and leaves, as we indicated previously that the poles will represent parents and children, as they are the children of feeders, or may be the parent of another pole, or it may be the parent of the leaves, which are meters.
- We will determine for each line its source and destination weather was any of hierarchical tree elements.
- After we will build our data structure as hierarchal tree now we can calculate the electric current at any pole or line, by using hierarchal tree query, where the electric current will be the summation of all electric currents of meters that connected to this pole.
- but the complexity will be in calculating electric current at any pole for any phase (A, B, C), where the meters distributed in 3 phases network, our proposed system will make it happen by propose algorithm to calculate current depend on hierarchical tree take into account phase type, by selecting just the meters of one of these phases or the meters of 3 phases.
- If we success with calculating electric current at any pole or line we can also calculate the electrical technical losses, by using forward approach (Top to bottom).
- we have the current at any pole or line already but the resistance value from source (root) to destination are unknown, but we know every line resistance value when build

LV_Line layer, by using hierarchical tree that we build we will can calculate the summation of line resistance (which is the a product of multiplication of the line's length in km by its resistance) from root (feeder) to determined pole or line. Then multiply this result by square of electric current that was calculated previously which, the result will be the electrical technical losses.

- This well be our proposed SDSS, where all elements of our database structure have location and we will help decision makers to manage the electrical network by give them this valuable information's about loads and electrical technical losses especially on specific phase.
- We will use relational database and geometric network in ArcMap for representing electrical data, to then build hierarchical model of data, after that we will export spatial data in hierarchy model to implement hierarchical tree queries in Oracle DB to calculate electric current and loss at specific pole or LV_Line and represent it through website using java programming language. The result will extracted and will import it again to ArcMap to do visualizations of it by detailed every phase network losses and loads.

The Figure [3.3] below that illustrates the mechanism of our approach in general.

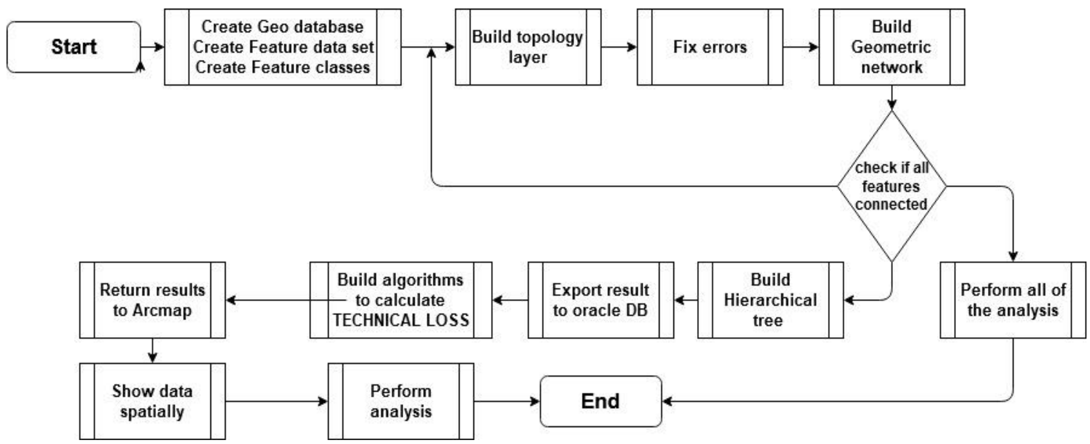


Figure 3. 3 :The flowchart that illustrates the mechanism of our approach

3.3 Use Case Diagram

Use case is a set of scenarios that describe the interaction between the user and the system, it is shows the relationship between "actors" and use cases. It helps in revealing needs and planning the project. Most of the use cases should be known during the first stage of the project, however, since the project is still outstanding, we will see more [39].

In figure [3.] explain the use case diagram of proposed system. The two main components of the use case diagram are:

- The actor: represents the user or other system that will interact with the system we modeled. In this system we have three main actors which are: Admin that control all system, the SQL Navigator, and Municipal Data System.
- Use case: is an external view of the system, reviewing some procedures and functions that the user can take to complete the task.
- Relationships: They represent the relationships between use cases, for example extends and include, the difference between them are illustrated as follow:

a) Extend: comes in the sense of expanding as the relationship between mother use case and subsequent use case is optional. Assuming it is not required to import the results of operations performed by SQL navigator to calculate current and loss into the ArcMap.

b) Include: It comes with a meaning that involves as the relationship between mother use case and subsequent use case is compulsory, meaning that in order to achieve what is in the mother use case, it must achieve what is in the subsequent use case. For example, the function of calculating the current must call the necessary data for it.

Admin tasks: collecting, Digitizing and editing relevant spatial data for medium and low voltage network in GIS, then built the Geometric network to connect the relevant geometric layers in order to express the complex electric system components and show the electric flow and its distribution spatially. Cables at 3 phases will be digitizing and relevant attributes will be adding just as material and cross section area, length will calculate geometrically, and the resistance will calculate mathematically. Then we going to present the network spatially and calculated measures were connected in order to produce semantic maps highlighted the distribution that helps making right decisions. Obtaining missing electrical data to build a spatial SDSS to calculate electrical technical losses using the capabilities of GIS by applying electric theories and equations using backward and forward approach. Cables at 3 phases were digitized and relevant attributes were added just as material and cross section area, length was calculated geometrically, and the resistance was calculated mathematically. Integrating computer science with GIS provided the ability to produce a spatial decision support system that helps to manage complex Electricity distribution network.

A 3D model will be creating to give a virtual really image of the system to help the decision makers to manage electrical network smartly and making right and effective decisions.

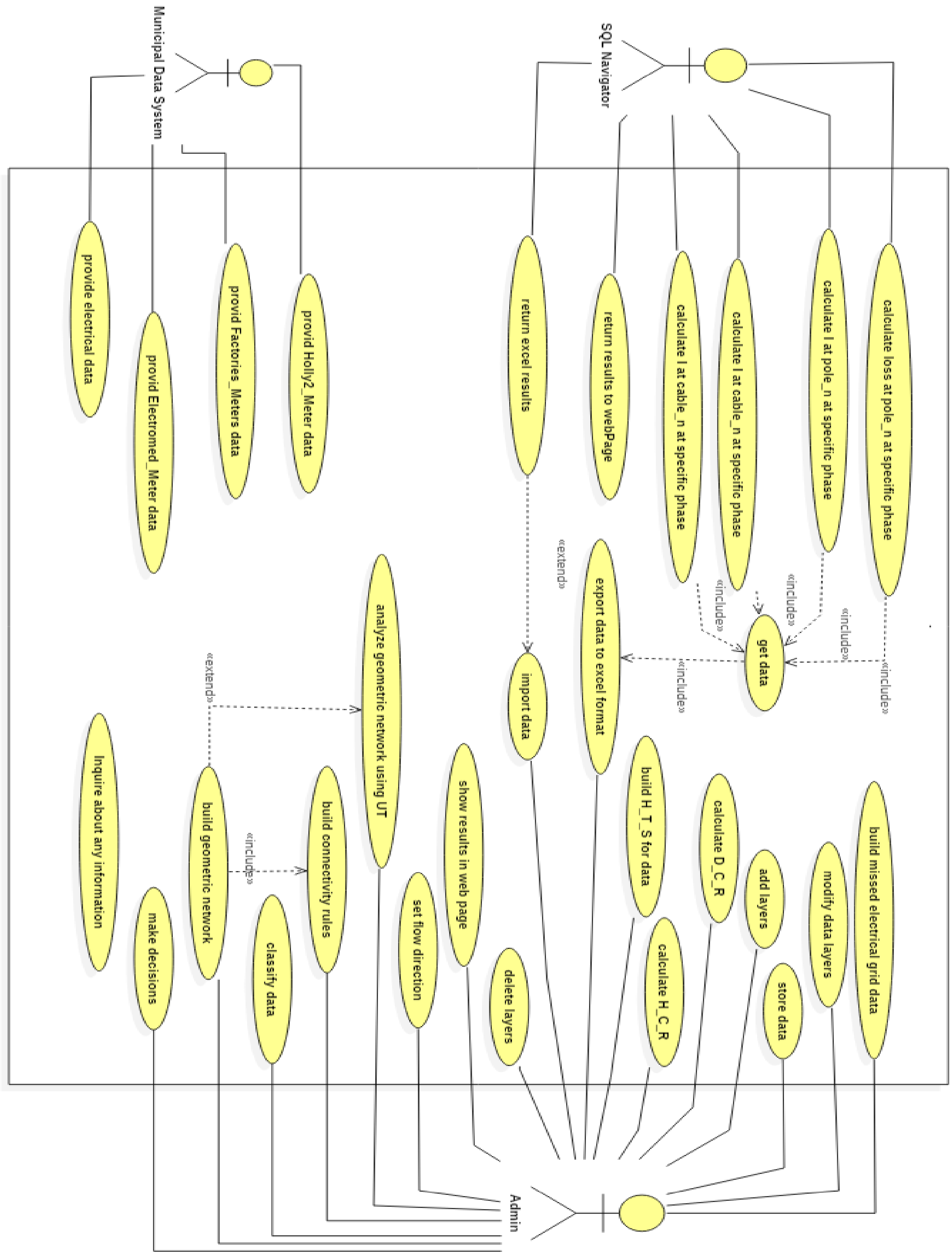


Figure 3. 4: Use Case Diagram

3.4 Spatial Decision-Support System (SDSS)

It is an interactive, system-based software that aims to help decision makers collect useful information in the form of a mixture of raw data, documents, personal knowledge, etc. that links data, complex analytical models, and data analysis tools to support business and organizational decision-making activities[40].

Decision support systems are considered one of the most important information systems that depend on computers, and they were a harvest of development in information technology during the seventies and eighties as a natural development for the way computers are used. This system simply focuses on providing appropriate support to improve the quality of decisions, as it works to achieve this requirement by incorporating data and models and software in an effective decision-making system. Given the nature of its composition, it is extremely important, as it carries in its establishment highly developed information technologies, which leads to the organization obtaining a competitive advantage for all of its competitors who do not use these systems [41].

According to this importance, there are many domains of its applications in institutions, and in order to achieve the effective application of these systems, there must be several factors, the most important of which is support for senior management in addition to the availability of the cadres in various fields of economic analysis, statistics and operations research [41]. Figure [3.3] bellow shows the SDSS model.

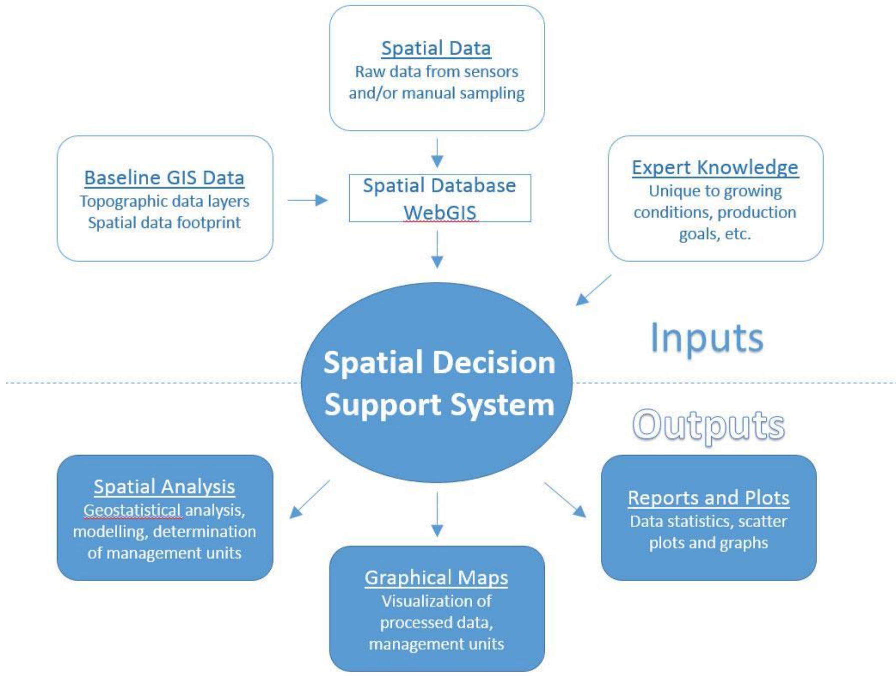


Figure 3. 5: The SDSS Model [42].

3.5 Geographic Information System as Decision Support System

GIS is one of the important tools that institutions, and organizations working in the domains of future planning and development (which represents regional and urban development strategies and planning in one of its areas) seek to use mainly in support of decision-making and to benefit from their high capabilities in monitoring, documentation, analysis, demonstration and other capabilities that It is required by the nature of those studies dealing with large amounts of spatial and descriptive data [43].

To maximize the benefit of the collected spatial data, institutions and companies are interested in converting geographic databases into an institutional form that allows more than one user or management to access and modify data simultaneously, which saves a lot of time, effort and cost in the medium and long term and later gives a broader horizon in data dissemination and design Institutional applications on them [43].

Many scientists and strategic experts describe the current era as the age of the information revolution, which is characterized by the revolution of telecommunications, remote sensing and information systems, which can provide, transmit and analyze information and important data at the moment to support decision-makers in many important decisions that require the accuracy, speed and reliability of the data and information [44].

It has also become certain to adopt a spatial analysis method (such as Topology Overlay, Raster Analysis, and Surface Overlay) using digital maps contributes to preparing the required analyzes for accurate development of areas and increases process efficiency and planning product. The goal of establishing an institutional geographic database is to implement technologies, methods, and standards that lead to the use of both geographic information systems data and services in a high degree of efficiency and effectiveness [45].

Therefore, when institutions establish a comprehensive institutional geographic information system, users of this data from different departments They can fully devote and increase the time required to perform the required analytical tasks on the spatial data while reducing the time spent searching, collecting the data required to perform those tasks. It can be said that institutional geographic information systems consist of technologies, human competencies, and the various data sources needed to create, preserve, display, research, and share geographic data and its services in the organization. Leading to an Effective Spatial Decision Support System (SDSS) [46].

Moreover, the capabilities of geographic information systems can be improved by integrating them with multimedia technologies to provide more realistic applications that make them a better tool to support decision-making due to the improvement in the accessibility of information related to development procedures and positive results from increased citizen participation and interaction [47].

Also, the process of publishing spatial applications on the Internet added wider capabilities by providing greater support to citizens concerned with development by providing them with real-time information about the projects under study where citizens can collaboratively participate in community development and on the other hand in building confidence and the right to participate in decision-making taken by the planners [48].

The study of current electrical systems of Qabatya city illustrates the need to develop new models for urban power management, especially in crowded areas for better management of electricity grids. The suggested approach is part of computer modeling to improve network efficiency. The approach we recommend is based on new models of distributed reasoning, dynamic and cooperative.

As part of this research, we propose to treat the control of the power grid as a system where decision-making is distributed among different components. The originality of this approach lies in proposing new mechanisms for thinking about solving electricity problems and improving grid management. Different models for the network well be developed in GIS. These models will take into consideration all electric grid attributes (types, location, etc.). We place ourselves in the context of decision support systems for the anticipation (prejudices or information) about the events leading to electric losses or outages. We will consider conflicting interests and priorities according to Feeders types, and so forth. All data for each entity represented in the electric system will be collected and worked upon, these data are low and medium voltage poles, transformer, Feeders and their types, data of buildings and roads and all about the electricity grid (all of this will be linked to the geographical location).

GIS techniques are suggested to digitize, save, visualize, analyze and manage the handled layers of spatial data. 3D models of the study case area will be built, visualized and presented to give better point of view to the electric system and the surrounding spatial effects.

3.6 Approach of SDSS for Electrical Distribution Grids

The proposed SDSS deals with the study of the performance of electricity distribution grids because of its importance in managing traditional and modern complex networks due to the tremendous development in electrical equipment etc. as it contributes to obtaining an integrated vision of the performance of the electricity distribution network in the various distribution and maintenance operations related to the electrical network.

3.6.1 Build SDSS Model

The proposed SDSS model is demonstrated in figures [3.4], after collecting, storing, designing, modifying and preparing data, then building geometric electrical networks for the electricity distribution network using geographic information systems in Qabatya city as a spatial decision support system.

After building the geometric network and linking all its elements through it, it will help decision makers to analyze the network using the capabilities provided by the Arc Map depending the exact locations of each element in the network, which helps this analysis in making the right decisions about network management or maintenance, etc.

A special data structure will be built to deal with the requirements and to enable calculation of the technical losses using the electrical network structure. The Palestinian electrical networks suffers in general and in this city in particular, the lack of instantaneous current readers for such data, The suggested model in this thesis I will attend to solve this problem by obtaining consumption data for each consumer during a certain period, from this information the electrical current will be calculated at every point in the network, by calculating the hourly consumption of each meter and obtaining historical data from the electricity system of the municipality of Qabatya during a period of time. After calculating the current at the meters it becomes lacking in its knowledge at any other location in the network. Therefore, a new data structure will be suggested to capable of calculating the current value at pole, any cable and any phase in the network.

By knowing the current and the resistance of the cables, we will suggest a way to calculate the technical losses at any pole and each individual phase in the network too, and the accurate results will be contributed to increase the accuracy of the network assessment and support the decision-making processes, especially when the results will be presented in the form of thematic maps and build a three-dimensional model that simulates the current state of the electrical network close to visual reality.

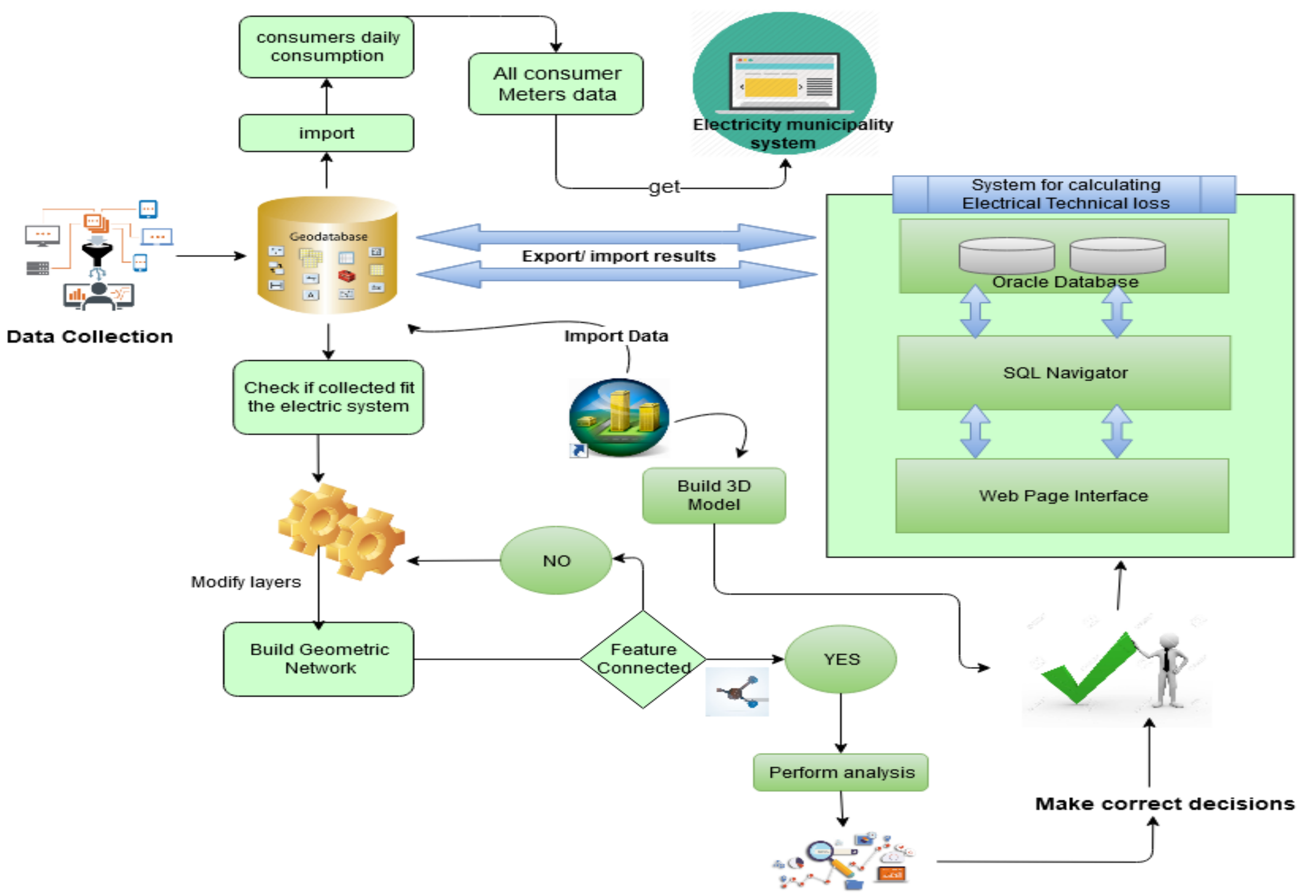


Figure 3. 6: Model Architecture

CONCLUTION

Our research methodology was discussed and the importance of GIS was described as a tool that supports decision support systems and its tremendous ability to deal with complex electricity networks. The Approach for modeling data structure for calculating technical loss in low voltage network was described and discussed. Hierarchical Model is one of the most effective method to calculate electrical technical Losses, we had presented the suggested SDSS model which was built based on arc map 10.3 and SQL oracle platform.

Chapter Four: Geodatabase design and development

Electrical distribution grid data can be stored, digitized, modified in a geodatabase. Geodatabase used to build the electrical geometric network that connects all electrical distribution network components which give us the ability to analyze electrical network, detect its problems which can help decision makers to take right procedures and decisions to solve it.

In this chapter we explain the thesis objectives and Electrical system geodatabase, then the geometric network and its capabilities in the analysis.

Finally the main UML diagrams to describe the flow of events in the proposed system, including class, sequence, and activity diagrams.

4.1 Goals and Objectives

The main goal is to build new spatial decision support system for electrical distribution grid based on GIS to enhance electrical distribution system in old crowded cities with difficult topography.

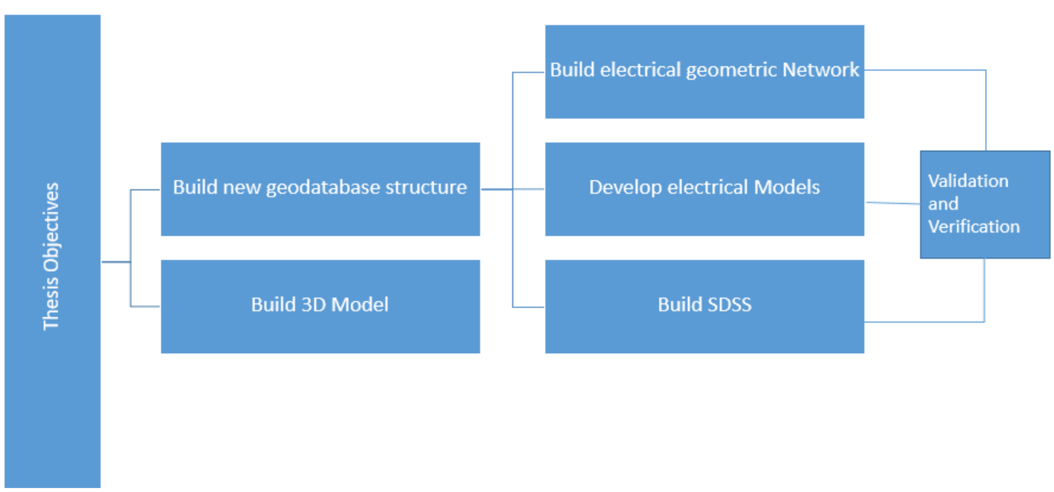


Figure 4. 1: Thesis Objectives

As shown in previous Figure [4.1], the objectives of this thesis are as follows:

Objective 1: built a geometric network that connects all electrical distribution network components which give us the ability analyzed electrical network, examine and present the flaw direction of the electric current, and detect its problems which can help decision makers to take right procedures and decisions to solve it.

Objective 2: Implement electric theories and equations to calculate daily and hourly power consumption were they helped to calculate the electric current for each consumer’s meter.

Objective 3: Calculate the electric current and technical losses at any pole, cable at any phase in medium voltage network using a hierarchal tree structure model.

Objective 4: Validation, verification and calibration of models.

Objective 5: Create a 3D model for the electric network and the voltage vs. length, phases were highlighted for each cable and each phase, the network will separate and each phase was presented individually. And then to present results of suggested SDSS spatially on the map, presenting, semantic maps using graduated color sympology for the electric current for each cable.

4.2 Electrical SYSTEM GEODATABAS

Databases are considered one of the most important reasons for the development and progress of information systems, as the world's data is stored in databases, and the databases also feed other systems and reports for different goals, the different programs that use databases, and the different goals of their existence, had make databases to take many forms and models. Everything collected without organization makes it difficult to access, and databases are no exception to this rule. So methodologies were founded for organizing and arranging databases to facilitate and accelerate searches and access to stored data. Some are traditional and some are modern, but in both cases, the programmer must have knowledge of what preceded and what is now.

GIS technology is built on the ability to organize databases as a series of layers that can be integrated and merged using its geographic location. On the basic level, every database of geographic information systems is organized in the form of a series of layers in order to answer questions related to a specific problem such as carbines, transport, environment and surface water etc. [49].

The geodatabase is the main organizational structure, data storage format and relational model in geographic information systems. It is a comprehensive container that includes different types of geographic data sets, the most important of which are Tables, Feature Classes, and Raster Dataset [50].

The geographic data model implemented in the design of the geographic database is the basis for all the activities, processes and analyzes that are subsequently performed in geographic information systems such as the production of expressive maps to support decision-makers, information retrieval, and the production of spatial analyzes[51]. To achieve these goals, Geodatabase Design must follow a deliberate and careful scientific approach. Good or Satisfying design of the institutional geographic database is produced by making sure of the good construction, effectiveness, and functionality that this design reflects, which enables [51]:

- Achieving the goals and supporting the predetermined needs.
- Contain necessary data without duplication.
- Organizing data institutionally, enables more than one user / department to access

data.

- Ease of editing, adding and managing them well.
- The ability to build institutional applications on it.

When designing a geographic database, the layers that are used during the design of the geographic database must be specified in addition to defining their content and how they are represented. This includes [51]:

- How to represent geographic data (for example in the form of lines, points, polygons, raster image or tables)
- How to organize data into classes of relationship properties
- Rules used to ensure the integrity and integrity of data and tables using: topologies or networks etc.

4.2.1 Inside the Geodatabase

The hierarchy and the schema of the geodatabase is classified to logical and physical schema [52]. The logical schema represent the metadata of the geodatabase, examples of logical schema the cables (line feature) can be presented as complex or simple edges, the main cables will be complex edges , the local cables that connected to the end users(meters) will be simple edges type. Every point in the electrical grid (connection points, transformers, feeders, poles, and meters) will be presented as junction in the network. When the geometric network will build every line will connected to other line through junctions.

There are many types of geodatabase, file geodatabase, personal geodatabase and enterprise geodatabase. The file geodatabase used to build the electrical distribution grid.

The second class of the schema is the physical schema which used to design the geodatabase for our electrical system as represent bellow:

- Feature Dataset: Created and stored within the Geodatabase which has the same coordinate system and spatial reference, where in it spatial relationships using topology and networks [53]. All collected data will store in geodatabase to have a geographical meaning, where every part of data will be linked to a location.

  Inside the feature dataset will be build all electrical distribution grid features which is: Cables, poles, towers, transformers, feeders, and meters features.

- Topology:

  What is Topology?

  This topic can be defined in a very brief way ((the topological process aims at the integrity of spatial data, so that we make the (Geodatabase) any metadata more accurate [54].

  So Structural Topology is a way for GIS to know the following:

  1- Where is a phenomenon in relation to other phenomena?

  2- Which parts of the different phenomena have a connection between them?

  3- How does communication occur between phenomena (to give us the ability to move between phenomena as in linear applications such as road networks, waterways, etc.)?

  Structural setup helps us ensure that data is not unnecessarily duplicated in the database. The database stores only one line to represent one specific border (compared to two lines, one for each polygon). The database here tells us that the line is the left side of one polygon and it itself is the right side of the adjacent polygon. There are three important concepts of structural composition in representing the spatial relationships of phenomena [54]:

1- Adjacency - to represent common borders

2- Connectivity - to represent common nodes with curves

3- Containment, or polygon definition - to represent polygons through curves, and to represent polygons within polygons as in the Islands phenomenon. The GIS program creates a database that maintains and tracks relationships as a series of common phenomena. In a regular map consisting of areas or polygons of the Earth's covering, we find that the polygons are composed of linear chains that we call Arcs - as in the Arc Info system, which have curves that polygons share, and others that do not share polygons. The database syntax permission is designed to keep a list of all the curves and how they share and relate to the information for each polygon. «» Linear database links Vector Database Links: The connection, as recorded in the structural composition in the database, allows us to perform operations such as identifying bridges and paths from one phenomenon to another. Relational inquiry capabilities with constructive data structures give us the ability to examine through complex logic to identify and discover sites worthy of our attention during GIS analysis processes, and here lies the power of these systems.

- Networks : It is a system consisting of many interconnected elements, such as lines and points, networks divides in ArcGIS into two groups [55]:

  a) Network datasets: what distinguishes this network is that the direction of the flow is two-way, such as transportation networks.

  b) Geometric networks which is applied to sewage, electricity and water networks, different from a network dataset is that the direction of the flow is restricted in one way direction, and this is logical. For example, the electricity network stream from the source towards consumers not vice versa.

4.3 GEOMETRIC NETWOR

Geometric networks: it is a modeling of utilities such as electricity, water, sewage, gas, flight networks, etc. It is called the infrastructure engineering network and it is subject to complex rules [56].

It represents a correlation between several feature classes files built inside feature dataset, these files be a line or point type, and we can benefit from this network to know the direction of flow through identifying sources and sinks with the possibility of analysis in the event of a break or malfunction in the network, it can find location of breakdowns, fractures etc. [56]. Geometric network will be built considering its geometric and topologic rules, geometric network is composed of edges that are connected. Connectivity rules for the network specify which edges are connected and at what points they are connected, commonly referred to as intersection junctions. These edges can have weights (attributes and properties) or flow direction assigned to them automatically according to the network graph, which dictates certain properties of these edges that affect analysis results such as electric lose. In the case of certain types of networks, source points (points where flow originates) and sink points (points where flow terminates) may also exist. In this research, as a case of utility networks, a source point correlates with an electric supply, and a sink point correlates with an electrical consumer (whether residential, industrial, commercial, or others). Networks define the interconnectedness of features in general. In GIS, it also defines the location and the spatial distribution and the integration with other layers such as buildings, roads, consumers and historic data. A set of tools, analysis and methods will be used or programmed to manage and optimize the suggested electric network in Qabatya city smartly.

When we say electricity geometric network, it will definitely be built on a number of feature classes that represent components of electricity grid: in our case the electricity component in general is the source that feeds the city of Qabatya, which is the Israel Electricity Company, extends to the connection points and then to the medium voltage network and medium voltage towers, after which it extends to the low voltage network and the low voltage poles to the consumers at the end.

Geometric Network Component

Geometric networks are consists of the following elements [77]:

1. Edges network features:

   It is a feature that has a certain length and the direction of the flow, and through it which the direction of the flow, it is created from Lines feature classes, for example, the transmission lines of electricity through which the electric current flows

   There are two different types of edges:

- Simple Edge: this type has only one in point and one out like sub-power lines
- Complex Edge: each line has more than one branch, like Medium voltage cables, and low voltage cables.

2. Junctions network features: It is created from points feature classes, which allows to connect two or more edges, and ease the transfer of flow between edges, for example :Feeders, fuses, switches

   There are two different types of junctions:

   - User-defined junctions: it is a junctions are created based on points feature classes, which were added during the construction of the geometric network, such as transformer points, feeders, poles etc.

- Orphan junctions: the network automatically builds it, upon completion of the construction of the geometric network as it is very important to clarify the network faults, especially at the ends of the edges, if there are points that are not connected to the edges, or if there is an edge that does not end with a point which is not true with the geometric network. A layer is added for this type called geometric network _Net_Junctions.

4.3.1 Model for the electrical Geometric Network

The electricity generation and distribution network for the city of Qabatya consists of several main components:

- MV_ Towers without transformer: they are medium voltage towers without a transformer, which is to carry medium voltage cables (simple junction).
- MV_ Towers with one transformer: they are medium voltage towers carries one transformer (transformer capacity ranges from 230-436 KVA), and also carry medium voltage cables (simple junction)
- MV_ Towers with two transformers: The same kind of MV_ Towers with one transformer but the difference is that it holds two transformers (simple junction).
- MV_Towers_IEC: The main source of electricity in the city of Qabatya, which is the Israel Electricity Company (simple junction).
- MV_Lattice Pole: it’s a poles for medium power transmission cables, which have ability to handle a huge cable loads (simple junction).

- Indoor transformer: it’s an internal transformer that is inside a facility or room, and in the city of Qabatya there is one transformer of this type, which is for a Qabatya well (simple junction).
- Connection Points: (simple junction) we can consider them as substitutes for switchgear, interested in examining the amount of electricity consumption for the city of Qabatya, connection Points are devices that are used to separate, connect, control and protect the electrical circuits and fittings, which is also a term that includes a wide range of products such as circuit breakers, switches, fittings with HRC fuses, grounding circuit breakers, and ground leakage cutters etc.
- Underground Cables: when suspended high-voltage cables tracks approach crowded residential areas, they are converted to another path buried underground with special specifications and protection systems (Complex edge).
- ACSR Cables (Aluminum conductor steel-reinforced): They are aluminum pneumatic medium voltage lines and steel reinforced, which are three-phase lines (ABC), chosen for its high-strength, high-capacity, good conductivity, low weight and its cost is lower than other types (Complex edge).
- Low voltage cables: It works whether to transfer or distribute electrical power in desert or rural areas and that is to cheapen its costs in relation to the ground cables, where the antenna is installed from the following basic parts: (poles, connectors, and insulators).
- Low Voltage cables (Complex edge) are manufactured according to British and international specifications and with a voltage of 600/1000 volts. These types of products are used in the distribution of energy and extensions for commercial or industrial buildings, external or internal, electrical machinery, ground or suspended

installations, and wet areas. Low voltage cables are three-phase lines (ABC).

- Feeders (simple junction): every transformer has feeders that feed specific zoon.
- Meters: each consumer have meter for consumption readings.

4.3.2 Geometric Network Analysis

In the applications of electricity networks, knowledge of the flow direction of electrical current along the electrical lines is essential and important for network management, as geometric networks allow us this feature by linking the network lines and identifying the sources and sinks for the network.

Managing the electric distribution grid by spatial geometric network will use all the analysis techniques to get a valuable solutions for solving the problems of interruptions and loss of electricity, as well as the ability to manage and control the grid and restructure it in a way that increases the efficiency of the electricity, which helps in reducing the economic and technical losses. We will also build a three-dimensional model for the network and region.

Utility Network Analyst tools used for set flow direction and to do many tasks that contribute to the analysis and management of the network through several available commands utility network analyst software is shown as follows [58]:

- Trace Upstream Task: to finds all network elements that are above a certain point on the network.
- Upstream Accumulation Task: to find the sum of the costs of all network elements that are higher than a certain point on the network.
- Path Upstream Task: to find the upstream path from a point on the network to the electricity source.

- Common Ancestors Task: to find all the features associated with a particular point through the electricity network.
- Connected Task: to find all lines that are connected to a specific point through the electricity network.
- Disconnected Task: to find all lines that are not connected to a specific point through the electricity network.
- Path Task: to find the path between two points on the network.
- Loops Task: to find the lines inside the loops.

Other network utility tool capabilities for electrical network is to know that if a power outage occurs in the network, we can know which consumers in the network that will suffer from power cutting and also know the exact location of malfunction is and then know the shortest path to reach this location for maintenance work, this means that we contribute to helping decision makers to take the correct procedures and decisions to solve the problem, for example knowing the closest or best alternative feeder in terms of its ability to increase loads on it and convert the area affected by the power outage to the alternative feeder.

4.4 UML Diagrams

UML is a unified modeling language with many purposes, it is generally specialized in software engineering and object oriented design notation. Use this language to create diagrams to describe computer programs, UML is not limited to software engineering, but rather geographic information systems too, and representation of organizational structures [59]. UML provides three looks to the system: a look at processes, a look at composition, and a look at behavior.

4.4.1 Class Diagram

Class diagram describes the static structure of a system. The classes represent an abstraction of entities with common characteristics. Associations represent the relationships between classes.

Class diagrams are used in almost all Object Oriented software designs.it is widely used to describe the types of objects in the system and their relationships to each other.

The classes consist of three things: the name, the attributes, and operations.

Class diagrams also display relationships such as containment, inheritance, associations and other things [60].

Association relationship is the most common relationship in the Class Diagram which link clarifies the relationship between instances of classes, for example, the LV_lines class is associated with the consumers meters class. Multiplicity of the association denotes the number of objects that can participate in the relationship. For example, a line object can be associated with more than one consumer meter, but one consumer meter can be associated with one line.

Another common relationship in class diagrams is generalization. Circular is used when there are two similar classes, but there are some differences. Look at the following "generalization":

For example, the Towers category and the tower transformer individual have some similarities like name and address, but each category has some of its own "attributes" and operations. The "class towers" client is a general form of the constellations category.

Figure [4.2] illustrates the class diagram where represents the main classes that form the core of the suggested system (each class have its own attributes and operations).

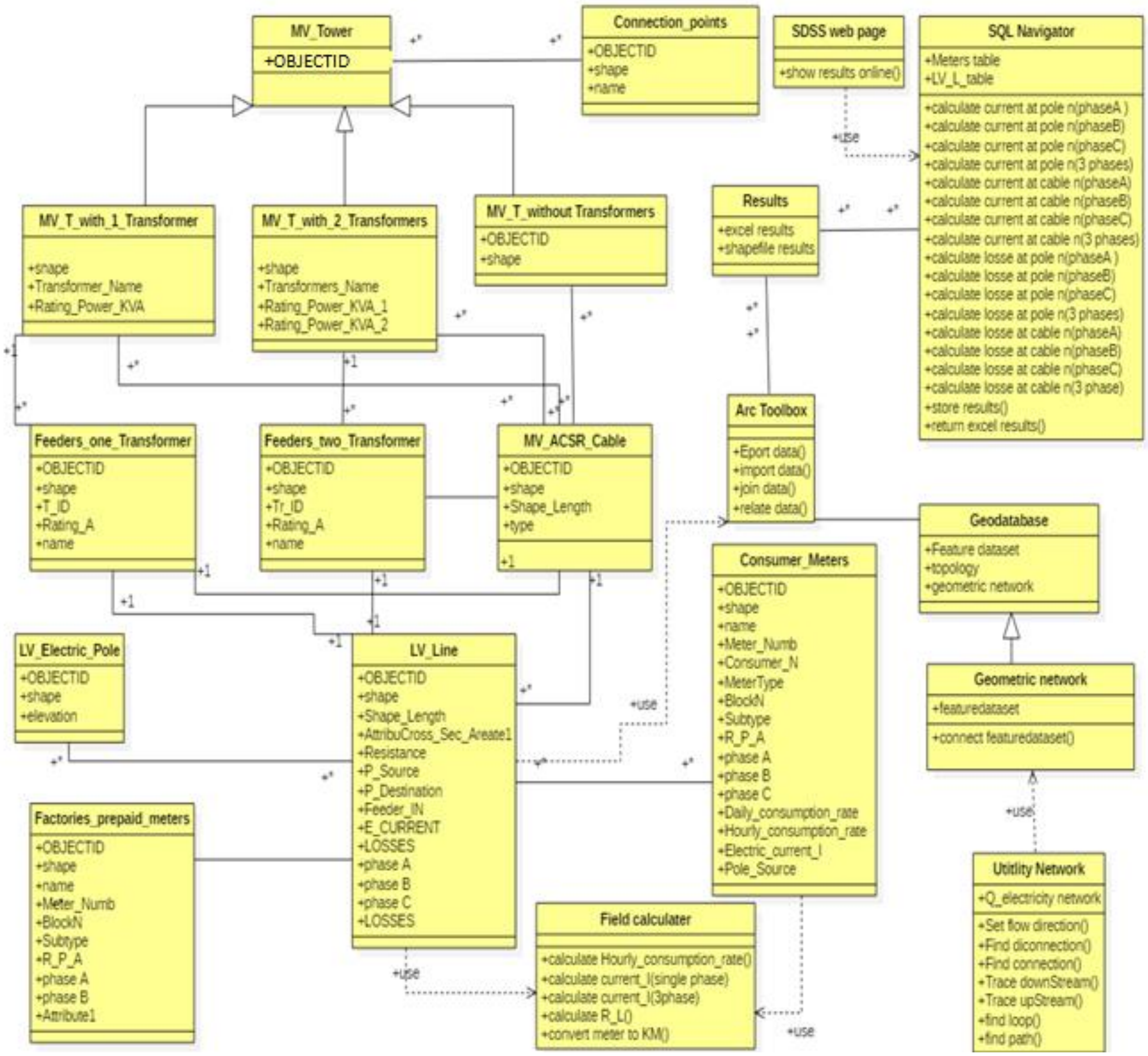


Figure 4. 2: Class Diagram

4.4.2 Sequence Diagram

Sequence diagrams explain the behavior of “use cases” when describing the objects and the messages passed between them. The charts are read from left to right and in descending order. The timeline displays the objects participating in the interaction. This consists of the vertical dimension (time) and the horizontal dimension (different objects) [60].

Scenario 1: Admin will have the ability to control the system as a whole as he performs some operations, first as explained in the figure [4.4] and figure [4.5], he inquire about the value of the electric current at any pole or cable, at any phase in the electrical network by using the SDSS website, and the system will retrieve the required information through some operations linked in a time sequence..

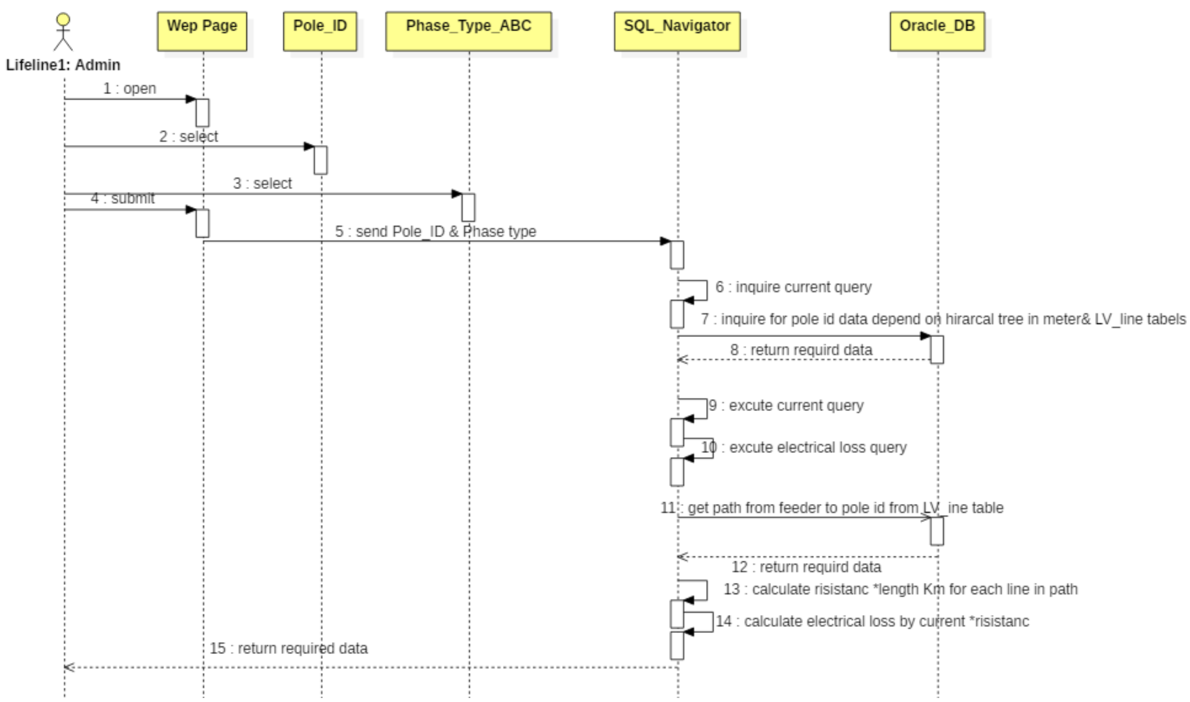


Figure 4. 3: sequence diagram that represent the current and electric losses calculation process at a specified pole and phase and displays it on the website

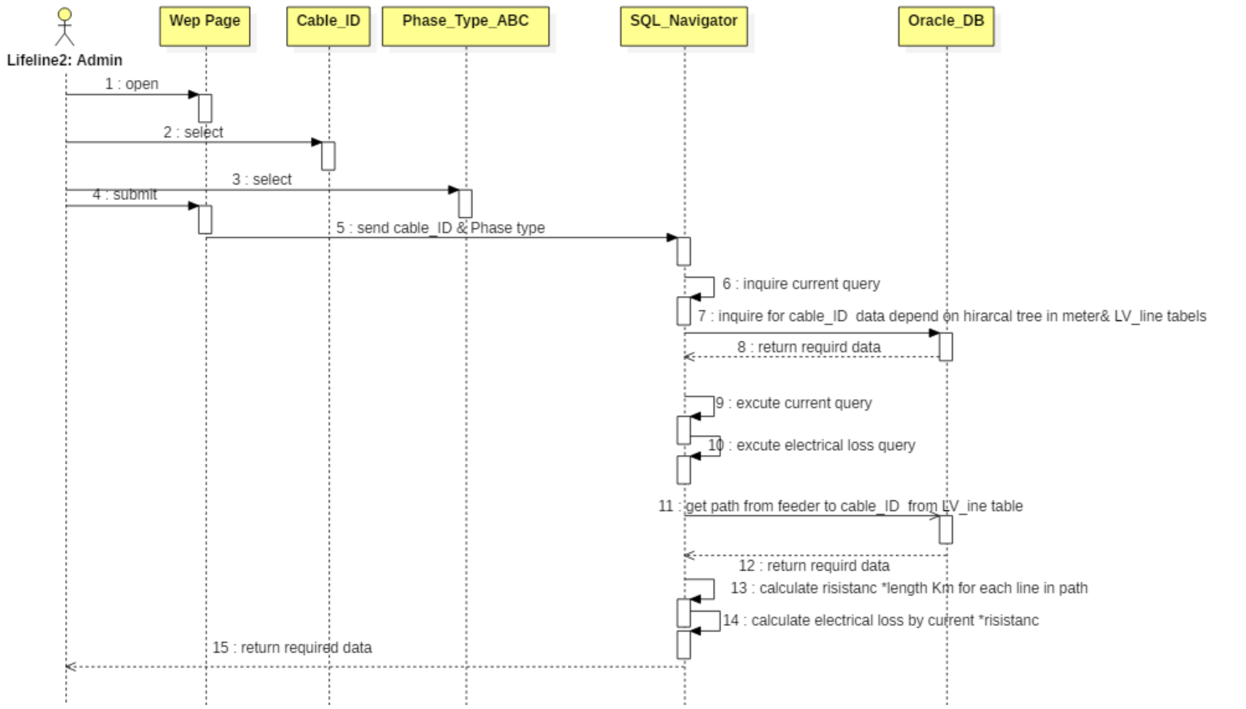


Figure 4. 4: sequence diagram that represent the current and electric losses calculation process at a specified cable and phase and displays it on the website

Scenario 2: As shown in figure [4.6], Admin will collect the data of the two types of meters from municipal electricity systems to calculate the D_C_R and H_C_R to calculate then the electric current at any meter for either single or triple phases.

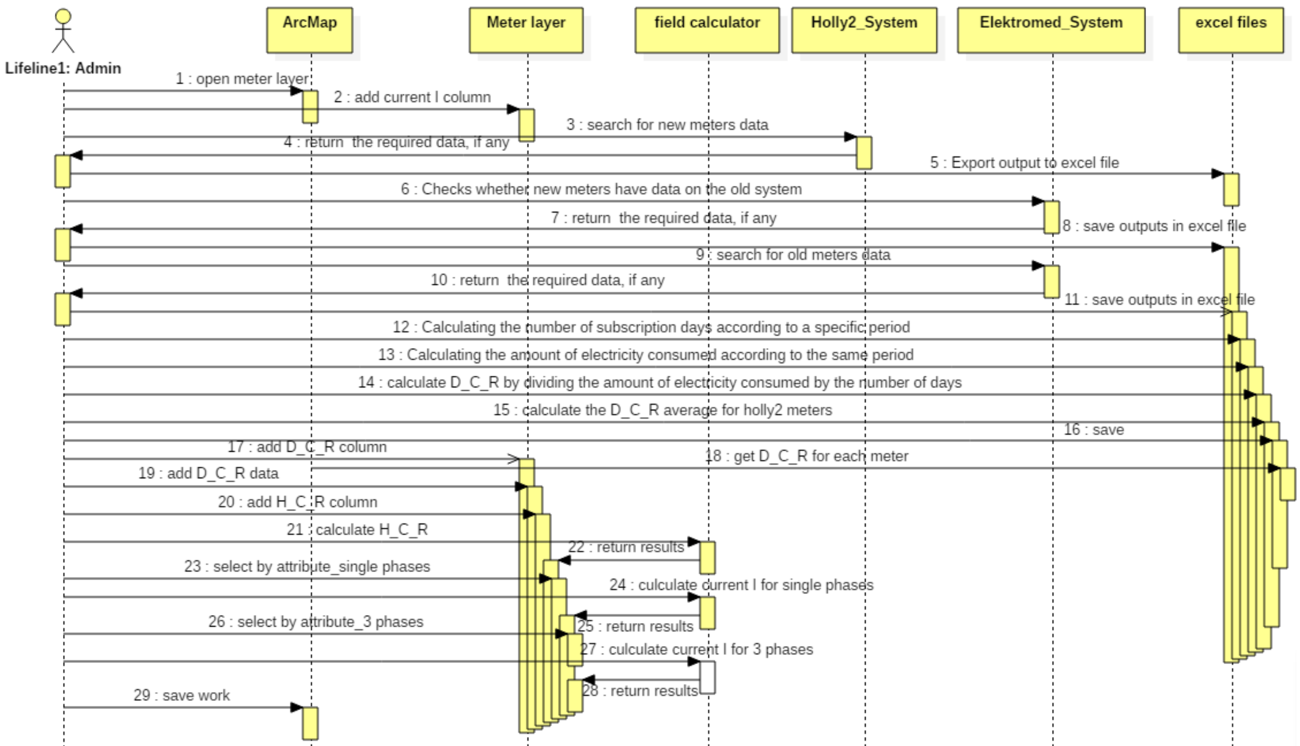


Figure 4. 5: sequence diagram that represent data collection and electric current calculations presses for single and triple phases

Scenario 3: represent building hierarchical modeling for LV_Line and meter data by admin as it detailed in the figure [4.7]. Whereas, through many addictive operations, admin will be built the hierarchical tree of lines (cables) and poles, through geometric network he will determine the pole source and destination for each line and store the pole id in new columns in LV_Line table, if the source of the line is the feeder, then he will store the feeder id in source column, and if the meter is the destination of the line, he will store the meter id in destination column.

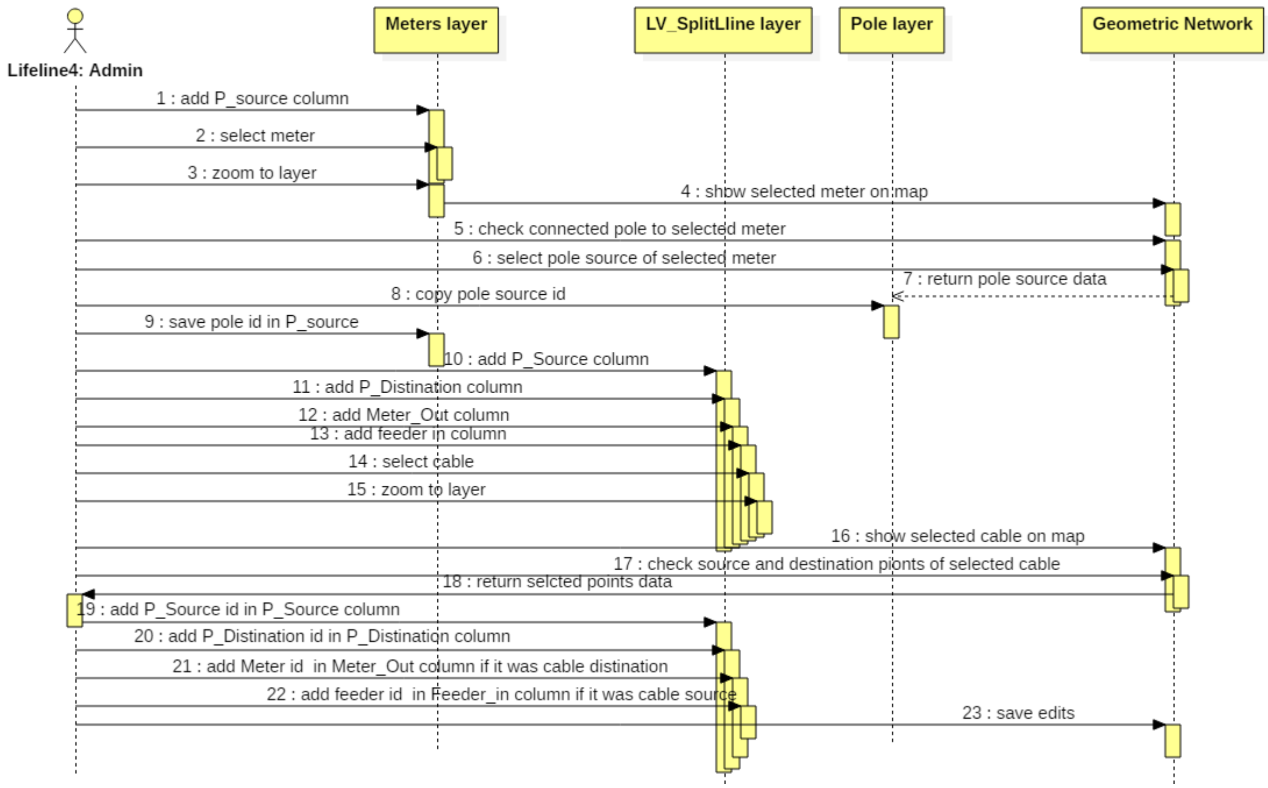


Figure 4. 6: sequence diagram that represent building hierarchal modeling for LV_Line and meter data

4.4.3 Activity Diagram

Activity diagrams describe system workflow behavior, they are similar to state diagrams because the activities represent the state of doing something. These kind of diagrams describe the status of activities by showing the sequence of activities performed, where it can show conditional or parallel activities [60].

The main reason for using Activity diagrams is for modeling workflow within the system that we design, as it is also useful for use case analysis by describing what is the actions we need to do and when they should occur, and describing a complex sequential algorithm and modeling applications with parallel processes.

Here in figures [4.8], [4.9] and [4.10] we explained how to calculate an electrical current and losses at a specific pole or line at determined phase.

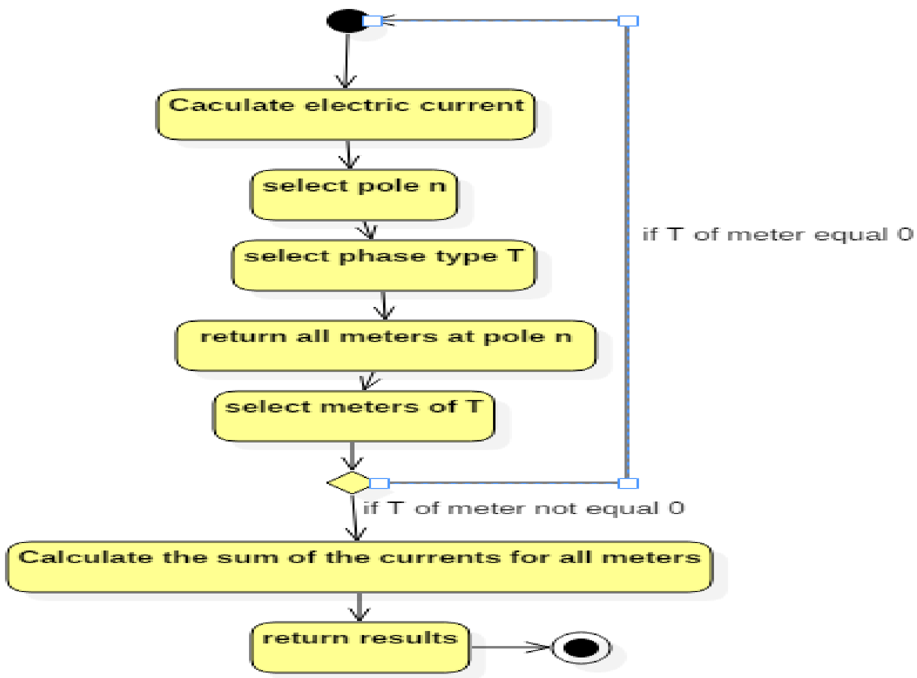


Figure 4. 7: Activity diagram the process of calculating electric current at specific pole and phase

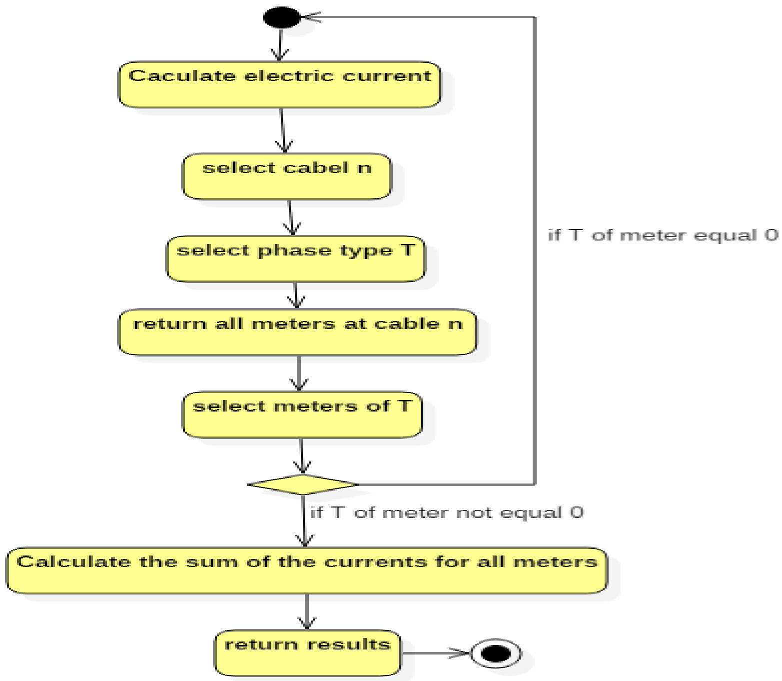


Figure 4. 8: Activity diagram the process of calculating electric current at specific cable and phase

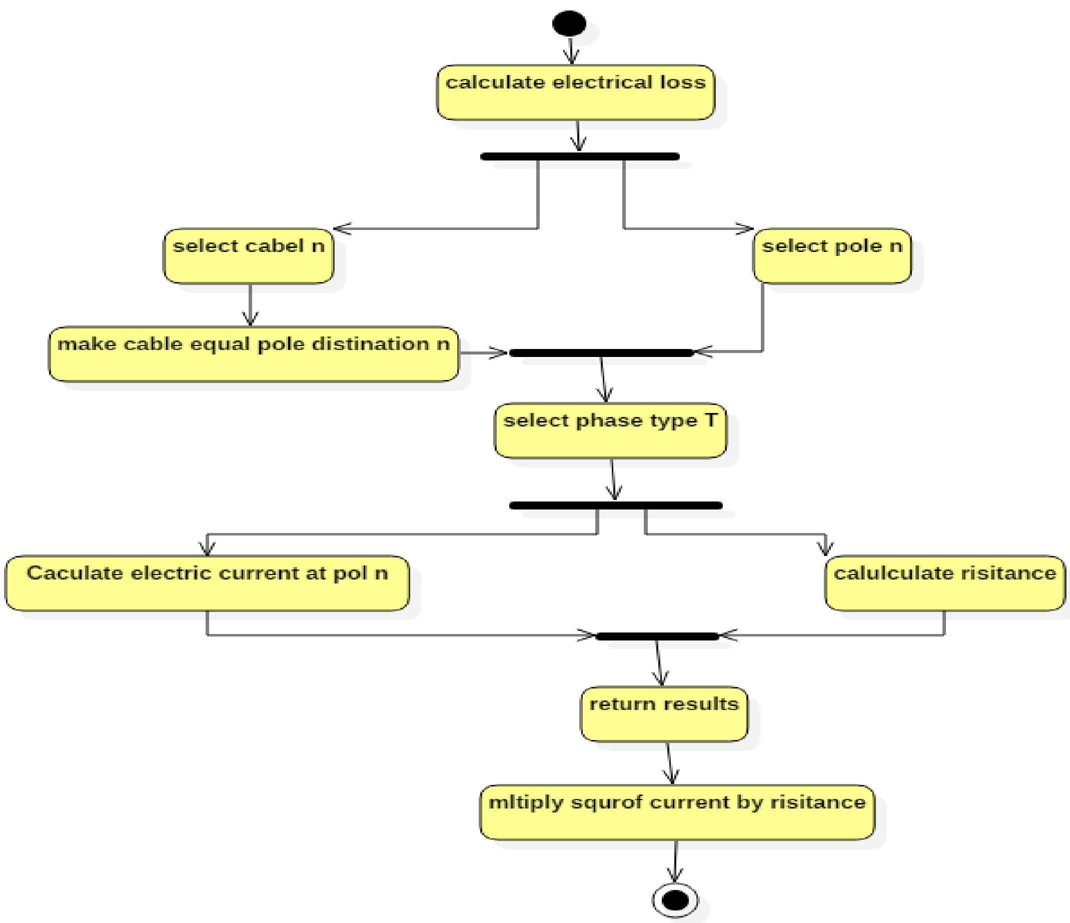


Figure 4. 9: Activity diagram the process of calculating electrical losses at specific pole or line and specific phase.

CONCLUTION

In this chapter we have describe the objective of our research, then how the data stored in geodatabase, illustrate the importance of geometric network in term of linking all electricity network elements and the ability to manage it and analyze its problems by using geometric network and its component.

Finally we have presented the software modeling for our system using UML to model all the system components, main actors and their behaviors and the interactions between them which illustrated in object oriented UML diagrams.

Chapter Five: Software development

In this chapter, the data collection and testing phases are illustrated. The first section is composed of the data collection part, editing, preparing and correcting data. Main part of the editing and digitizing process was building correct Geometric network, and applying network analysis and examining the results. the second section describes the implementation of calculating the electric loss using SQL Navigator for Oracle and java to show system result, add to this special section to explain the main steps of building 3D model for Qabatya using ArcGIS Arc Scene 3d abilities to create 3D surfaces and 3D visualization for Qabatya city medium and low voltage electrical grid as part of the SDSS.

5.1 Study Area

Qabatya city was chosen as this thesis study area as demonstrated in figure [5.1], this city was chosen because of the availability of the geometric and geographic data for building the suggested system of network in one hand, in the other hand the complexity of the old city data and its topology, add to this the lack of consumers properties and meters electric data and the increase of the rate of losses in electricity in the city, whether it was a technical or non-technical losses.

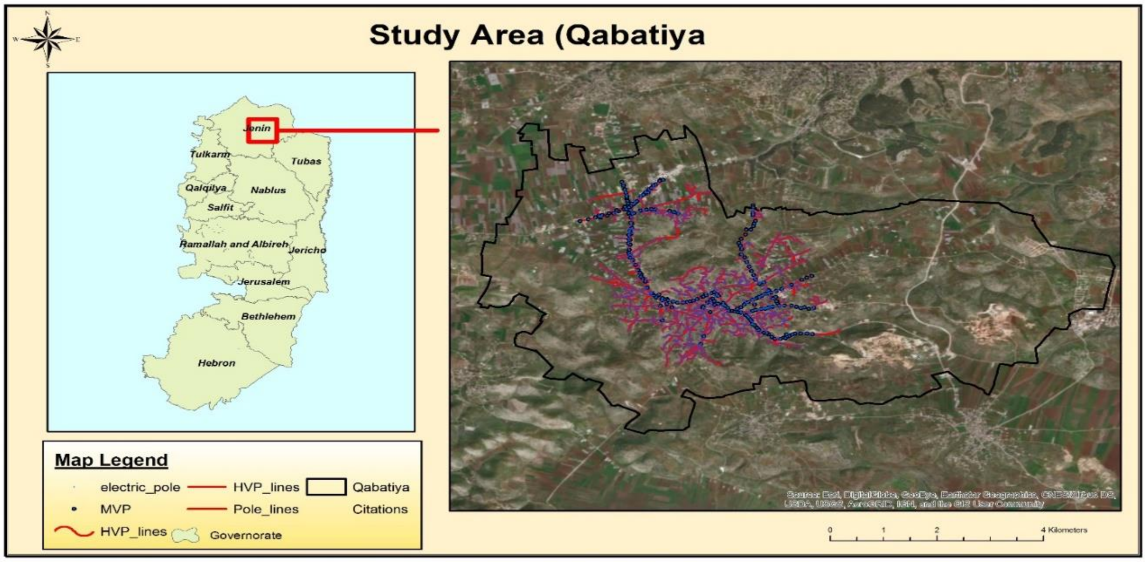


Figure 5. 1 : The Study Area, Qabatya city

5.2 Data Collection and Preparing

Preliminary data were taken from Qabatya Municipality was the low voltage network (LV Pole and LV Lines) shown in figure [5.2], all consumers and meters data, Geomolg (the __ website) Qabatya Aerial Photo 2018 and Palestine Explorer for Qabatya blocks an parcel registration.

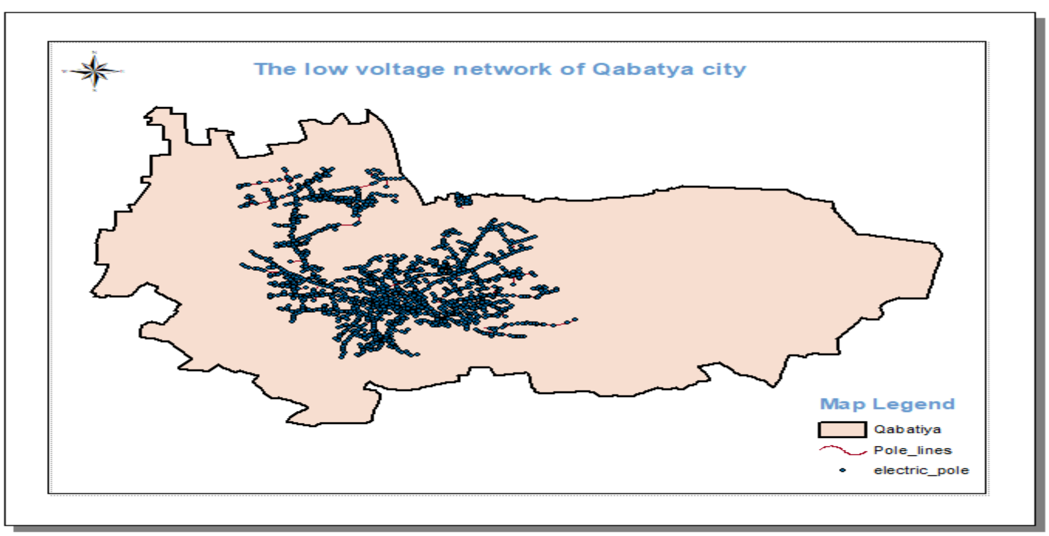


Figure 5. 2: The low voltage network

The medium voltage network data was obtained from the electricity department of the municipality of Qabatya city (MV Pole and MV Lines) which shown in figure [5.3].

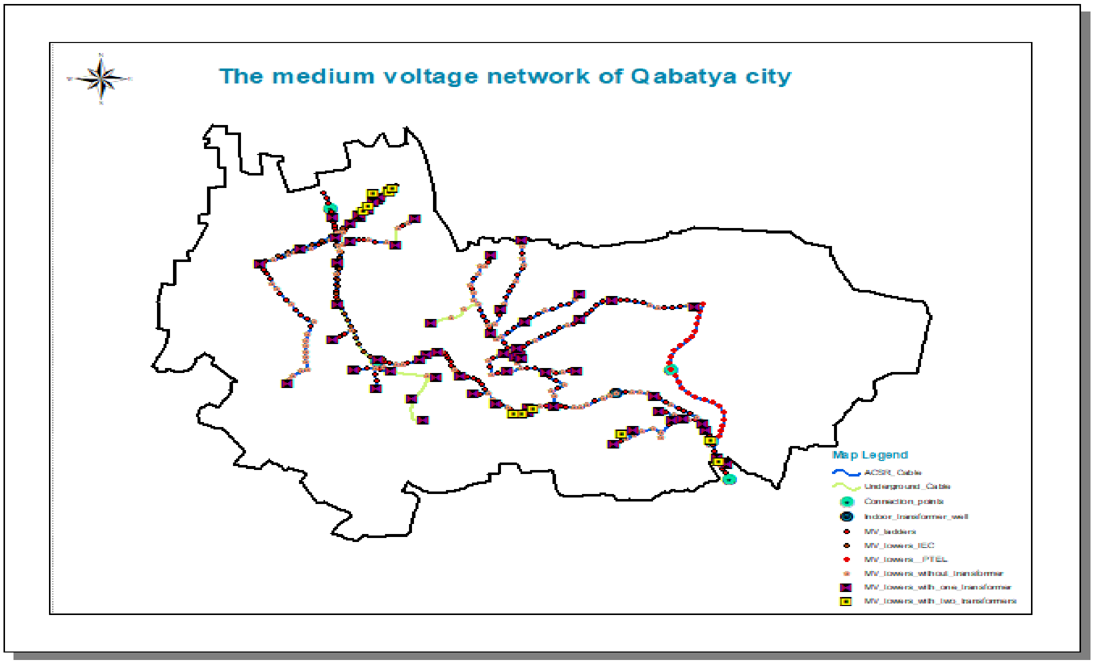


Figure 5. 3: The medium voltage network

The achieved data has been disaggregated to assist in the search. Lines' and transformers' types are examples on these data. Figure [5.4] shows all obtained data layers.

ACSR_Cable
Big_Industrial_Consumers
Connection_points
Indoor_transformer_well
LV_ElectricPole
LV_PoleLine
MV_ladders
MV_towers__PTEL
MV_towers_IEC
MV_towers_with_one_transformer
MV_towers_with_two_transformers
MV_towers_without_transformer
Qabatiya_Land_Boundary
Underground_Cable

Figure 5. 4: All data layers we have until now

Low and medium voltage networks have been linked together and installed on Qabatya city Aerial Photo 2018 to find out the errors and shortcomings in the overall network. Figure [5.5] shows overall Electrical Distribution Grids of Qabatya city.

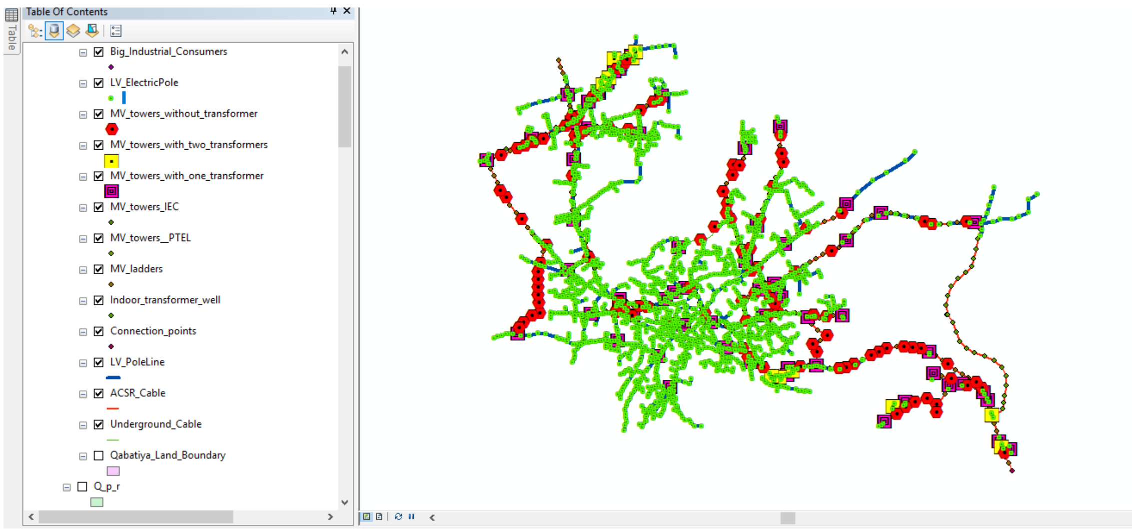


Figure 5. 5: Electrical Distribution Grids of Qabatya city

One very important missing data was the kilowatt-hour electric Meters data of consumers. No computerized data about these meters was available, while this data is very important for the objectives of this study. Therefore, this study had to take care of making these data available, and this has been performed.

The following figure [5.6] shows a table of the first sample of meters data of the stone factories in Qabatya city, where they are classified as the largest consumers of electricity in this city.

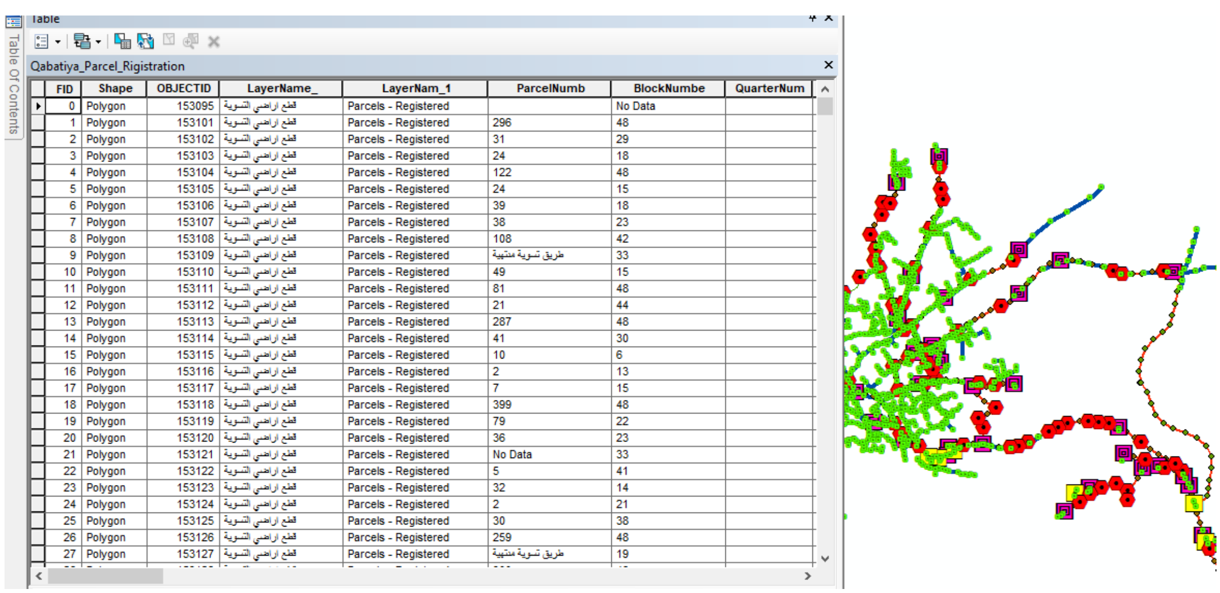
	A	B	C	D	E	F	G	H	I
1	الرقم	رقم المشترك	رقم العداد	اسم المشترك	BlockNumbe	رقم القطعة	معامل محول التيار	B_P	Parcel_block
2	1	000808	00000000	محمد بلال صادق كميل	22	1	40	22001	10022
3	2	008003	00000000	فايز احمد اسعد اسعد	22	21	120	22021	210022
4	3	008004	00000000	حازم عبدالرحمن احمد	22	20	80	22020	200022
5	4	008005	00000000	محمود حسن عبدالرحمن	22	13	120	22013	130022
6	5	008006	00000001	عبدالرحمن ناجي مصطفى كميل	17	28	120	17028	280017
7	6	008007	00000001	لميع كايد نايف خضر و ربيع كايد نايف	17	27	80	17027	270017
8	7	008008	00000000	محمد اسماعيل عبد الرحمن أبو طالب	17	27	120	17027	270017
9	8	008009	00000001	محمد احمد كامل زكارنة	17	27	120	17027	270017
10	9	008010	00000000	جهاد محمد عبدالرحمن	17	27	120	17027	270017
11	10	008011	00000000	غسان عبدالرحمن محمد الرب	17	27	200	17027	270017
12	11	008012	00000000	عبدالرحمن ياسين عبدالرحمن كميل	16	13	80	16013	130016
13	12	008013	00000001	حسن عبدالرحيم محمد زكارنة	17	25	120	17025	250017
14	13	008014	00000000	محمد احمد عبد كميل	17	12	120	17012	120017
15	14	008015	00000000	محمود غضبان عبد الرحمن عساف	16	13	80	16013	130016
16	15	008016	00000000	بلال صادق محمود كميل 1	22	1	80	22001	10022
17	16	008017	00000001	محمد صبري احمد كميل	16	13	200	16013	130016
18	17	008018	00000000	زياد محمد سليمان خزيمية	16	26	100	16026	260016
19	18	008020	00000000	باسم عبد الله علي سباعنة	22	19	120	22019	190022

Figure 5. 6: Sample of consumer data

Meter numbering system in this study is based on the Block and parcel numbers for each consumer. These numbers have been achieved from the Palestinian Center for Studies in Ramallah. The consumers table has been merged with the blocks table according to block and parcel numbers by using join tool. Data incompatibility appeared for some consumers. Additionally, the data was insufficient as consumers were scattered on the map sporadically. Therefore, and to make the study as accurate as possible, a case study of only one block has been chosen. In this block, the parcel number data of most electrical consumers were available. At the same time, the number of consumers and the variety of their nature: single and three phase consumers, different phases, was enough to represent a complete electrical system. The consumers in this block are mainly connected to one medium/low voltage transformer. Consumers connected to other transformers have been safely neglected, because this does not influence the accuracy and the reliability of the results. Moreover, taking these consumers into consideration does not improve the accuracy or the reliability of these results, so we take a sample of one block where it contains many parcels and consumers. This was a new challenge to face the same problems by increasing the number of consumers, then repeated the previous steps to solve the problem and also found an incompatibility between the data of the municipality and the data of the study center. In Table [5.1] below shows sample of consumers before joining process, and figure [5.7] shows sample of consumers after joining the Qabatya_Parcel_Regestration shapefile with consumers excel file.

Table 5. 1: Sample of consumer data before join.

نوع الاشتراك	القطعة	الحوض	اسم المشترك	الرقم
سكن-بناية سكنية	151	35	شاهر محمد يوسف كميل	1
سكن	151	35	روضه محمد قاسم عبيد	2
سكن	85	35	علاء الدين محمد راغب كميل	3
تجاري	107	35	قاسم محمود قاسم حمامده	4
سكن	61	35	جميل اسعد محمد حمامده	5
تجاري	111	35	محمد عبد محمد عساف	6
سكن	130	35	ساميه ناصر محمد كميل	275
سكن	118	35	علي بلال علي كميل	276
سكن	27	35	ركن الدين محمد يوسف كميل	277



FID	Shape	OBJECTID	LayerName_	LayerNam_1	ParcelNumb	BlockNumbe	QuarterNum
0	Polygon	153095	قطع اراضي التسوية	Parcels - Registered		No Data	
1	Polygon	153101	قطع اراضي التسوية	Parcels - Registered	296	48	
2	Polygon	153102	قطع اراضي التسوية	Parcels - Registered	31	29	
3	Polygon	153103	قطع اراضي التسوية	Parcels - Registered	24	18	
4	Polygon	153104	قطع اراضي التسوية	Parcels - Registered	122	48	
5	Polygon	153105	قطع اراضي التسوية	Parcels - Registered	24	15	
6	Polygon	153106	قطع اراضي التسوية	Parcels - Registered	39	18	
7	Polygon	153107	قطع اراضي التسوية	Parcels - Registered	38	23	
8	Polygon	153108	قطع اراضي التسوية	Parcels - Registered	108	42	
9	Polygon	153109	قطع اراضي التسوية	Parcels - Registered	طريق تسوية منتهية	33	
10	Polygon	153110	قطع اراضي التسوية	Parcels - Registered	49	15	
11	Polygon	153111	قطع اراضي التسوية	Parcels - Registered	81	48	
12	Polygon	153112	قطع اراضي التسوية	Parcels - Registered	21	44	
13	Polygon	153113	قطع اراضي التسوية	Parcels - Registered	287	48	
14	Polygon	153114	قطع اراضي التسوية	Parcels - Registered	41	30	
15	Polygon	153115	قطع اراضي التسوية	Parcels - Registered	10	6	
16	Polygon	153116	قطع اراضي التسوية	Parcels - Registered	2	13	
17	Polygon	153117	قطع اراضي التسوية	Parcels - Registered	7	15	
18	Polygon	153118	قطع اراضي التسوية	Parcels - Registered	399	48	
19	Polygon	153119	قطع اراضي التسوية	Parcels - Registered	79	22	
20	Polygon	153120	قطع اراضي التسوية	Parcels - Registered	36	23	
21	Polygon	153121	قطع اراضي التسوية	Parcels - Registered	No Data	33	
22	Polygon	153122	قطع اراضي التسوية	Parcels - Registered	5	41	
23	Polygon	153123	قطع اراضي التسوية	Parcels - Registered	32	14	
24	Polygon	153124	قطع اراضي التسوية	Parcels - Registered	2	21	
25	Polygon	153125	قطع اراضي التسوية	Parcels - Registered	30	38	
26	Polygon	153126	قطع اراضي التسوية	Parcels - Registered	259	48	
27	Polygon	153127	قطع اراضي التسوية	Parcels - Registered	طريق تسوية منتهية	19	

Figure 5. 7: Sample of consumer data after joining two tables (Qabatya_Parcel_Regestration shapefile and Excel file for consumers).

The medium and low voltage networks for the chosen block have been built. All feeders of the transformer and all phases of each feeder have been spatially modeled. All consumers of the transformer have been spatially connected to the appropriate phase and feeder, as well.

Based on the aerial photo of Qabatya 2018, the exact location of each element of the network has been identified and represented on the spatial model in a correct way to get real data and to build the database completely and properly.

As a result of the huge number of meters in the city of Qabatya and the difficulty of getting all of them at a specific time, we decided to limit our study on transformer No. 44 in Qabatya electricity network, where it has three feeders, including the low-voltage network extending to consumers (Meters).

To complete all the meters on this transformer No. 44 by referring to the municipality engineer and taking all the meters on this transformer, determine to us all the meters on each feeder specifically, determine each meter if it is single phase (phase A or B or C) or 3 phase. Next step was referring to the electricity systems of the municipality of Qabatya to get data for each meter (consumer number, meter number, date of each payment, and the amount of charged electricity).

Also, one of the obstacles we faced was the existence of three systems:

- The old Electromed meters system
- The new Holly2 meters system
- Industrial and commercial meters system

- The looking at the new meters system to make sure there is a meter for this consumer in the new system and if did not find any data for him then this meant that he was still on the old system.

- The following steps are get a sales report and all other information to do a data analysis for the consumers:

- **The new Holy2 system:**

a) From the main program window fill the name of consumer in search field to get the consumer number copy the consumer number from the search result

b) From the sales inquiry screen, paste the consumer number in the consumer number field and inquire about the consumer

c) Export the information to an Excel file and choose the information we need.

In the following figures [5.9 - 5.13] we show how we did some of these operations to get holly2 meters data

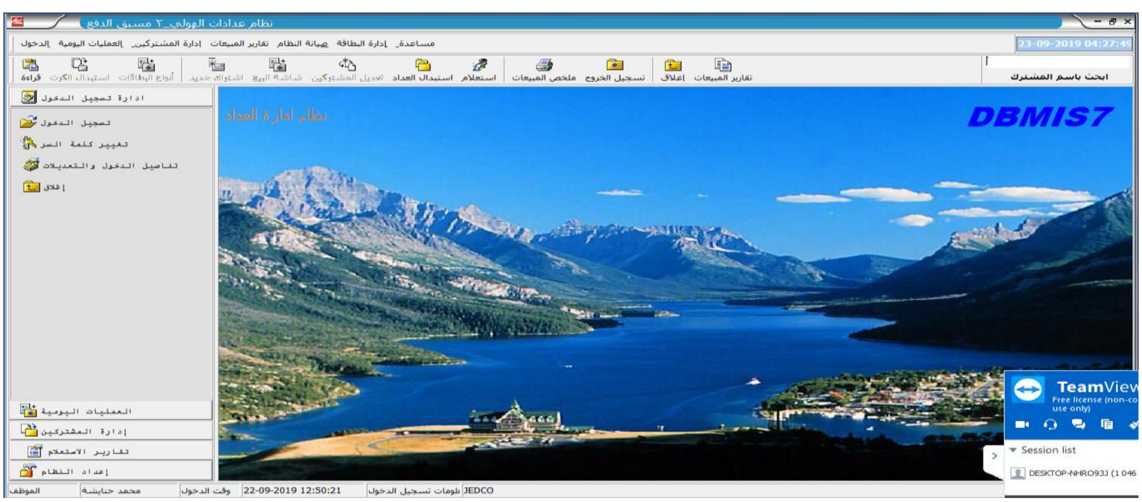


Figure 5. 8: Main Holy2 program window

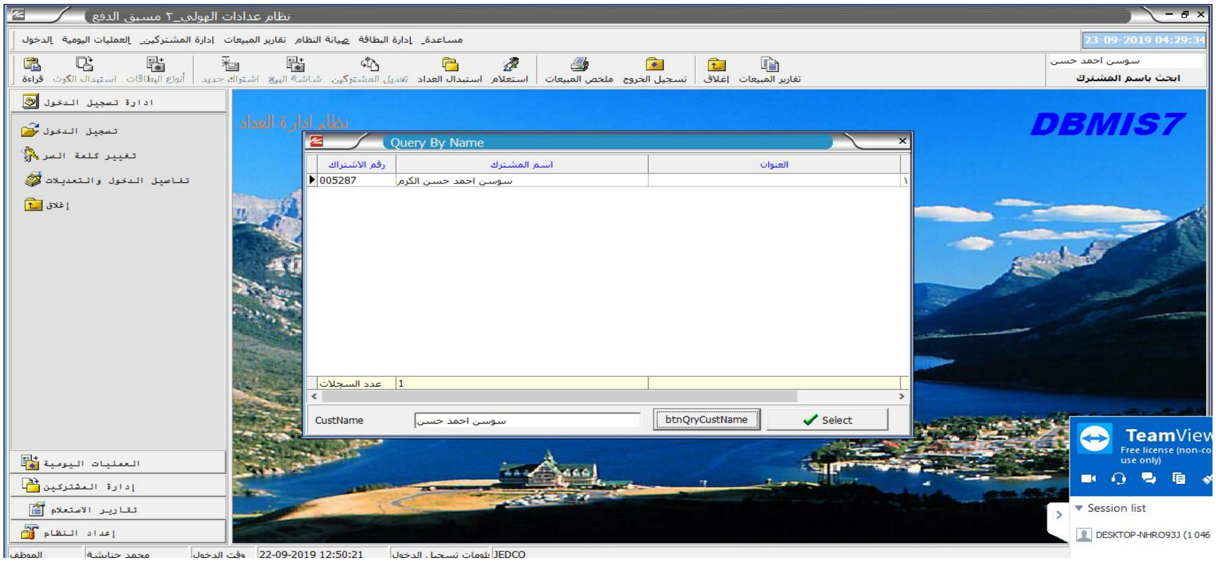


Figure 5. 9: Query by name screen

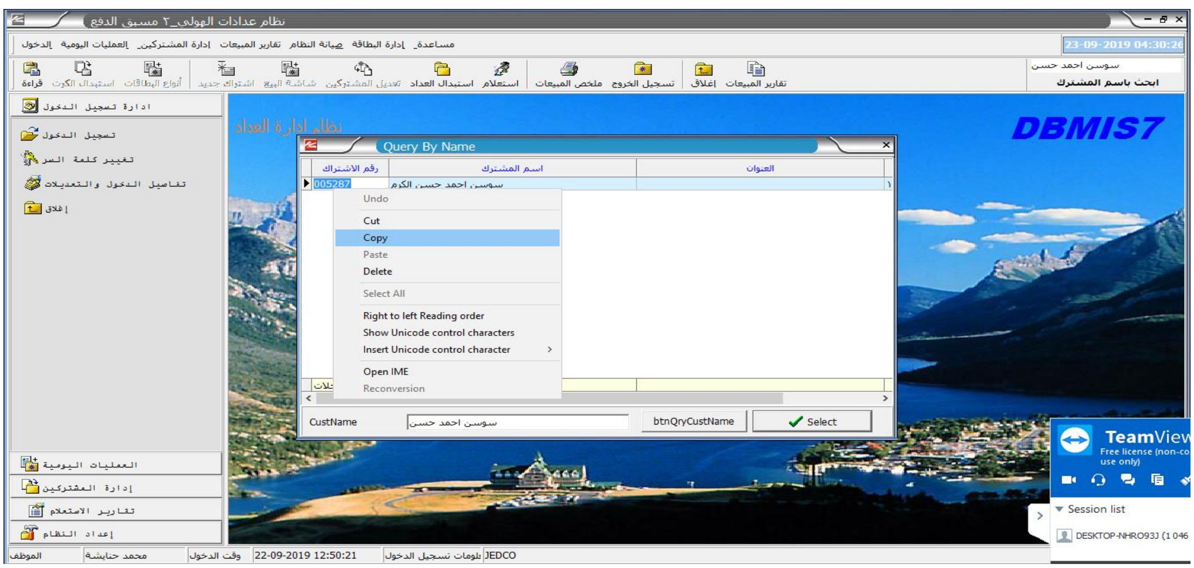


Figure 5. 10: Copy consumer number

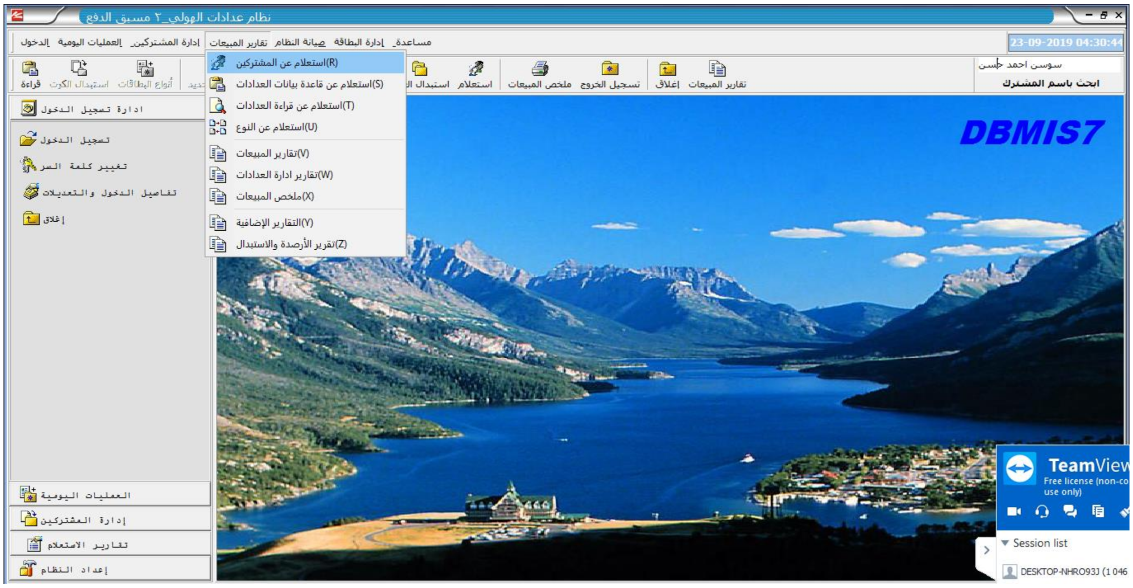


Figure 5. 11: select sales inquiry from sale report menu

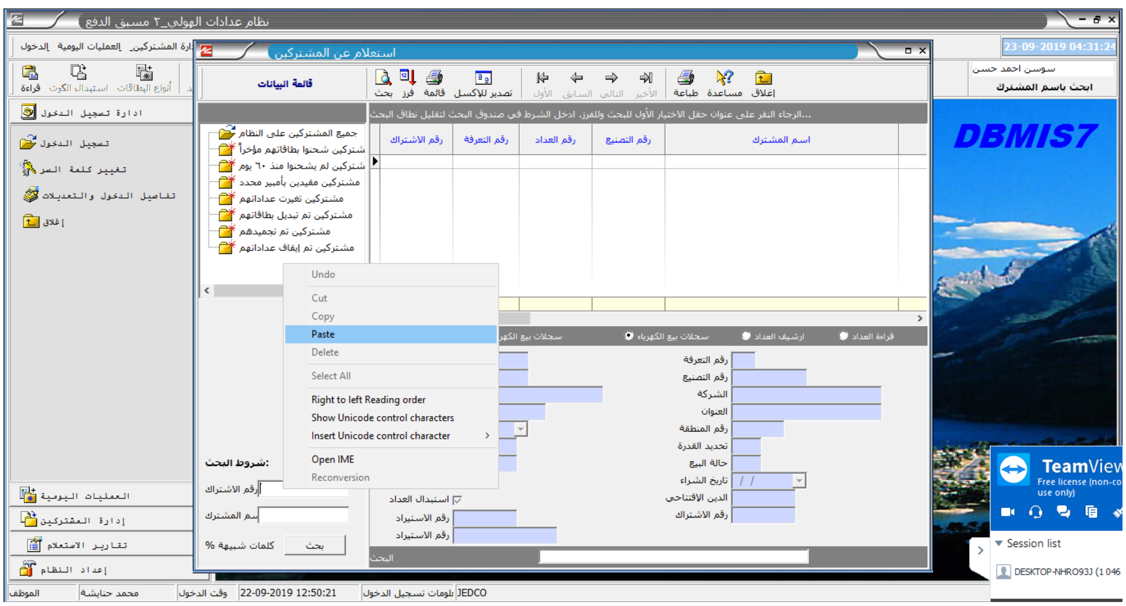


Figure 5. 12: Paste consumer number in consumer number field

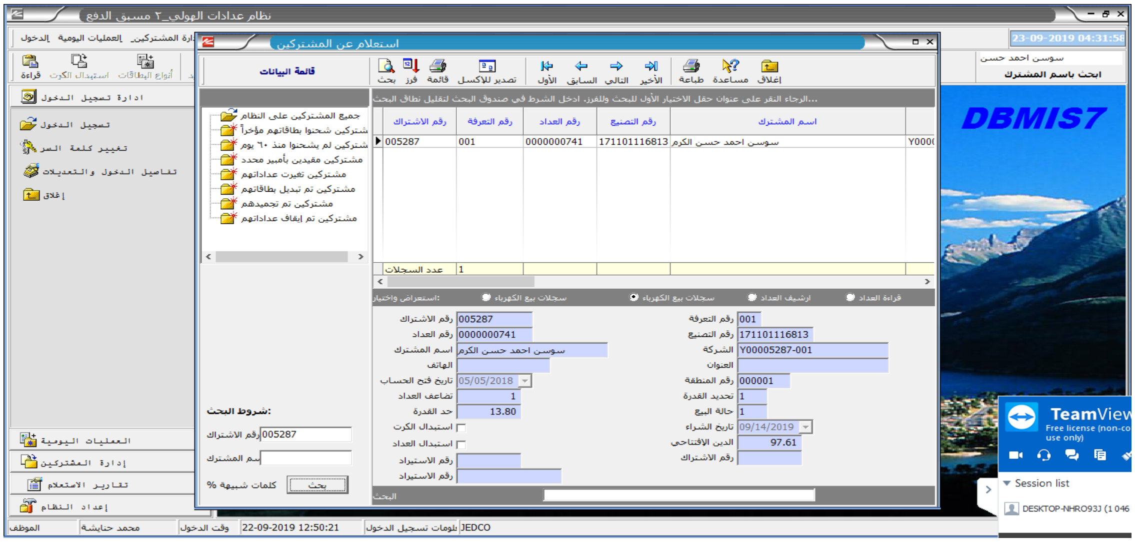


Figure 5. 13: search results

- **The old Electromed system**

a) From left of the program window, choose the sale procedure.

b) Enter the consumer name in the name box and click search

c) Copy the consumer number.

d) From left of the program window, choose the sale procedure again.

e) Enter the consumer number in the consumer Number field, then click on the search icon.

f) After the main consumer data (the meter type, meter number, etc.) appears, click on the sale offer icon at the bottom of the screen and then on a print order after all the consumer shipping data appears

g) Clicking on the company logo Electromed twice and then all the data appears on a web page, we were making a selection all the data and copy them to an Excel file and save it in the name of the consumer and his meter number.

The method of obtaining Electromed meters is shown in figures [5.14 – 5.17].

Figure 5. 14: search for consumer name

Figure 5. 15: search results

Figure 5. 16: search for consumer number

Figure 5. 17: search results

Afterwards, ten tables were produced in order to clarify the relationships between each component in the network and the other. These tables are as follows:

- MV_towers_with_one_transformer: show all MV transformers holding one transformer on them.

- MV_towers_with_two_transformers: to show all MV transformers holding two transformers on them.

- MV_towers_without_transformer: to: to show all MV transformers holding without any transformers on them.

- Feeders_one_T: feeders on towers for one transformer. Figure [5.18] shows this table.

- double_Transformers: to distinguish the transformers carried on MV_towers_with_two_transformers

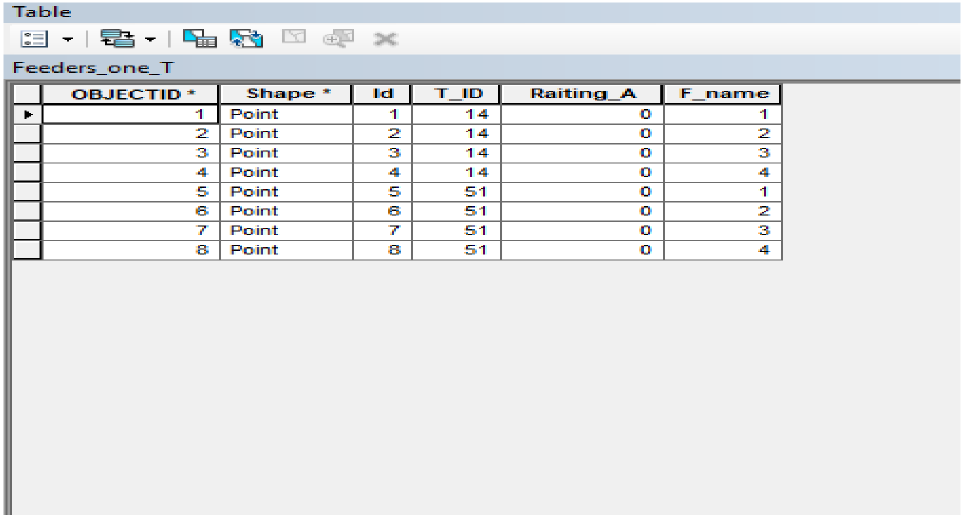
- LinesABC_one_T: for one transformer towers lines A for phase A, lines B for phase B, and lines C for phase C. These cables linked with feeders and pole after the feeder, in order to distinguish and find out each meter on any phase connected by connecting the line ABC id (primary key)to the meter by adding line ABC id (foreign key). Figure [5.19] shows this table.

- Feeders2Transformers: feeders on towers for two transformer. Figure [5.20] shows this table.

- LinesABC_2_T: same LinesABC_one_T but for two transformer. Figure [5.21] shows this table.

- Factories_prepaid_meters: Meters for chainsaw consumers.

- Consumers Meters: The meters for residential and commercial consumers, whether they subscribe to single phase or 3 phases.

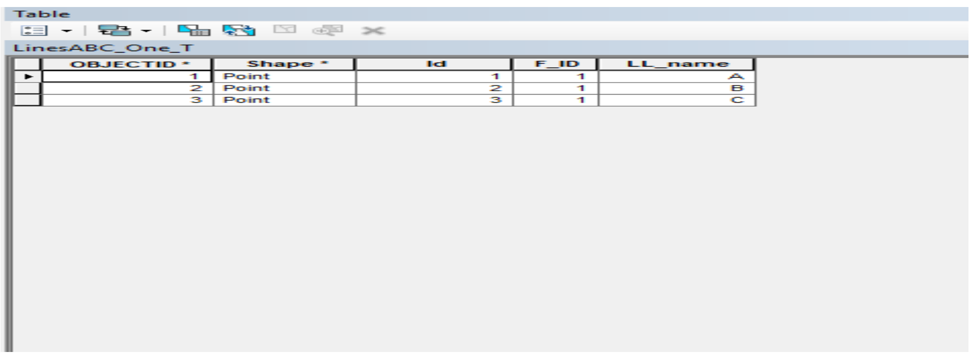


Table

Feeders_one_T

OBJECTID *	Shape *	Id	T_ID	Raiting_A	F_name
1	Point	1	14	0	1
2	Point	2	14	0	2
3	Point	3	14	0	3
4	Point	4	14	0	4
5	Point	5	51	0	1
6	Point	6	51	0	2
7	Point	7	51	0	3
8	Point	8	51	0	4

Figure 5. 18: Create Feeders Table for MV_towers_with_one_transformer

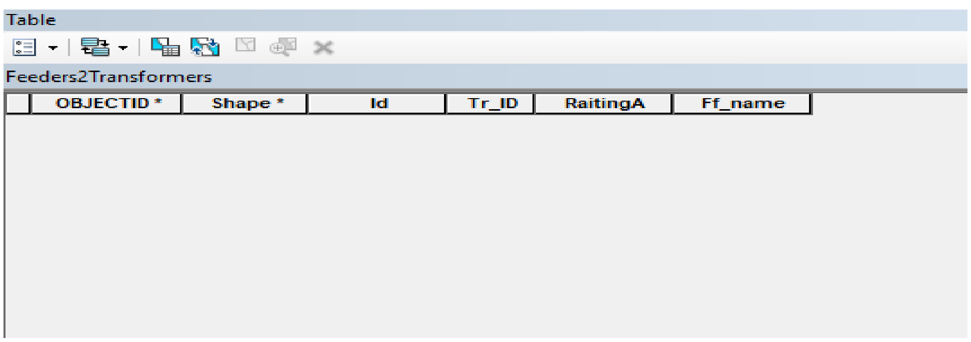


Table

LinesABC_One_T

OBJECTID *	Shape *	Id	F_ID	LL_name
1	Point	1	1	A
2	Point	2	1	B
3	Point	3	1	C

Figure 5. 19: Create Lines ABC Table for Feeders of MV_towers_with_one_transformer



Table

Feeders2Transformers

OBJECTID *	Shape *	Id	Tr_ID	RaitingA	Ff_name

Figure 5. 20: Create Feeders Table for MV_towers_with_two_transformers

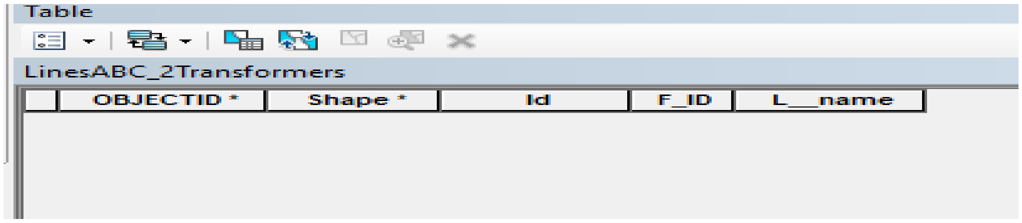


Figure 5. 21: Create lines ABC Table for Feeders of MV_towers_with_two_transformers

Afterwards, the medium voltage network was reconfigure by modifying the lines, deleting wrong lines, adding feeders to each transformer, drawing three phases for each feeder and modifying low voltage network. Figure [5.22 to 5.26] shows examples of data adjustments.

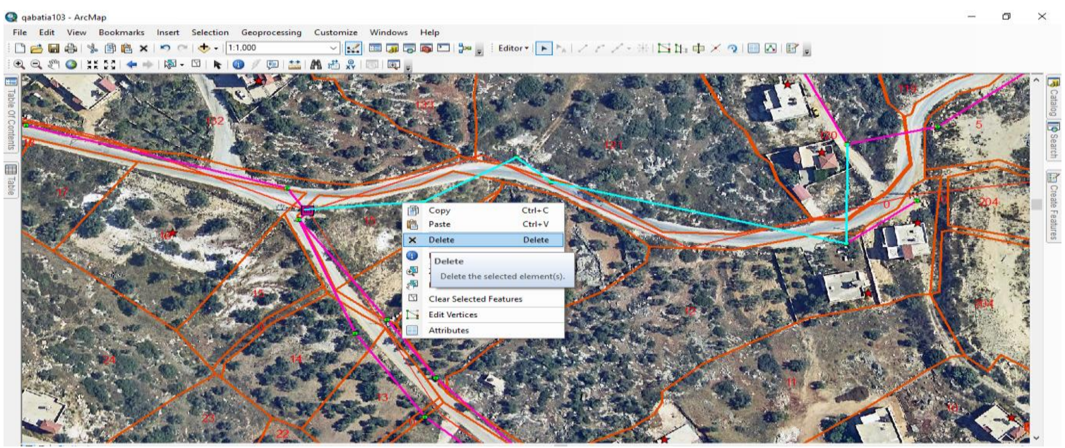


Figure 5. 22: Modifying MV lines

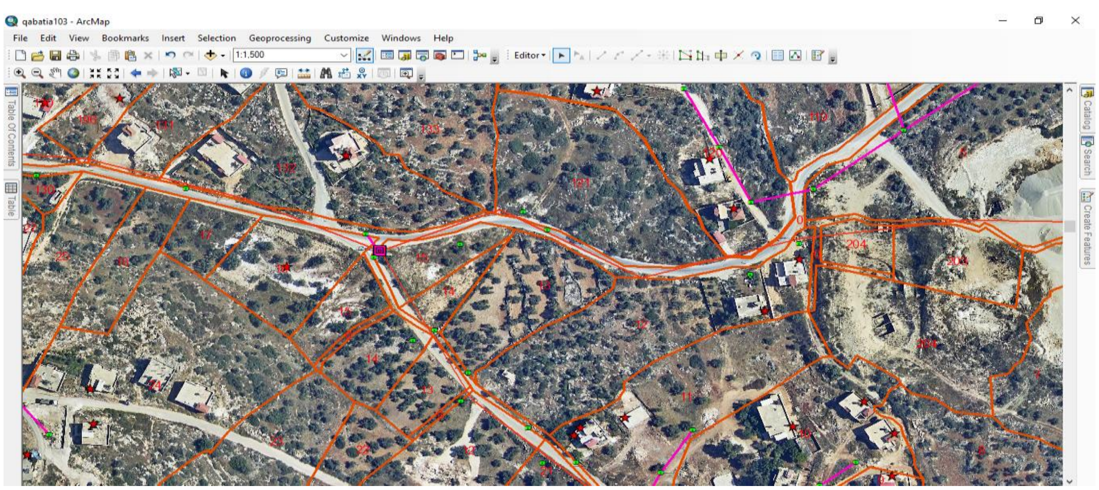


Figure 5. 23: Modifying MV lines

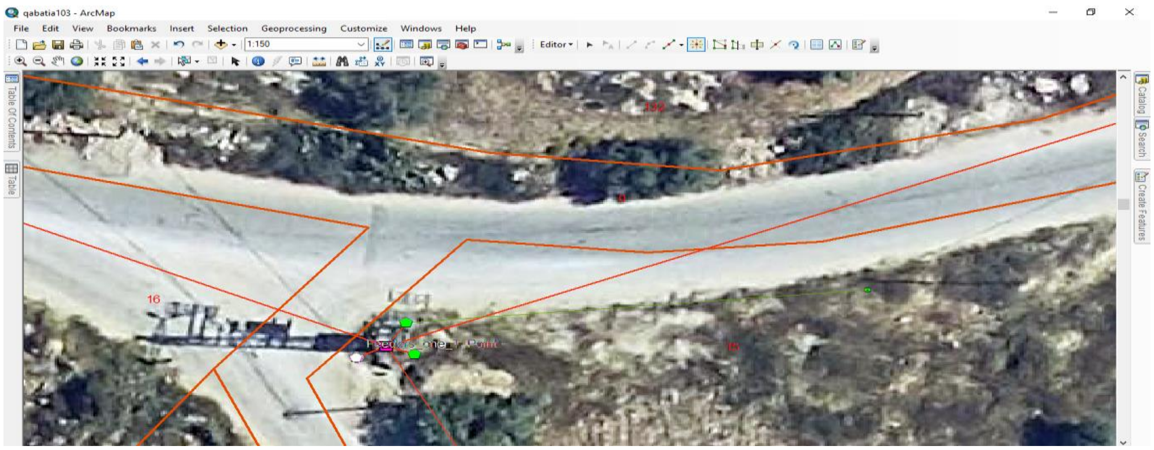


Figure 5. 24: Adding feeders for each transformers

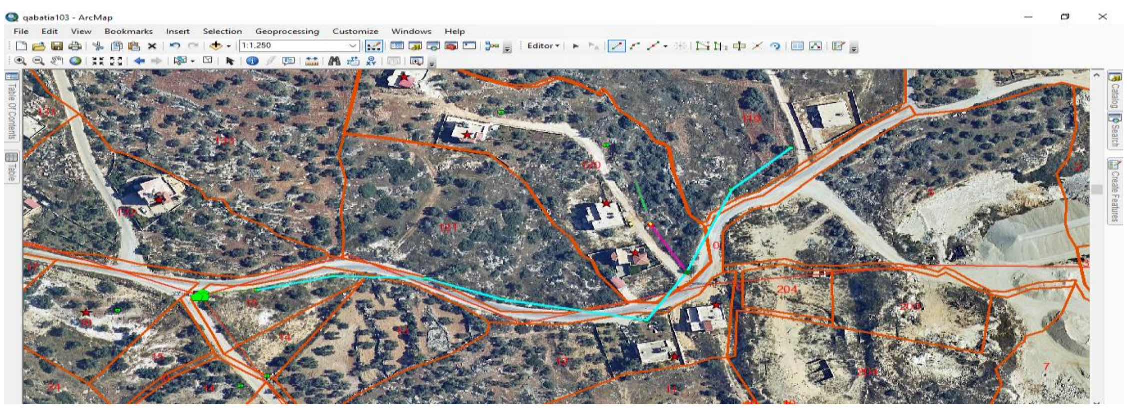


Figure 5. 25: Draw LV lines for each feeder

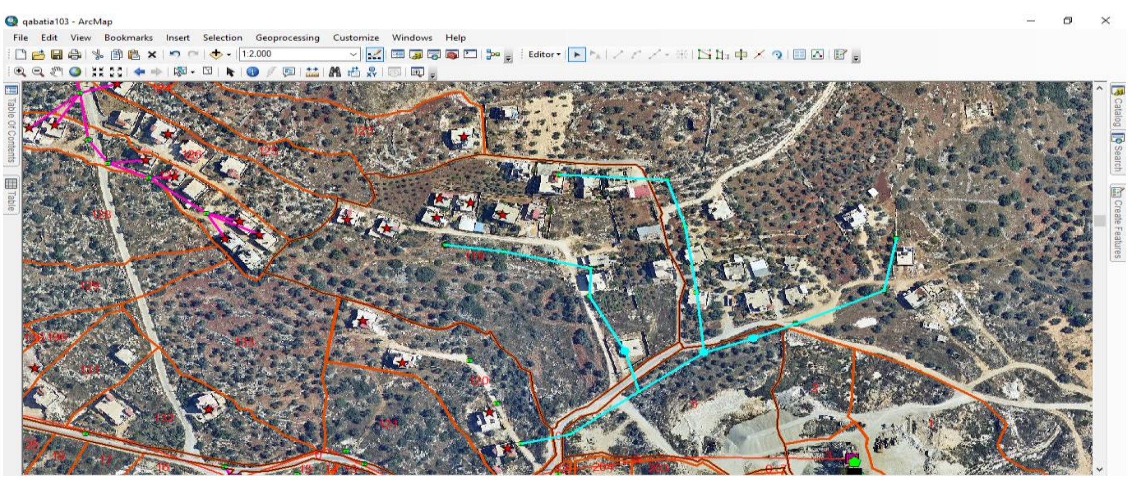


Figure 5. 26: Deleting all unneeded lines and poles that and some wrongly drawn lines or not connected to any transformer

The first sample taken was the data of the stone factories in Qabatya, where they are classified as the largest consumers of electricity in this city.

The using of arc tool box will help us to do many things an processes on the data, which is a program that contains the tools of geographic information systems and program converts between different formats of GIS files, and there are two versions of it: first program that supports the conversion of 150 formats of these files and this program comes with an arc info system, the other program supports the conversion of 30 types of these files and comes with ArcView program [61].

Connect the tables together: Often during the analysis there is the need to link the attributes in two separate tables, and we may do this when allocating the attributes in a separate table by itself to geographical features and then you can make a map of the geographical features or you can analyze the geographical features using the additional attributes

Join Tool: Join a table using a common field, the connection works to append the attributes to the original table as long as the link is established and the attributes connected to the attribute table will be saved to the data set and the method of the connection can be used with one-to-one relationships and all-to-one relationships. [61]. In GIS the join can be done based on spatial relationship and location.

Relate Tool: Connecting two tables, linking can be used with a one-to-many relationship or with a multi-type relationship to several. There are many records in the linked table that refer to one record in the original table [61].

Tables must now be linked to make the more logical data by using (join and relate) tools

First built relations between:

- The MV_ two transformer with double_Transformers tables via a primary key (transformer ID) and foreign key located in double_Transformers table (T_ID)
- the transformer with feeders tables via a primary key (transformer ID) and foreign key located in feeders table (Tt_ID), for one and two transformers
- The Feeders with three phases tables for one and two transformers via a primary key (Feeder ID) and foreign key located in Lines ABC table (F_ID).
- Consumers with three phase's tables via a primary key (line ID) and foreign key located in Consumers table (A_ID, B_ID, C_ID).
- Factories_prepaid_meters with three phase's tables via a primary key (line ID) and foreign key located in Factories_prepaid_meters table (A_ID, B_ID, C_ID).

The joining and relating of tables in geodatabase illustrated in figures [5.27 – 5.33].

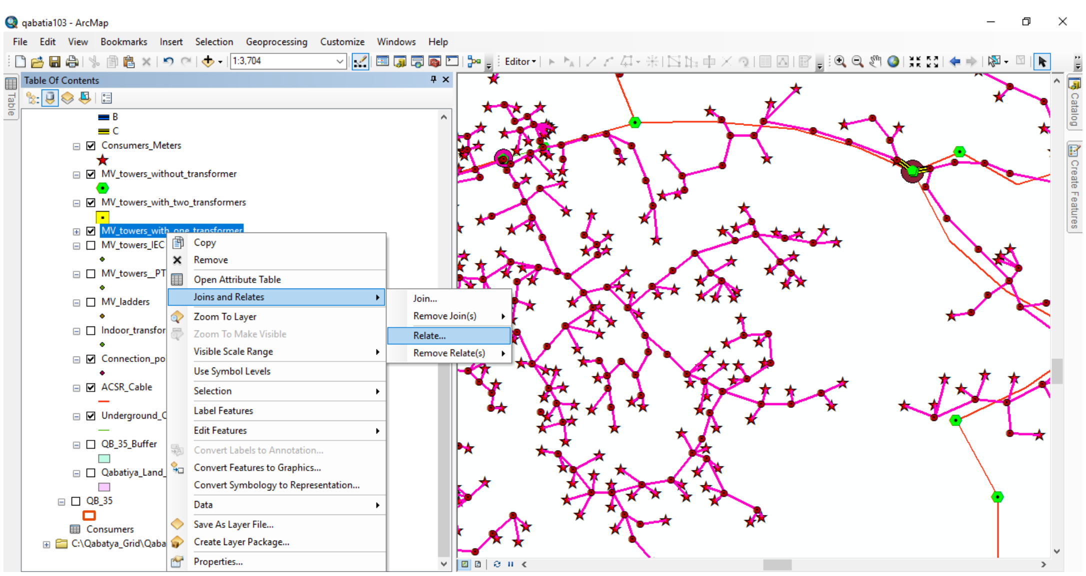


Figure 5. 27: Relate the transformer with feeders tables

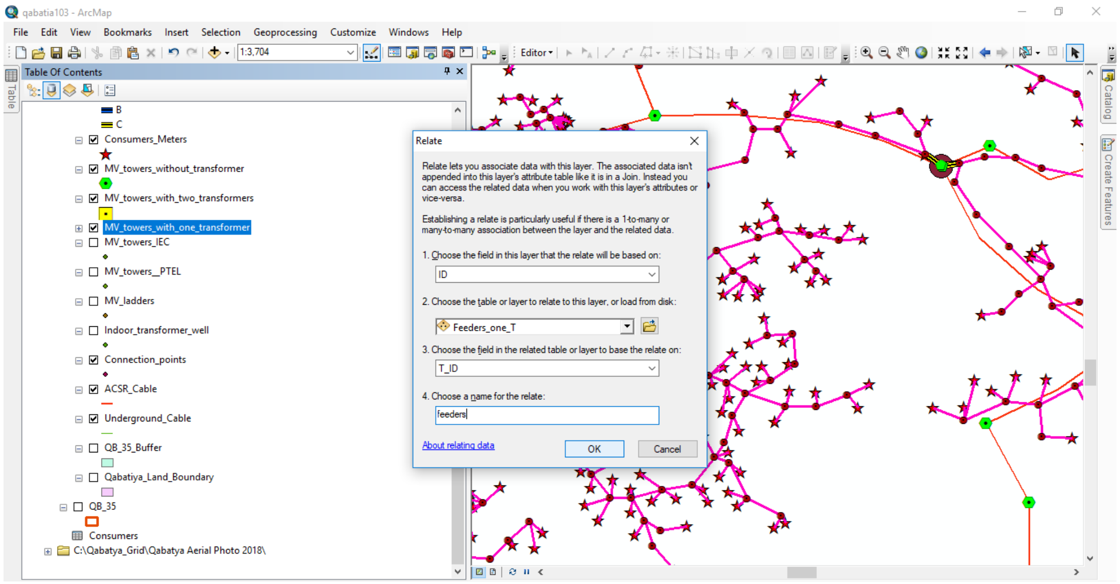


Figure 5. 28: Relation between Transformers and Feeders tables

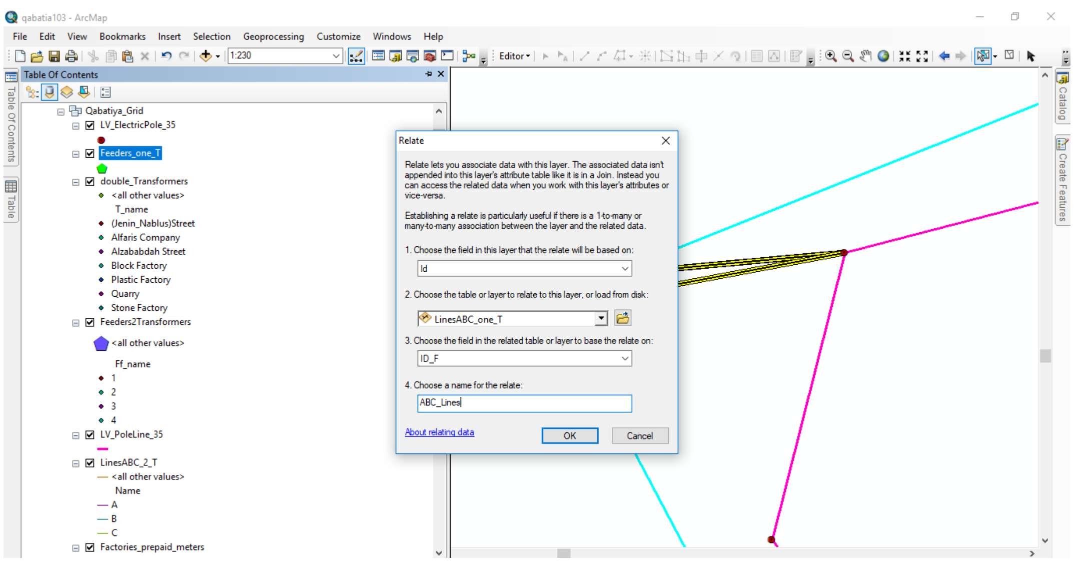


Figure 5. 29: Relate the Feeders with three phase's tables

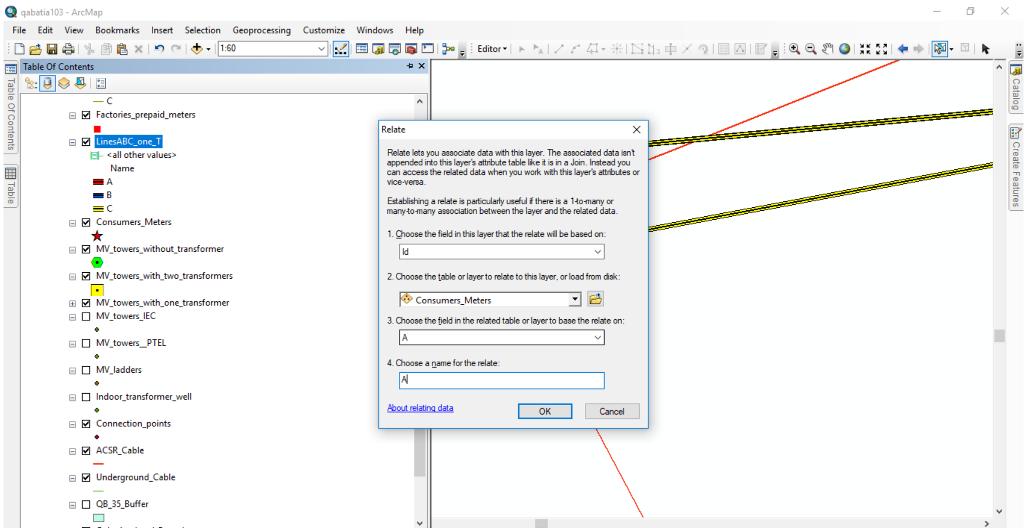


Figure 5. 30: Relate the Consumers with three phase's tables (phase A)

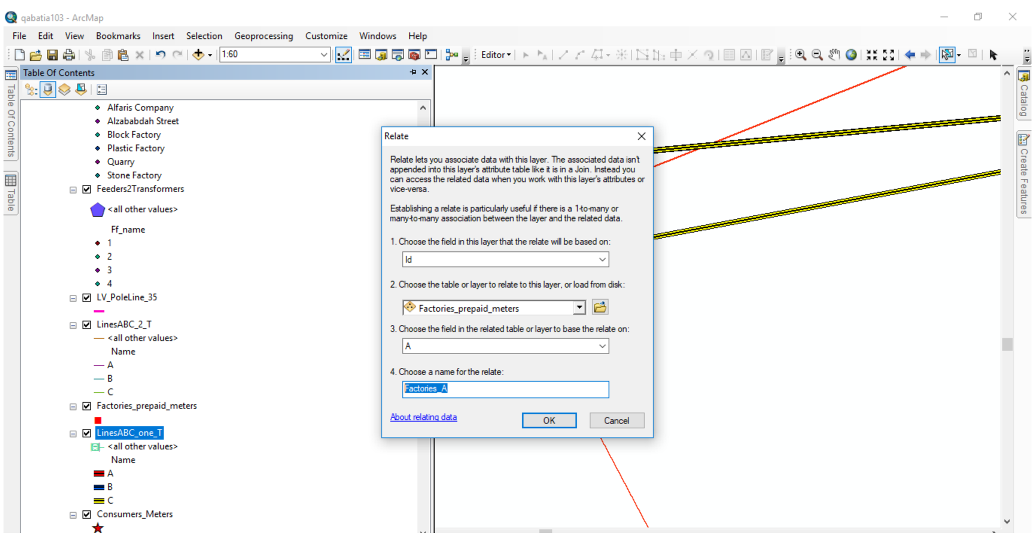


Figure 5. 31: Relate the Factories_prepaid_meters with three phase's tables (phase A)

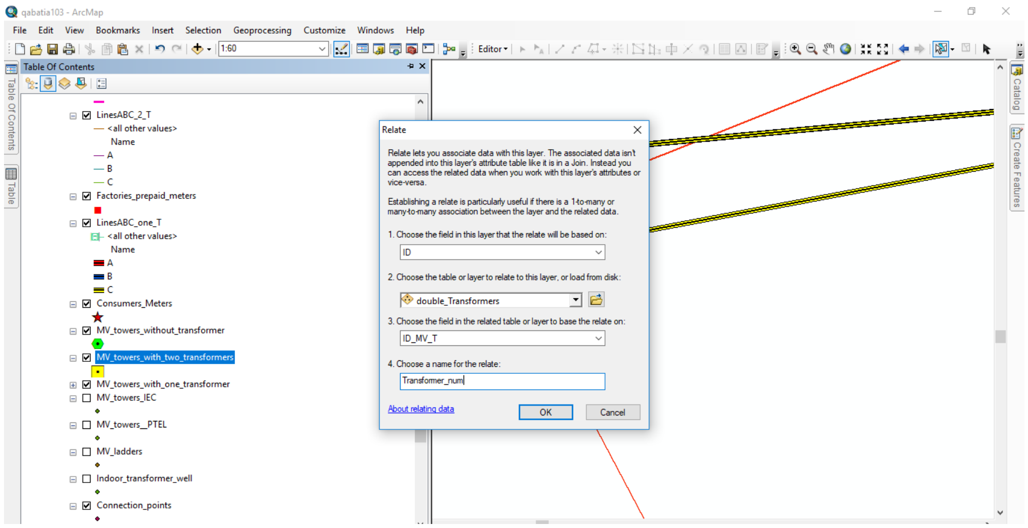


Figure 5. 32: Relate the MV_ two transformer with double Transformers tables

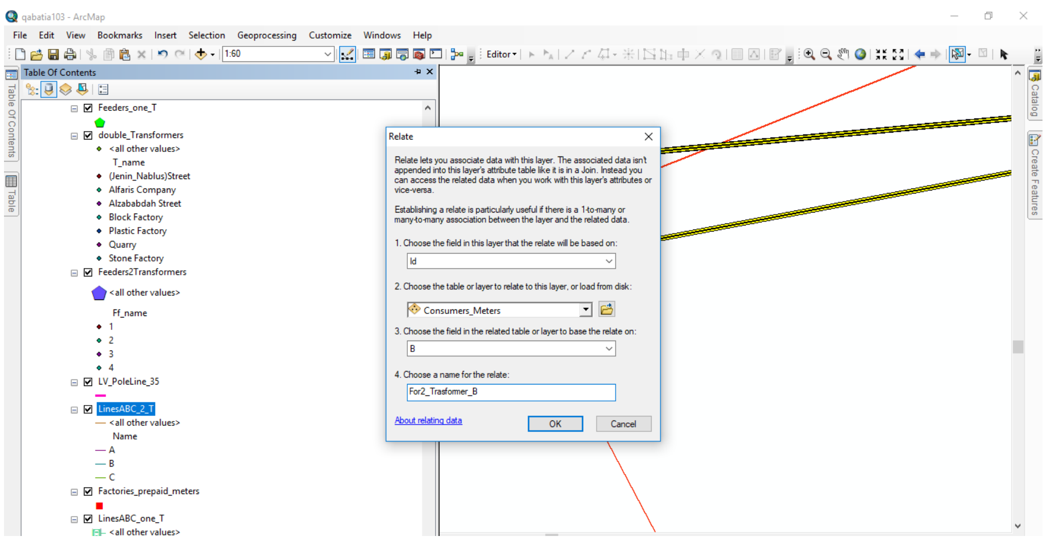


Figure 5. 33: Example of linking phases with consumers tables (whether household or industrial)

Buffer

A buffer in GIS is an area concerning a map feature measured by distance or time, where through the buffering tool can be created isolated areas at a certain distance that you enter into the program [62], when we decided to tack particular zoon (Block 35) in Qabatya network, the using of buffer became substantial to extract the electricity network on a Block

35 that is 200 meters away, it is enough just to enter the information in the ArcMap to determine for you a circle that includes the field of this basin, this shown in the following figures [5.34, 5.35].

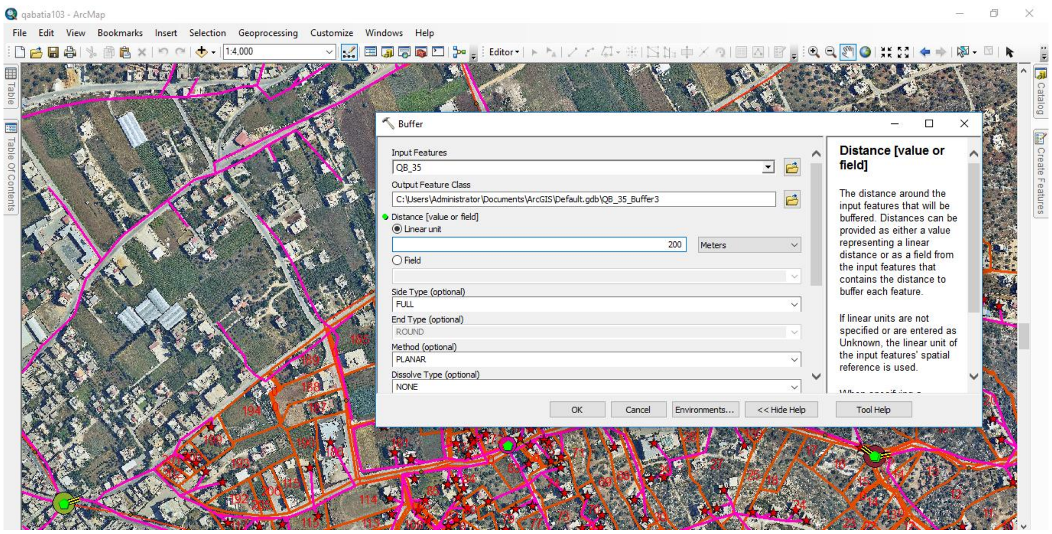


Figure 5. 34: Extract the electricity network on a Block 35 that is 200 meters away

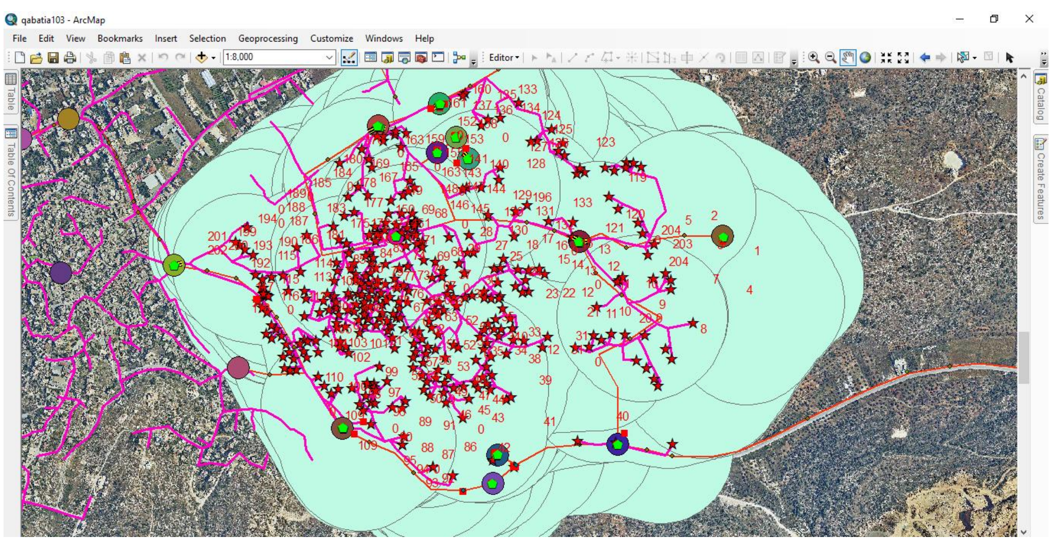


Figure 5. 35: Buffer output

Clip:

Clip Tool: It is a tool that is based on clipping a data through a polygon / area layer, this is done by setting the upper, lower right and left for coordinate points on the vector and crop it.

A clip for any data set using the boundaries of any data set that is polygonal (Buffered area _block 35) was done and the parameters are divided at the places where they intersect the border of the cropping, the part outside this limit is careless and this tool is mainly used to crop the data set to the region boundary that is studied for analysis [62].

In our case it must clipping the two layers of poles and low voltage network on the basis of the previous Buffer area (QB_35_Buffer), all cropped layers will be the same area size of buffered area, which illustrated in [5.36- 5.37] figures and the result of new zoon shown in figure [5.38].

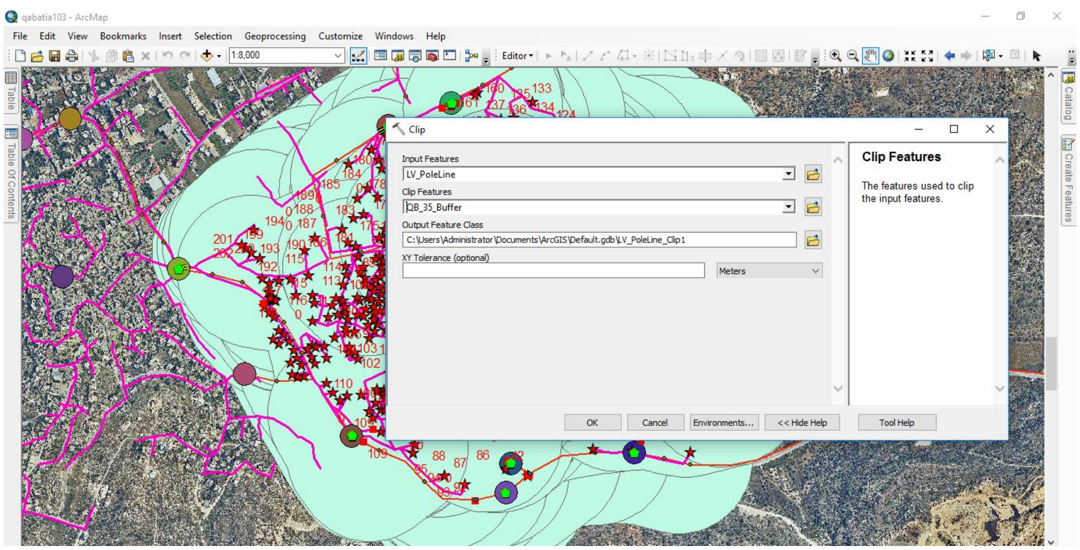


Figure 5. 36 : Clipping the LV_PoleLine layer on the basis of the previous Buffer area.

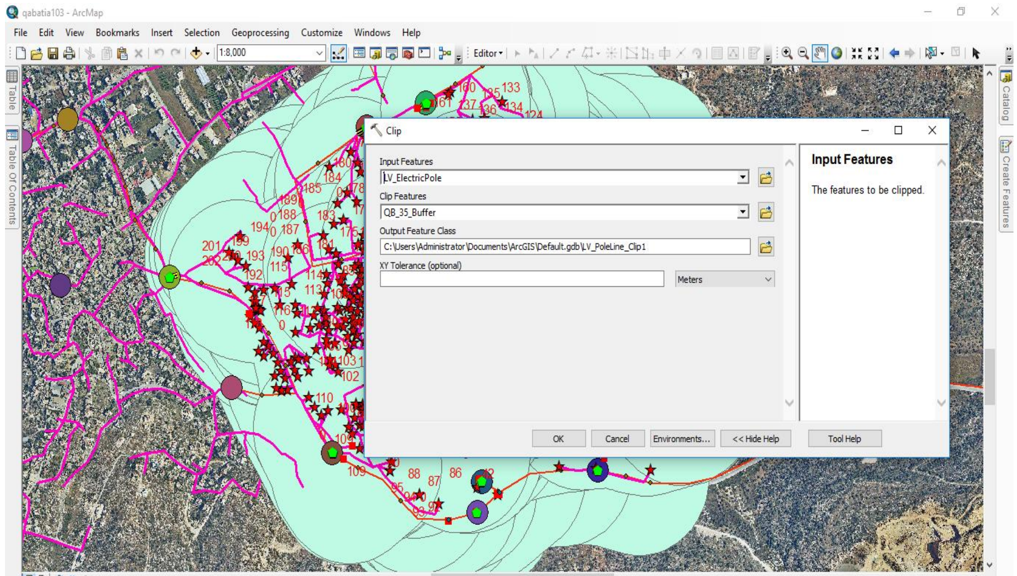


Figure 5. 37: Clipping the LV_ElectricPole layer on the basis of the previous Buffer area.

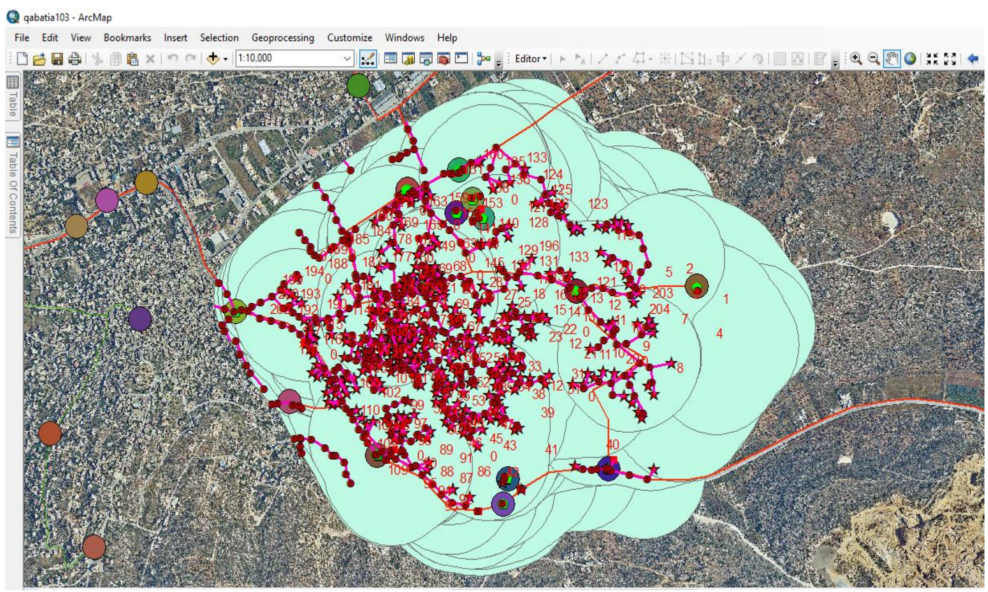


Figure 5. 38: Clipping output

Modify data using Editor Toolbar: when cropped the data based in buffer area some of lines or poles in the network will be not connected to other which will cause errors when building a geometric network, so to delete unnecessary and unrelated data we will use editor tool bar to modify data which as shown in pictures in figures [5.39 -5.41].

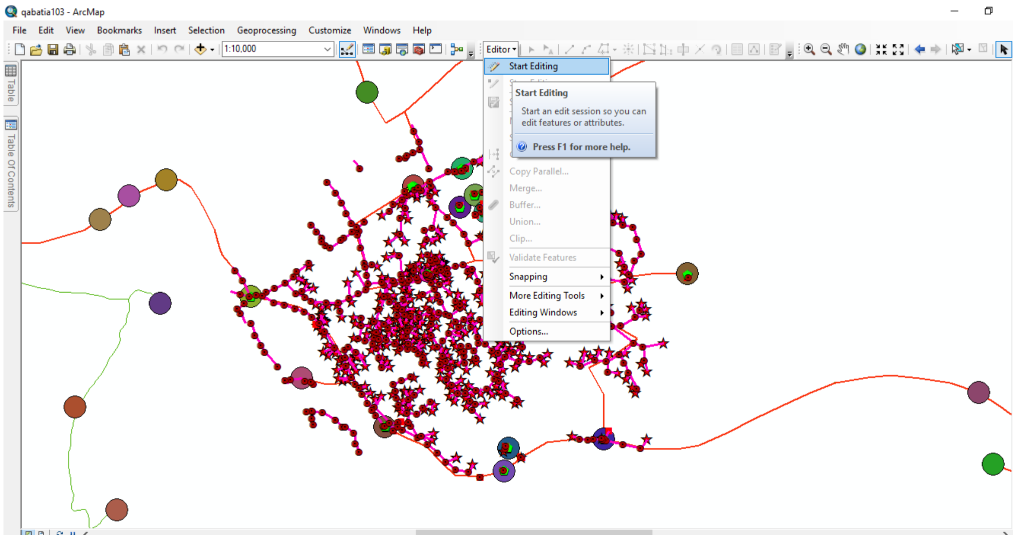


Figure 5. 39: Start Editor Toolbar for modifying data

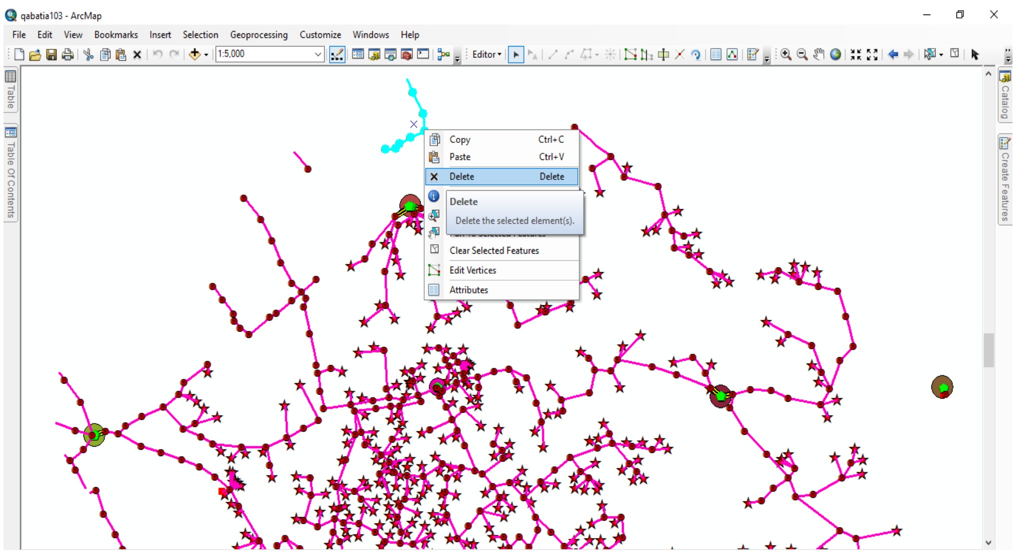


Figure 5. 40: Example of deleting unconnected lines

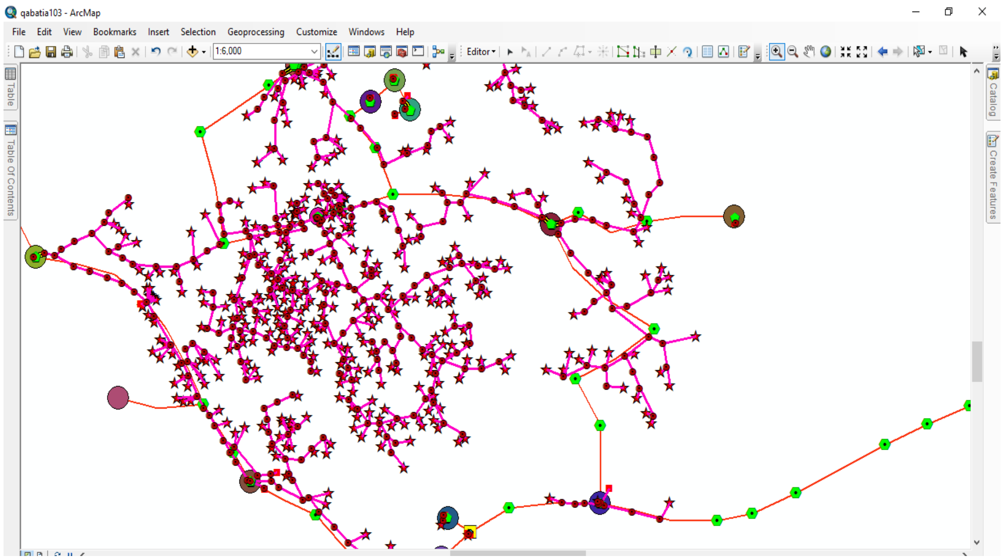


Figure 5. 41: Data after editing

Topology

As explained previously the importance of Topology in improving data in Chapter 3, so we need to how to create a topology by firstly opening the Qabatya_Grid geodatabase in ArcMap catalog interface to make its topology for layer we need to fix it, then click and choose New Topology which illustrated in figures [5.43 -5.42]. By new topology layer errors in our data will appear when determined the topology rules shown in figure [5.44 – 5.45].

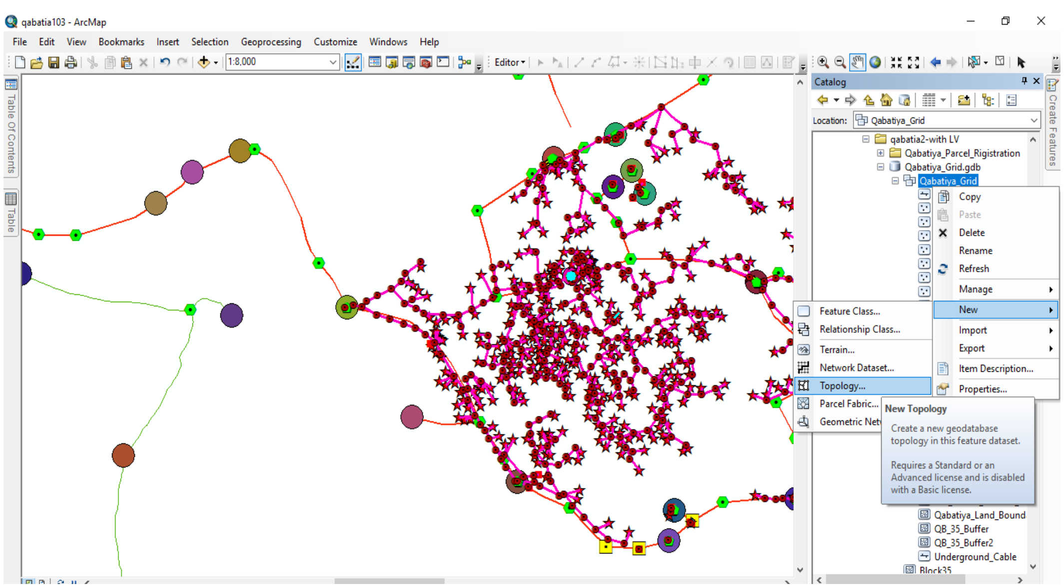


Figure 5. 42: Open the ArcMap catalog to make new topology

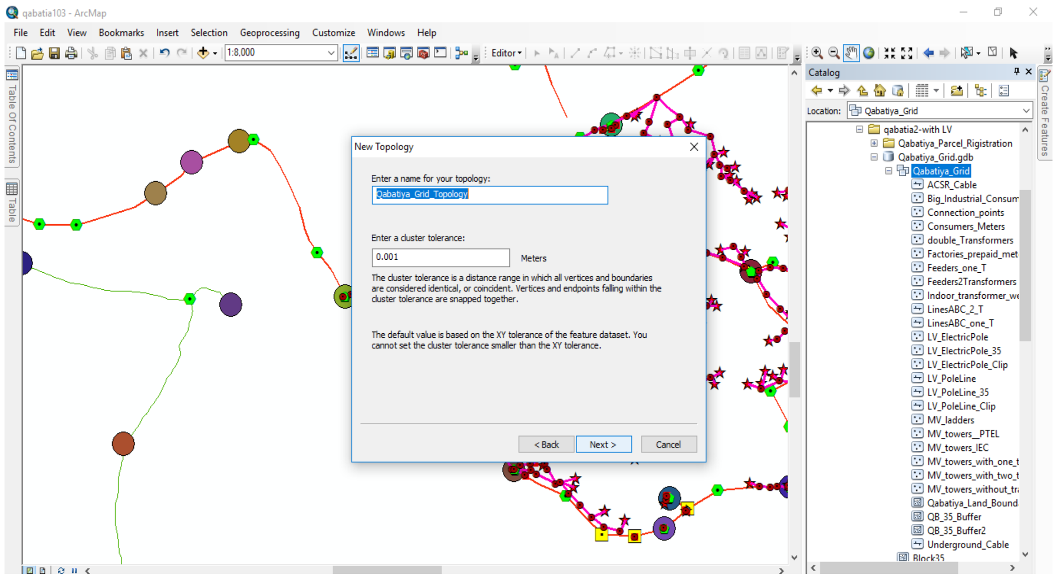


Figure 5. 43: Create new topology

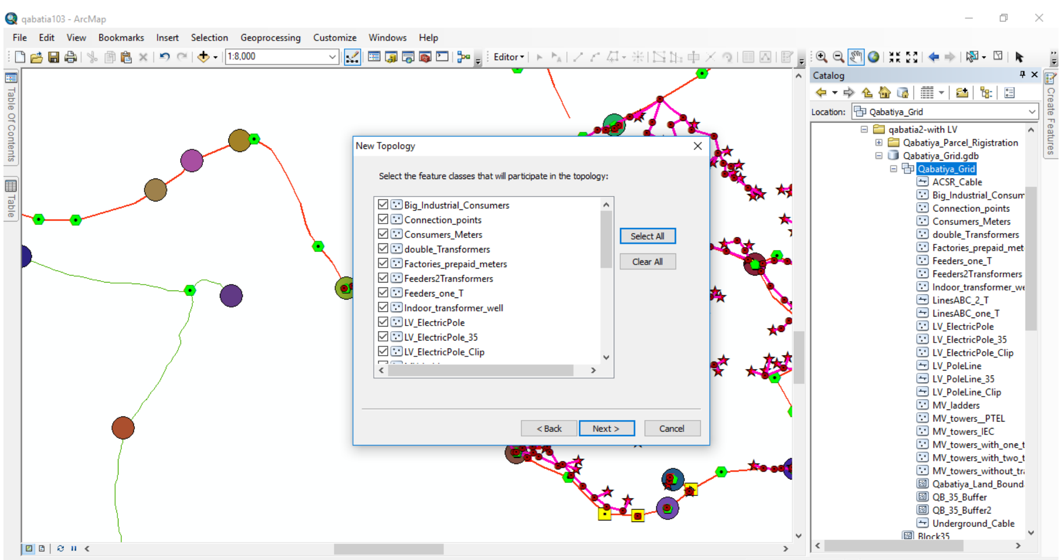


Figure 5. 44: Choosing the layers that will participate in the Topology

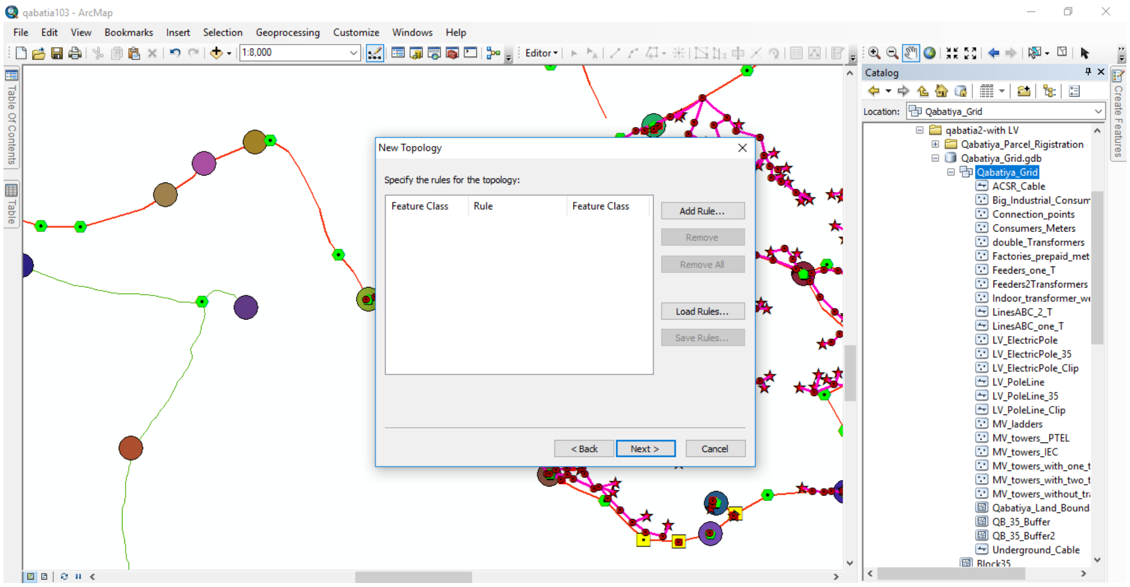


Figure 5. 45: Add topology rules to achieve the quality of the work we do

It is clear to us that there are many rules (procedures) that can be implemented in the topology process, each rule that was used to correct errors in the network to know how to implement and the cases in which we use each one and the type of layer that this process can be performed on, whether it is a type of lines or Points or polygons, the following topology rules are used for our data:

1. **Must not have dangles:** It is done on the lines, in order to ensure that all the lines touch each other at the ends of it where each end of the line must match the end of another line

To solve this problem, orders are used [63]:

- Trim : In the event that the line exceeded the corresponding line
- Extend : In the case of the line it did not reach the edge of the corresponding line
- Snap: it is a manual solution by moving the vertices to the opposite edge in both

cases

2. **Must not have pseudo nodes:** It is done on the lines, in order to make sure that the single line is composed of one unit, not cut into parts and this problem is solved by using merging as it merges all the line parts into one piece [64].

3. **Must not intersect:** It is done on the lines, in order to ensure that the lines do not intersect with each other of the same layer, and to solve this problem: In case that the two lines intersect at a point, they are separated from each other, but if the two lines intersect with a long section overlapped with each other, the overlapping part is removed from one of the two lines [64].

4. **Must be covered by Endpoint:** It is done on points and lines, and it is useful for making sure that all the end of the lines are covered by points, and to solve this problem, points are added to the lines that lost the points that represent the end of them [64].

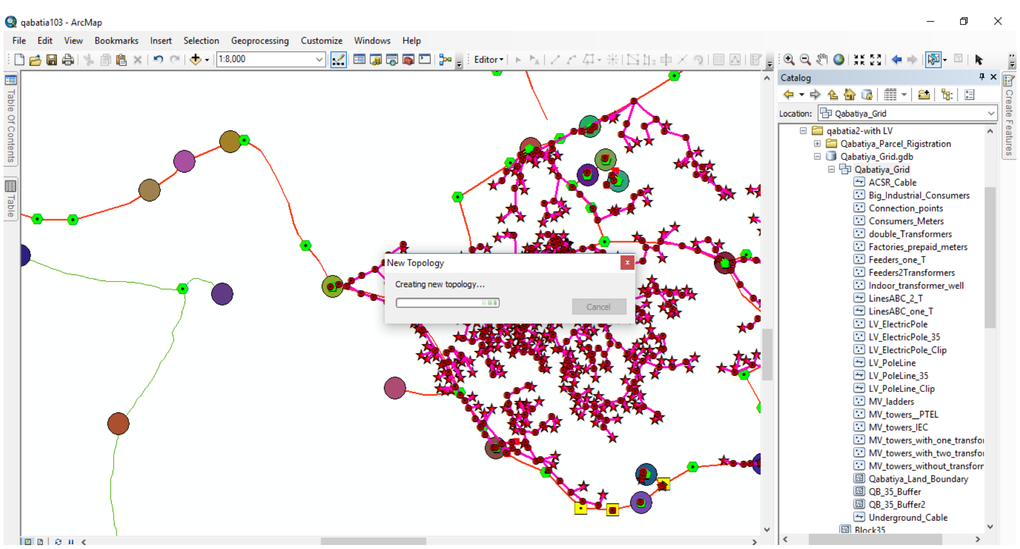


Figure 5. 46: Conducting the topological process

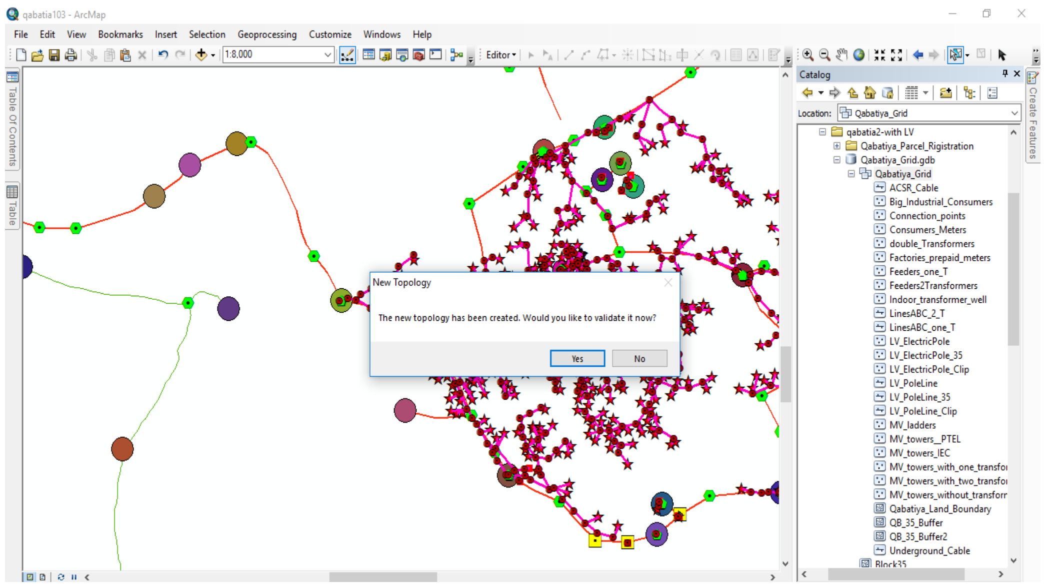


Figure 5. 47: This window asks us whether we want the correction or not

And now after completing all the processes inside the topology within the Arc catalog, the last stage of the topology process begins, which is the correction because the previous procedures determined for us where the errors are and it will be modified inside the arc map in the same way that was explained when listing the procedures and how to solve

And now we must get to know the editing tools in the ArcMap

Customize—Toolbar—Topology

Error Inspector make the ability to inspect topology errors in a table that show the rules violated, the data or feature classes participate in the errors, the geometry of the errors, the feature IDs of the features involved in the errors, and marked as exceptions errors .. You can also decrease the errors shown in the error Inspector table to errors that occur in the currently visible map extent, or errors of a given type, , marked as exceptions errors (https://desktop.arcgis.com/en/arcmap/10.3/manage-data/editing-topology/finding-topology-errors-with-the-error-inspector.htm) select the layer to be modified to start the correction, and verify request, which detects errors in the specific layer, by choosing which actions to edit its errors and then pressing on Search Now as shown in the figure, by pressing right on the first Error, a window with a set of options will open which are: Zoom to – Pan to _ Trim _ Extend - select Feature - Show rule descriptions - Mark as exception. Here choose (Zoom to) to go for the error and correct it which is in this examples of topology rules must not violated: Must not have dangles and must be covered by end points, which illustrated in figures [5.48 – 5.51].

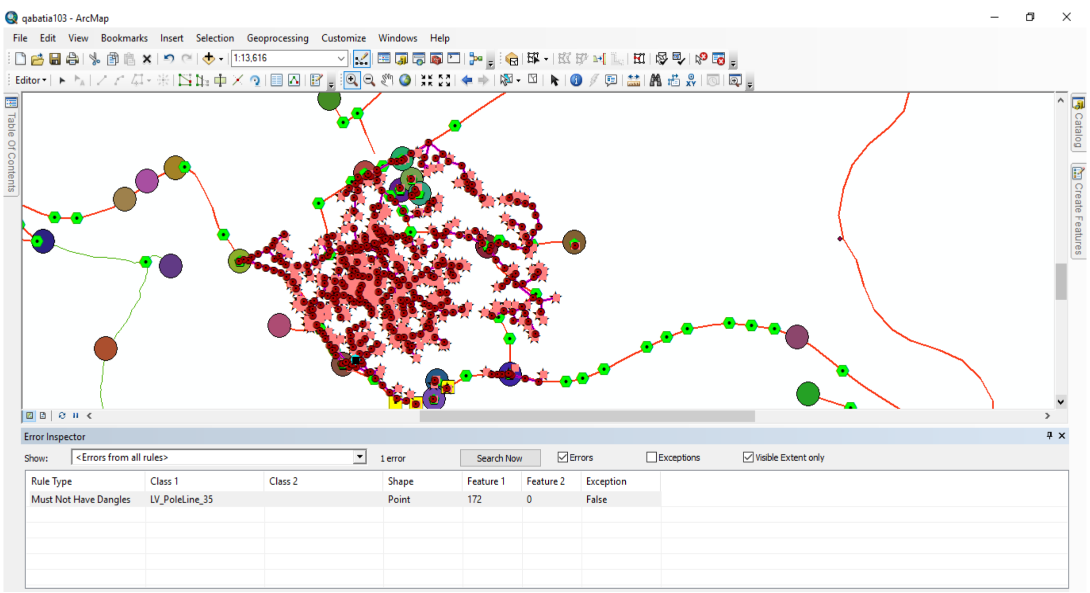


Figure 5. 48: Must not have dangles

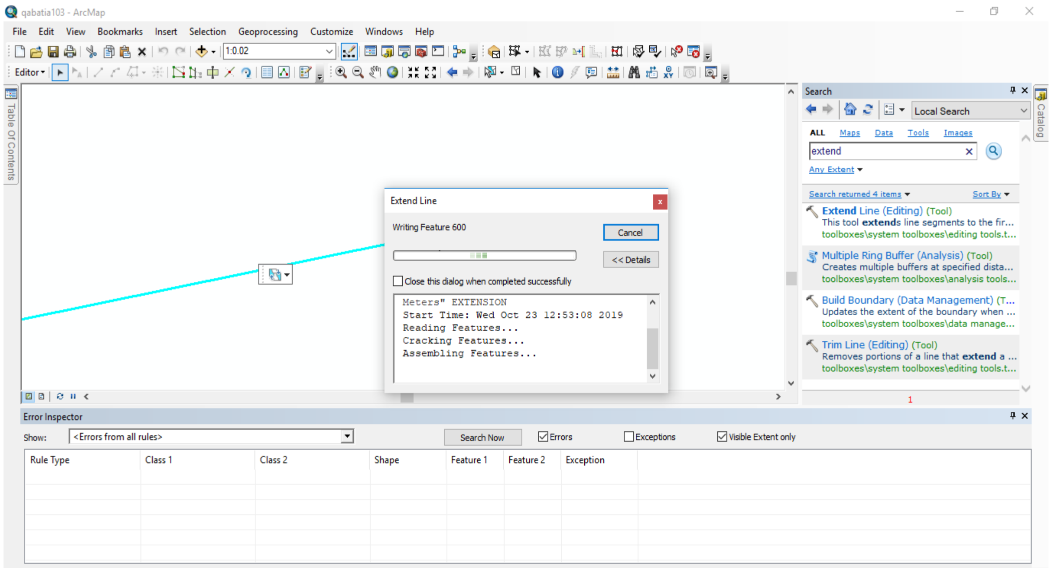


Figure 5. 49: Solving error

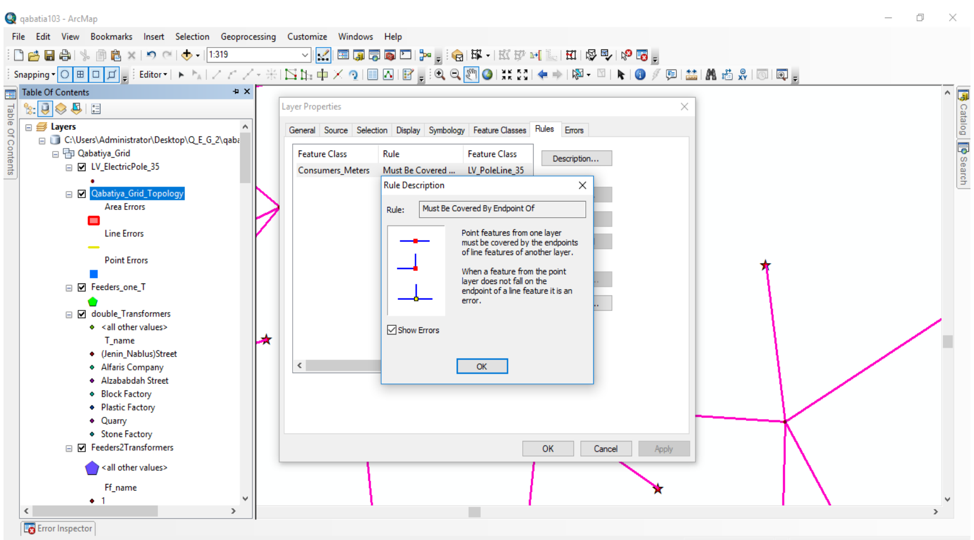


Figure 5. 50: Must be covered by end points (LV_PoleLine, Metes)

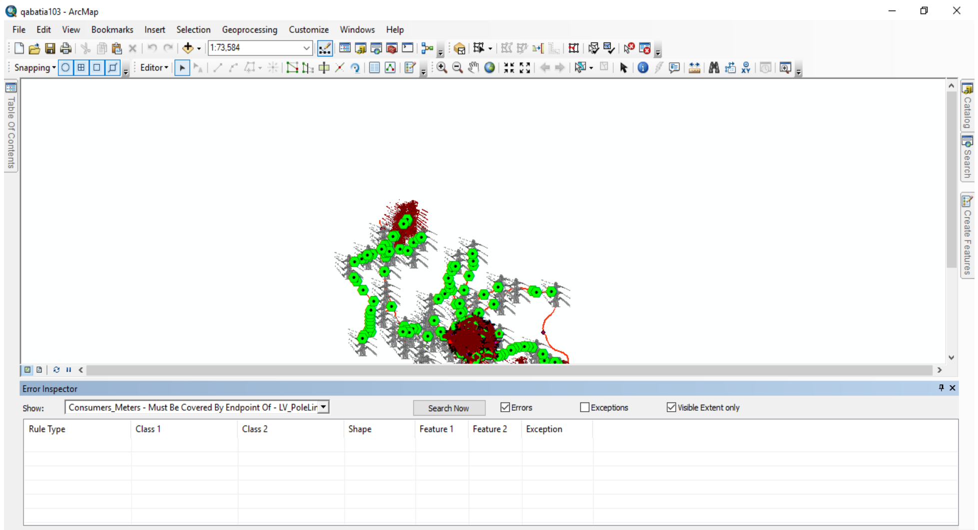


Figure 5. 51: After solving all errors indicated by the topology

At this stage, we have the ability to distinguish each feeder and its related elements, as shown in the figure [5.52] below, so we can see each meter connected to any feeder and any transformer, and also detail all meters on any phase.

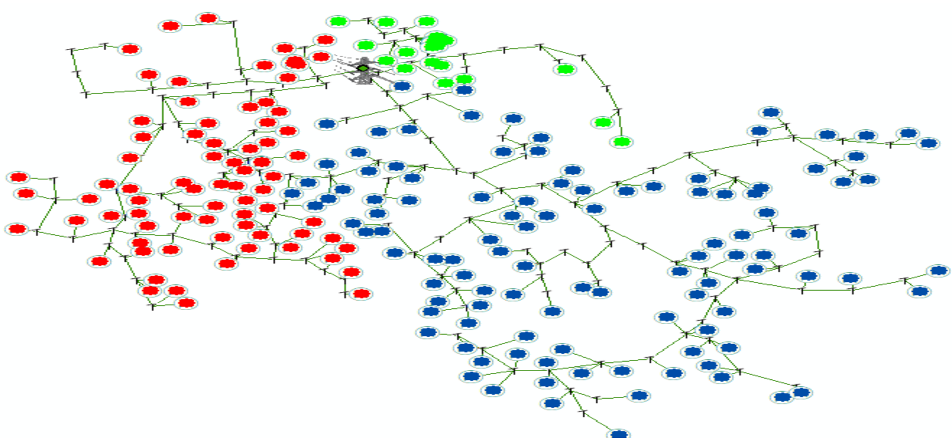


Figure 5. 52: Results for Zoon (Transformer 44_LV_ network) of study area network was separated for each feeder individually

5.3 Geometric Network

When started work on this project, we decided to build the electricity network for all Qabatya, including medium and low voltage lines, and which is explained in the following section. And to build the network we must take into consideration the conditions for building

Geometric Network [65]:

- Must have a layer containing the electrical network and a layer that contains the source and sink of the network, the now was prepared in previous sections to fit geometric network.
- These layers must present in Feature dataset, we create a new feature dataset the have Palestine_1923_Palestine_Grid projection (XY coordinate system), and all feature classes in it must have the same projection.
- There should be at least one source for the network, which is connected points.
- There should be at least one sink for the network, it will be the pole and meters feature classes.
- each network intersection has a point (junction), and that point does not have to be a source or sink for the network
- It is not necessarily that every point or line in the sink is important in the sense that it will be analyzed.
- After building the network, the ArcMap builds a layer that indicates network errors, meaning that it supports the topological process
- Geometric networks deal with networks that are not controlled by manually by humans, such as water and electricity networks, where the network is controlled through ready laws from the program
- Their directions are determined by their properties.

Steps of building electrical geometric network is illustrated in figures [5.52 -5.55].

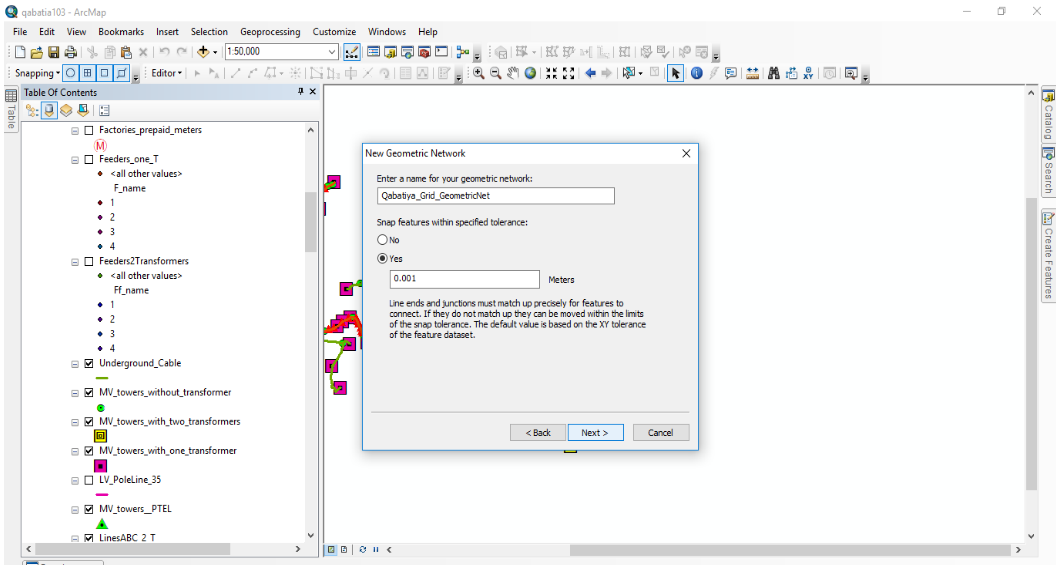


Figure 5. 53: Create Qabatya_Grid_Geometric Network

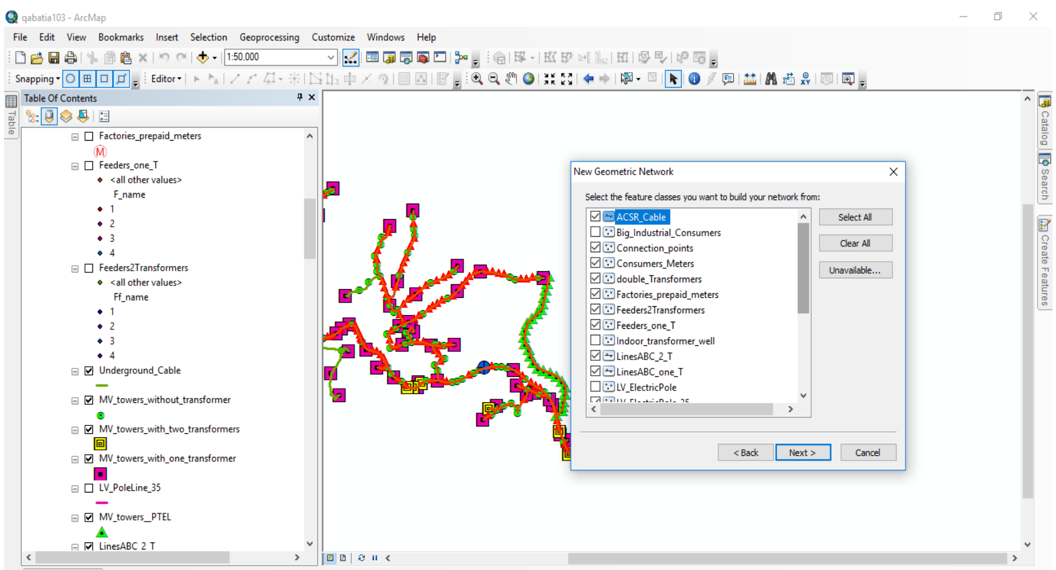


Figure 5. 54: Choose layers that participate in the Geometric Network

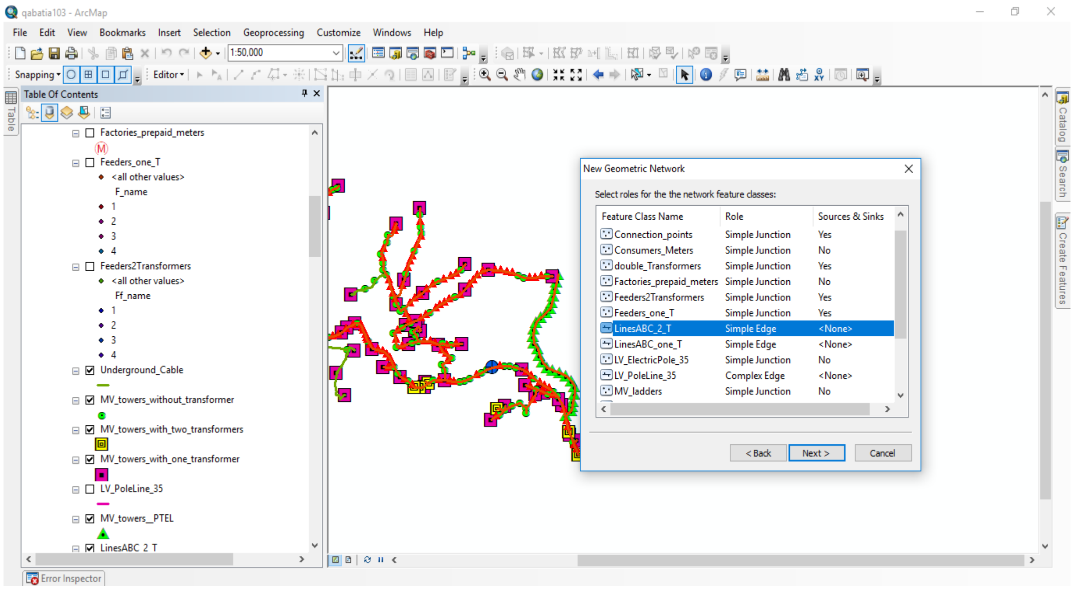


Figure 5. 55: Select the roles fort the layers that participate in the Geometric Network

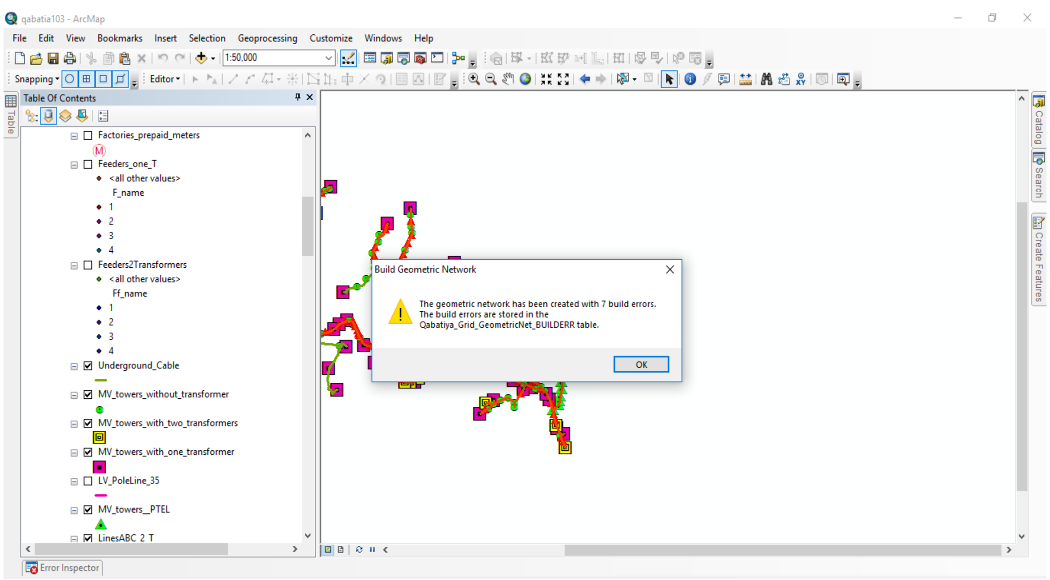


Figure 5. 56: The errors shown by the Geometric Network

The errors shown by the Geometric network stored in two layers:

- A new layer is called Geometric network Net_junction: here we have 220 errors of this type, for example, showing points at disconnected wires. Which is show in following figure :

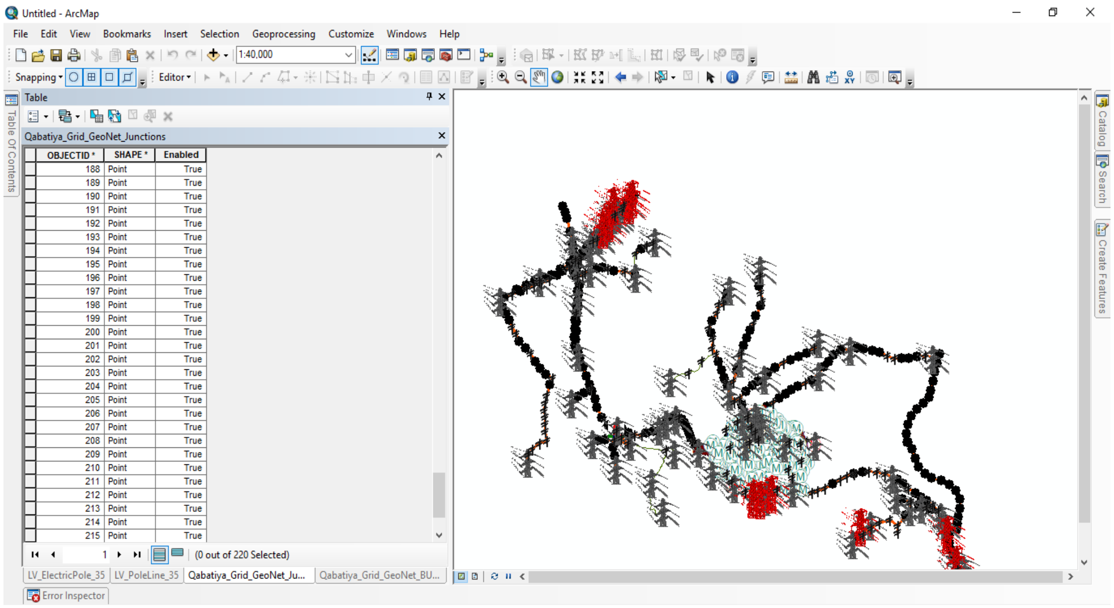


Figure 5. 57: Errors stored in Net_Junction Table

- The network build errors table: ""The table is used by the Network Build Errors command within ArcMap to identify the features with invalid geometries"". We have 7 errors here, clarifying the types of errors according to theirs ID and types was by using Esris's Help Desktop such as:

  Error type number 16 means that the junction is not connected to any other edge feature. Which also shown in figure [5.57]:

Table

Qabatiya_Grid_GeoNet_BUILDERR

ErrorID *	ClassID	ObjectID	ErrorType
1	24	31	10
2	9	63	16
3	14	5	16
4	9	41	16
5	24	23	16
6	23	50	16
7	23	11	16

Figure 5. 58: Errors stored in network build errors Table

Now we will start by identifying and correcting each error on the original Feature classes For example, we see here some errors such as: Overlap between lines and also an extended line, which are not true, especially since we determined by the topology that the end of each of the LV_Lines should be a point, which is a meter in our case. We will explain it in the following figures [5.58, 5.59].

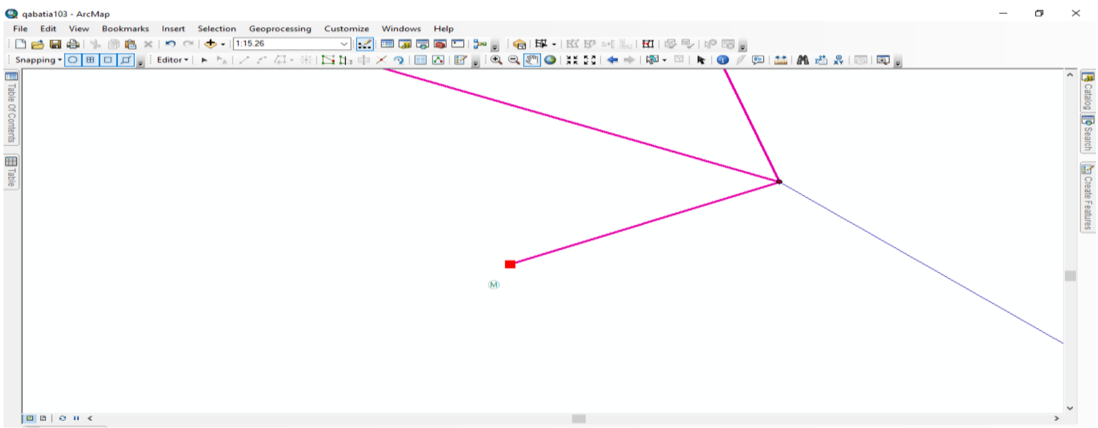


Figure 5. 59: Example of one error (Meter is not connected to any line)

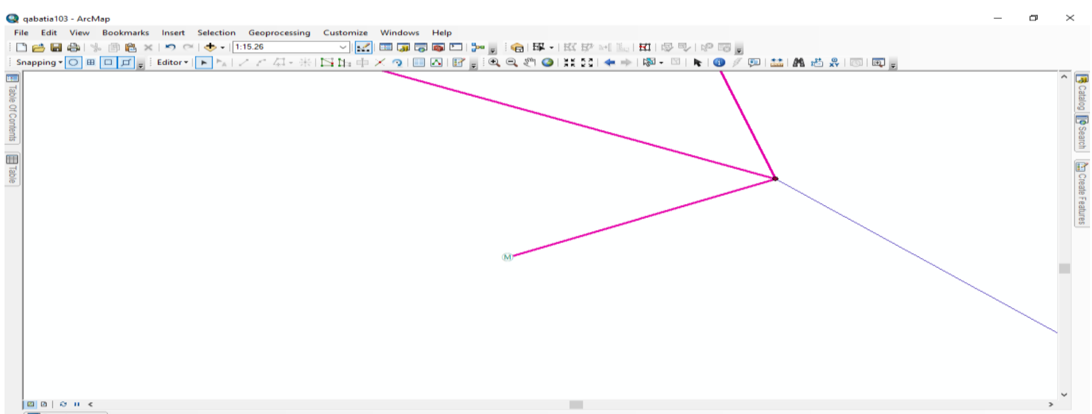


Figure 5. 60: Connect meter to its line

5.4 3D Model

Creating 3d Surface:

In order to export and create 3D surface for the study area ground, contour polyline layer was used. 3D analysis tool was applied to extract elevation raster file from topo polylines. See figure [5.79] demonstrates the tool Topo to raster that create an elevation raster surface from the contours topography polylines.

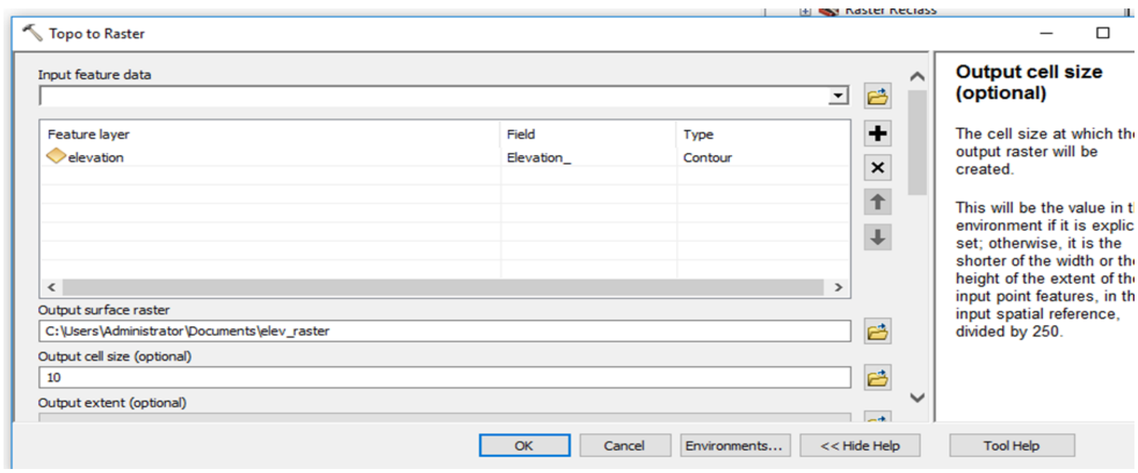


Figure 5. 61 : Topo to raster to extract elevation raster file

To visualize the elevation raster as a 3d elevation surface, the base height was set as the raster values

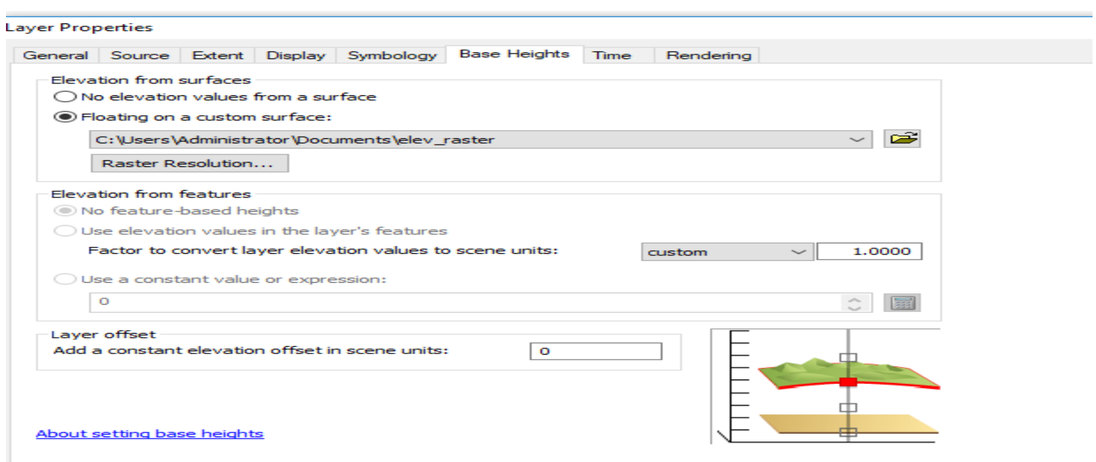


Figure 5. 62: Topo to raster to extract elevation raster file

In order to calculate and extract for each building vertex point the elevation according to the elevation.

The elevation raster didn't take into account the buildings surface. Data management was implemented to convert the building polygons into their point's vertices as demonstrated in figure [5.81].

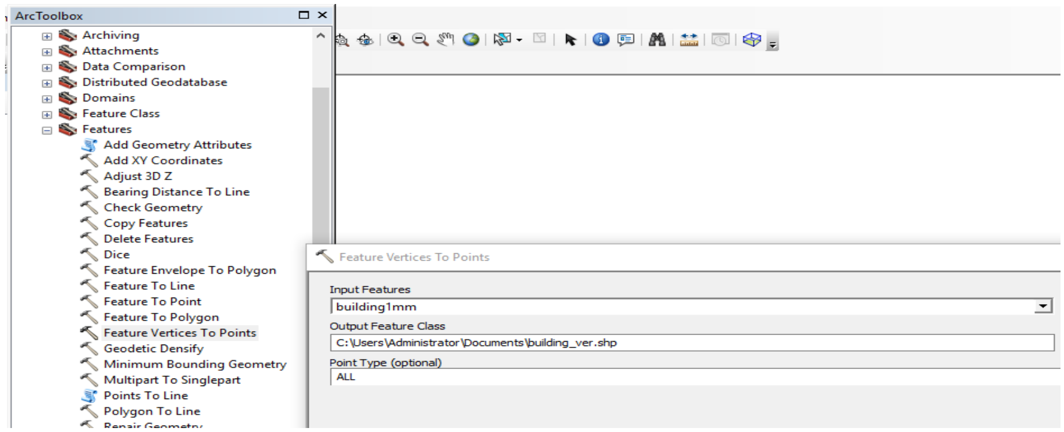


Figure 5. 63: Topo to raster to extract elevation raster file

In order to calculate and extract for each building vertex point the elevation according to the elevation raster the tool extract multi values to points was implemented to give each building's point an elevation

See figure [5.82].

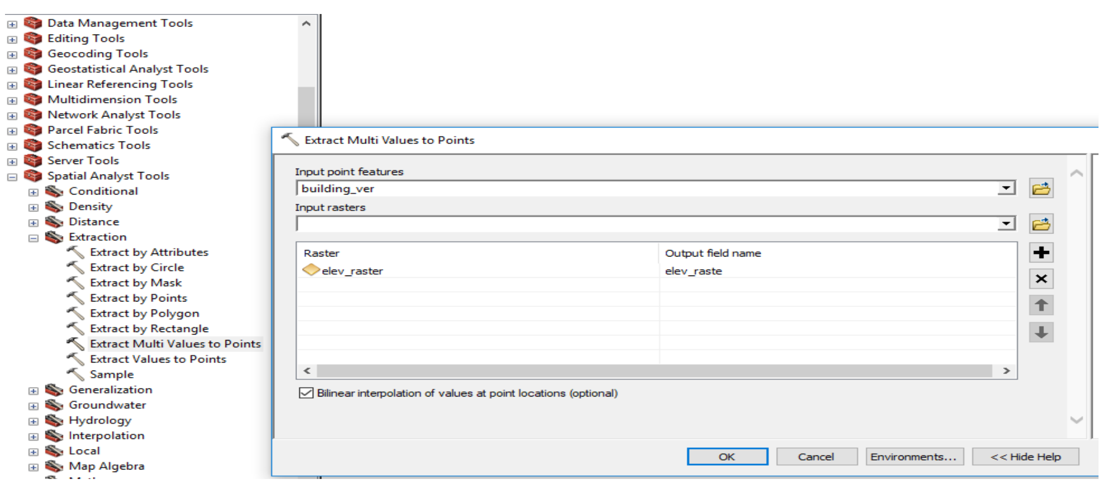


Figure 5. 64: Topo to raster to extract elevation raster file

For each building all his points will be taken and an average of their elevations will be calculated and considered as its elevation as demonstrated in the summarize tool applied on the ORIG_FID field in the buildings' vertices layer table attribute.

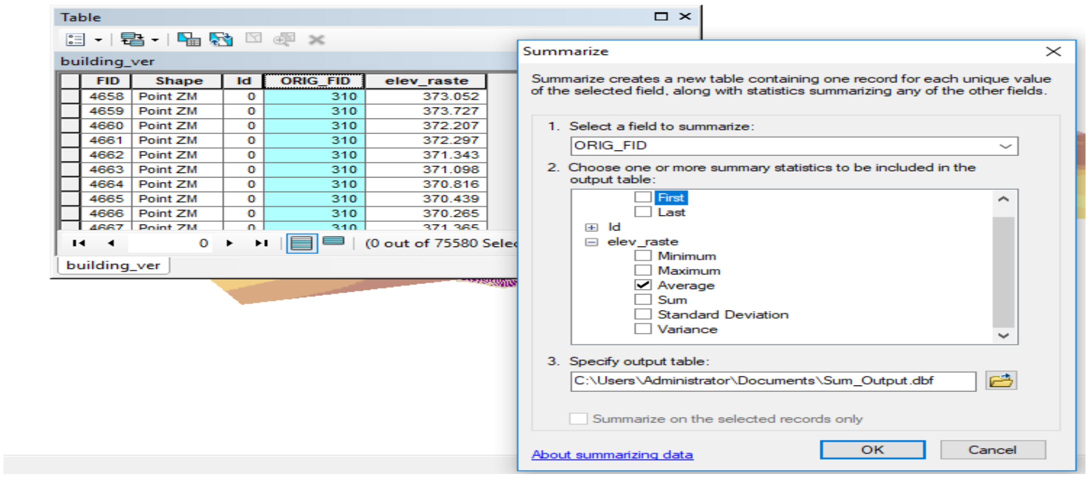


Figure 5. 65: Topo to raster to extract elevation raster file

In order to match for each building the elevation of its vertices Join by table was done to add the relevant field with the calculated elevation.

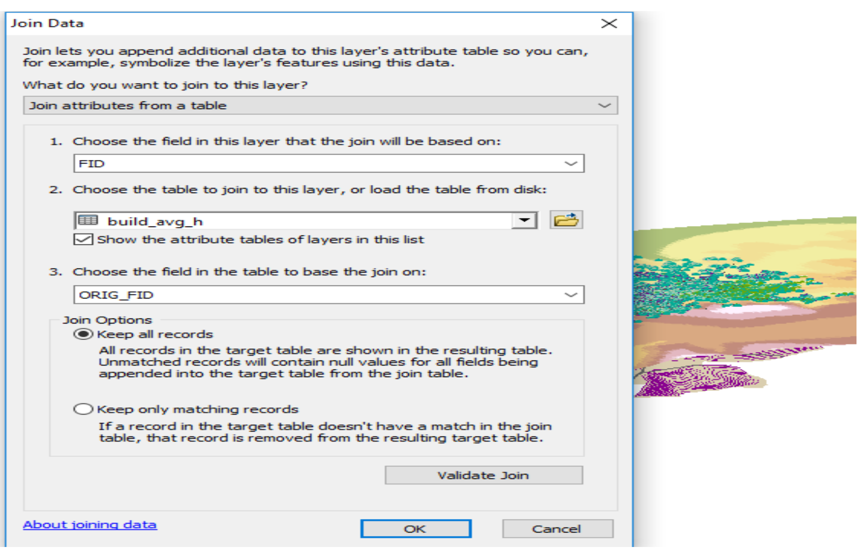


Figure 5. 66: calculated aveg height for each building form the output summarize table

Creating triangulated surface:

In order to create a 3D Surface considering the contours and the buildings surface a TIN was applied using Delaunay constrained triangulation. The contours layer was added as hard line, while the buildings were added twice, first as fill surface and their boundaries as hard line borders. See figure [5.85].

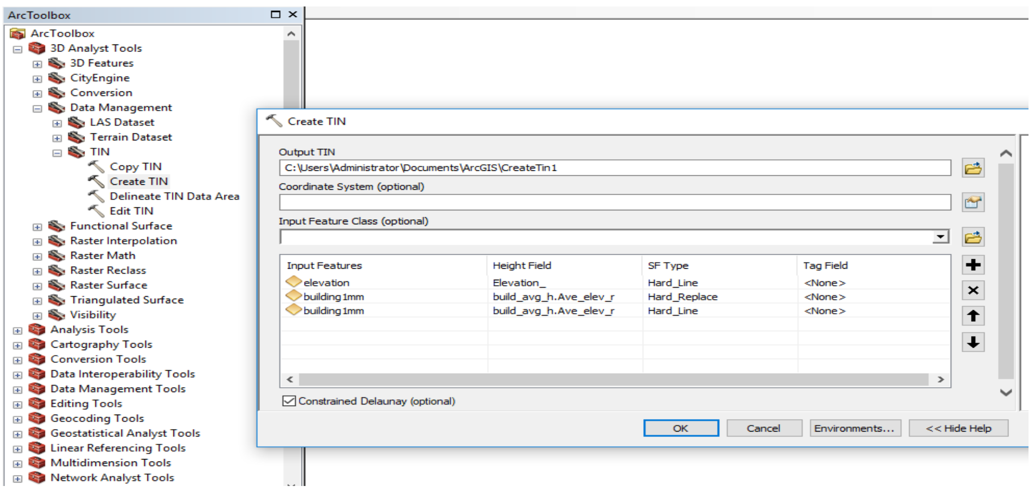


Figure 5. 67: create tin that take into account the building surface and boundaries

Changing the sympology of the result TIN

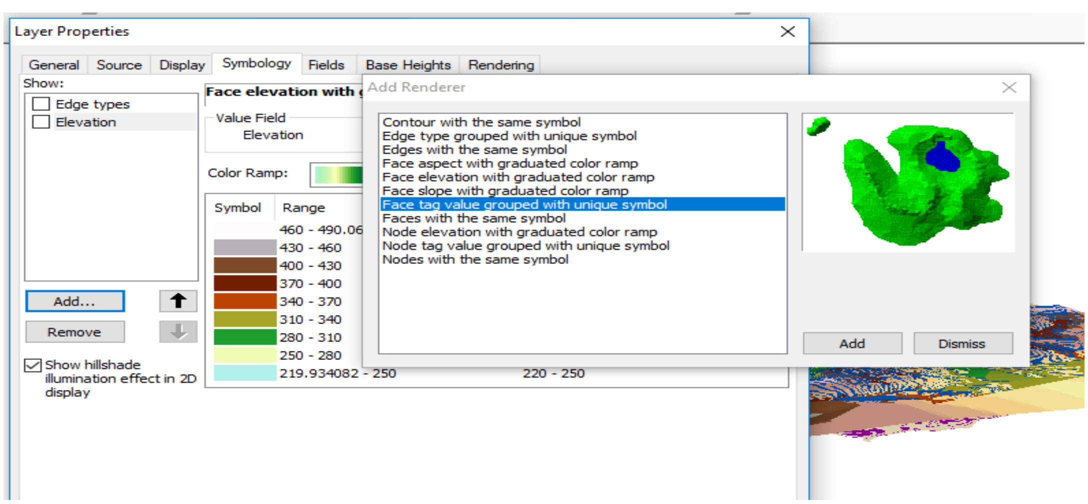


Figure 5. 68: create tin that take into account the building surface and boundaries

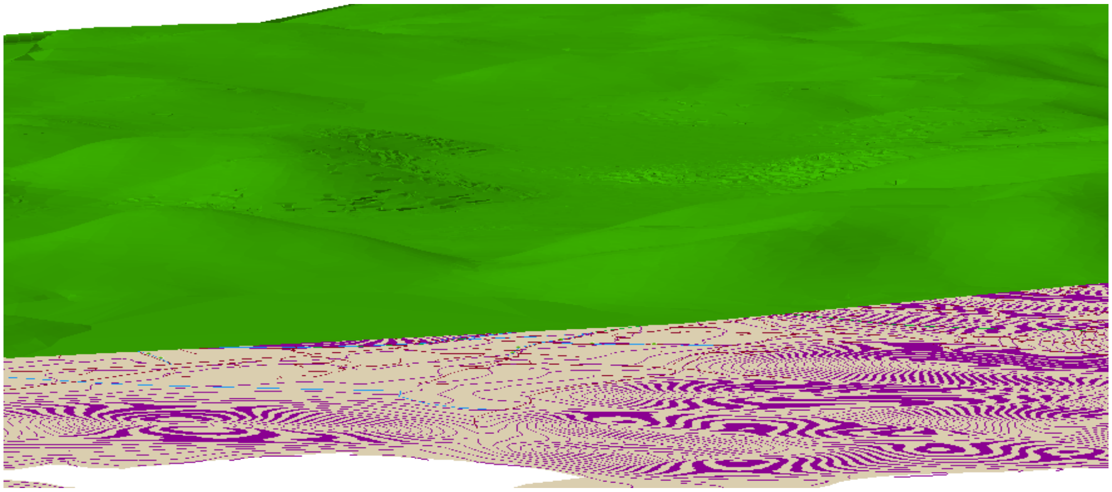


Figure 5. 69: Tin as surface

Extrusion for the building:

The buildings will be added as 3D features or as 3D visualization by applying extrusion using constant value or values from relevant field from the attribute table. The lack of elevation data for the buildings and their floors number to be able to create a real 3D model and accurate.

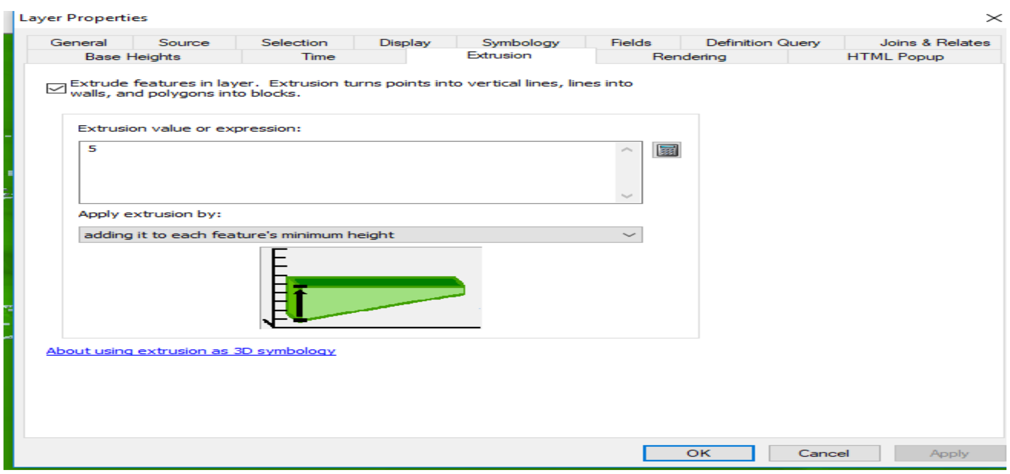


Figure 5. 70: Tin as surface

Define the base height:

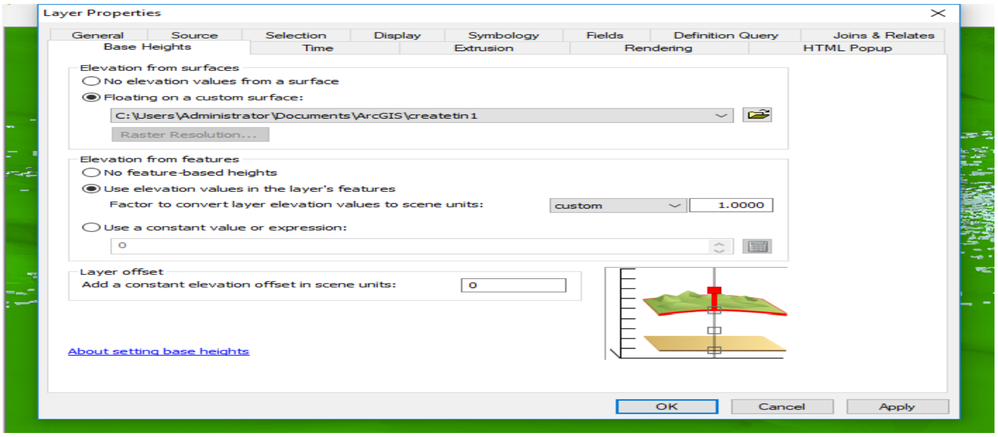


Figure 5. 71: define base height

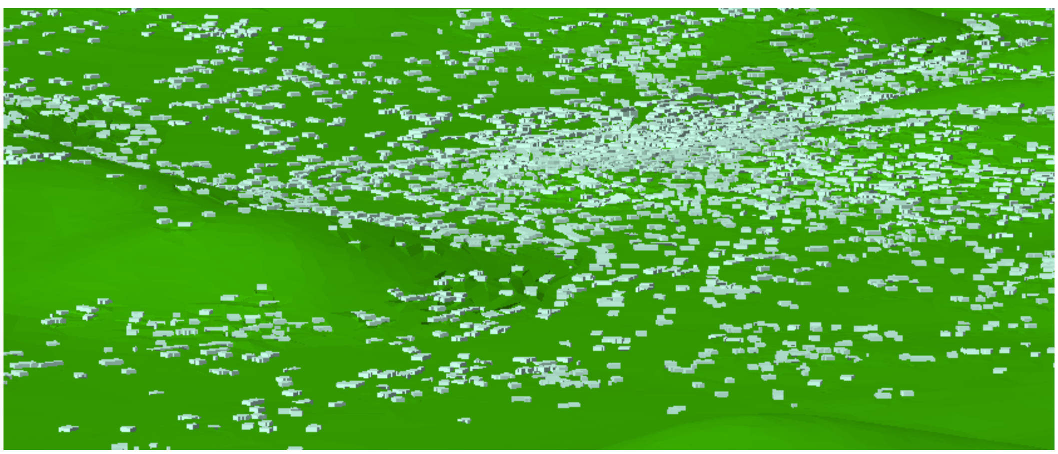


Figure 5. 72: The results

The roads:

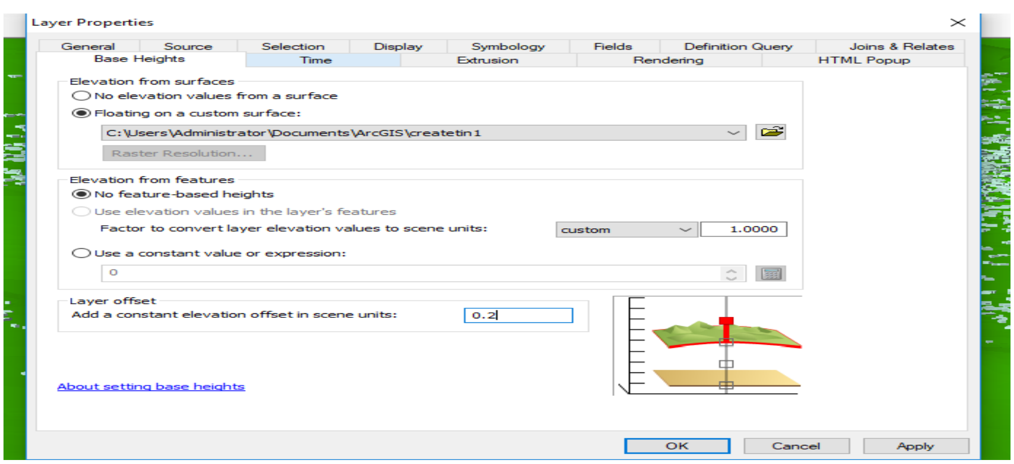


Figure 5. 73: The results

5.5 Detection of non-technical electricity losses

Now that our vision has become clear, our focus became on a more important goal, which is to study the electricity losses, the next step is to get new data, which is the instantaneous current in the wires (LV_E_ Lines), and this is one of the obstacles that we faced, as there are no instantaneous current readers for the current at a specific time, and to solve this problem is to get this information in another way, by calculating the hourly consumption of each meter through doing many processes.

As a result of the huge number of meters in the city of Qabatya and the difficulty of getting all of them at a specific time, we decided to limit our study on transformer No. 44 in Qabatya electricity network, where it has three feeders, including the low-voltage network extending to consumers (Meters).

a) **Our approach to calculate electric loss:**

After obtaining the complete information for each consumer and storing them with Excel files, we moved to the stage of calculating the daily consumption for each consumer, but we faced a new obstacle which is the difficulty of obtaining a uniform time period for calculating the daily consumption of each consumer where what restricts us is that the meters are prepaid meters where each consumer charges his card at different times from the others.

To solve this problem our suggestion was calculating for each consumer his daily consumption separately by calculating the number of days from the start of his subscription to the present time.

When started calculating the number of consumption days for the consumers of the new type of meters (holly2), one of the other difficulties was that some consumers had a subscription period of no more than a few months and to increase the accuracy of the accounts we searched for them in the old system and took their old information and took the average of the old and new. Our processes to calculate D_C_R which shown in figure [5.60]:

a) Firstly: calculate number of consumption days in all excel files of all consumers through subtract the first electricity charging date from the last charging date.

b) Calculate The amount of electricity consumed by summation for all quantities of electricity consumed except for the last shipment to the last date we calculated, as it is logical at this date that this shipment is not considered to be consumed yet.

c) Daily consumption rate (kWh) = number of days / amount of electricity consumption.

For new consumers (Their meters are of a holly2 type): we calculated the average daily consumption in their old and new consumption files and then calculate the average.

	C	D	E	F	G	H	I	J	K	AL	AM
1	الرقم الاشتراك	عدد مرات ال	مبلغ الشحن	خصم أو ردي	رقم التعرفة	اسم التعرفة	التعرفة	تكلفة الكهرب	تاريخ الشراء	الكهرباءالمستهلكة	الرصيد المس
2	000619	1	0.00	0.00	001	منزلي	1.00	0.00	2019-06-10	0.00	0.00
3	000619	2	0.00	0.00	001	منزلي	1.00	50.00	2019-06-10	0.00	0.00
4	000619	3	0.00	0.00	001	منزلي	1.00	46.52	2019-06-14	70.28	40.76
5	000619	4	0.00	0.00	001	منزلي	1.00	34.56	2019-06-26	153.97	89.30
6	000619	5	0.00	0.00	001	منزلي	1.00	38.91	2019-07-03	220.81	128.08
7	000619	6	0.00	0.00	001	منزلي	1.00	40.65	2019-07-08	290.76	168.64
8	000619	7	0.00	0.00	001	منزلي	1.00	38.04	2019-07-16	356.28	206.64
9	000619	8	0.00	0.00	001	منزلي	1.00	37.17	2019-07-25	420.56	243.91
10	000619	9	0.00	0.00	001	منزلي	1.00	50.00	2019-08-18	483.03	280.12
11	000619	10	0.00	0.00	001	منزلي	1.00	36.08	2019-09-03	561.96	325.89
12	000619	11	0.00	0.00	001	منزلي	1.00	44.78	2019-09-09	609.62	353.55
13	000619	12	0.00	0.00	001	منزلي	1.00	32.60	2019-09-29	708.05	410.64
14	000619	13	0.00	0.00	001	منزلي	1.00	39.56	2019-10-11	764.59	443.45
15	000619	14	0.00	0.00	001	منزلي	1.00	31.73	2019-11-01	766.31	444.46
16	000619	15	0.00	0.00	001	منزلي	1.00	37.82	2019-11-15	889.53	515.90
17	000619	16	0.00	0.00	001	منزلي	1.00	88.69	2019-11-28	953.51	553.01
18											
19									171		
20									D_C_R	5.576081871	
21									D_C_R in old meter	9.41585	
22									avrg	7.495966	

Figure 5. 74: Calculate daily consumption rate in excel files.

5.5.1 How to calculate the Hourly consumption rate for each consumer

After storing D_C_R information for each meter in meter feature class. We can now calculate H_C_R by field calculator as follow

$$H_{C_R} = D_{C_R} * 1000/24 \qquad [4]$$

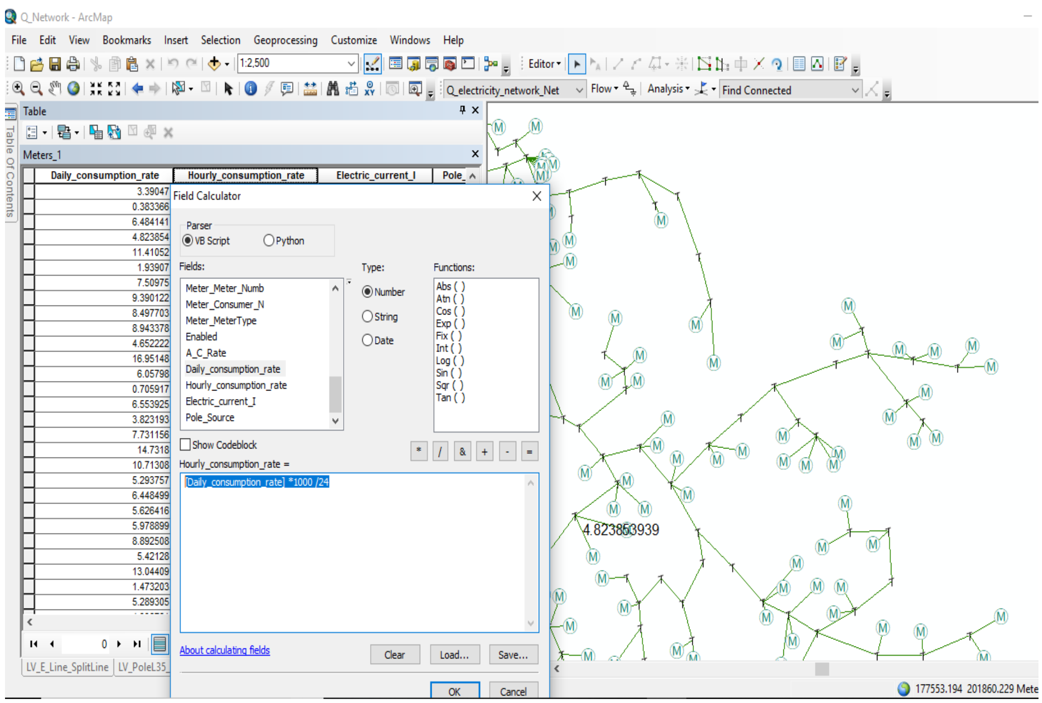


Figure 5. 75: Calculate hourly consumption rate

- **Calculate the Electric current for each consumer:**

1. For Single phase: by using the equation no.(1) in chapter 3, and to do this in ArcMap firstly we calculate Electric current for all meters considering as single

phases.

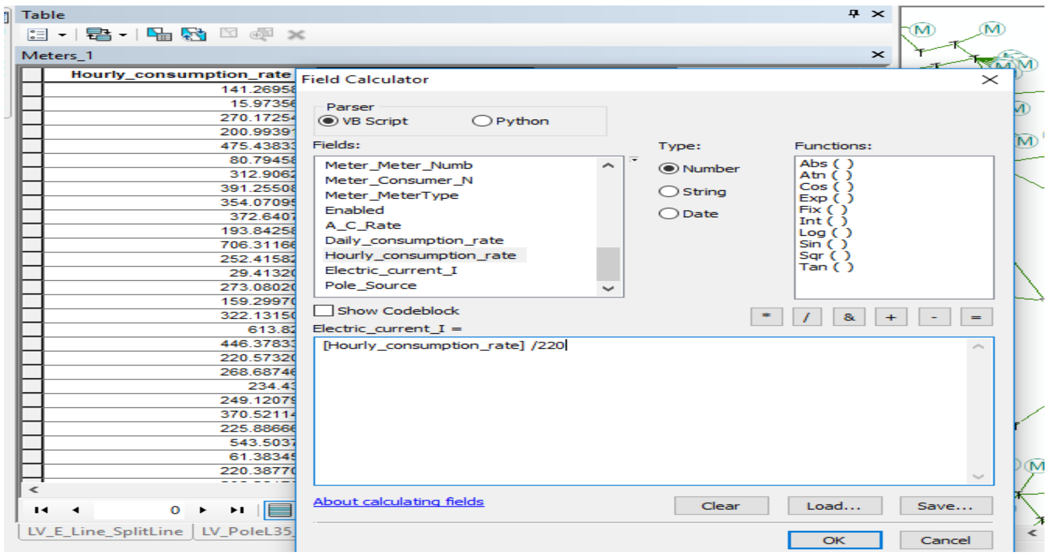


Figure 5. 76: Calculate Electric current for single phase

2. For three phases: Firstly we select all meters that are in three phases by select by attributes tool that shown in figures [5.63,5.64]:

The query we used is: [Consu_Meters_A] =33 AND [Consu_Meters_B] =33 AND [Consu_Meters_C] = 33 OR [Consu_Meters_A] = 34 AND [Consu_Meters_B] =34 AND [Consu_Meters_C] =34 OR [Consu_Meters_A] =35 AND [Consu_Meters_B] =35 AND [Consu_Meters_C] =35

To calculate (I) we used this equation we used equations no. (2 and 3) illustrated in chapter 3.

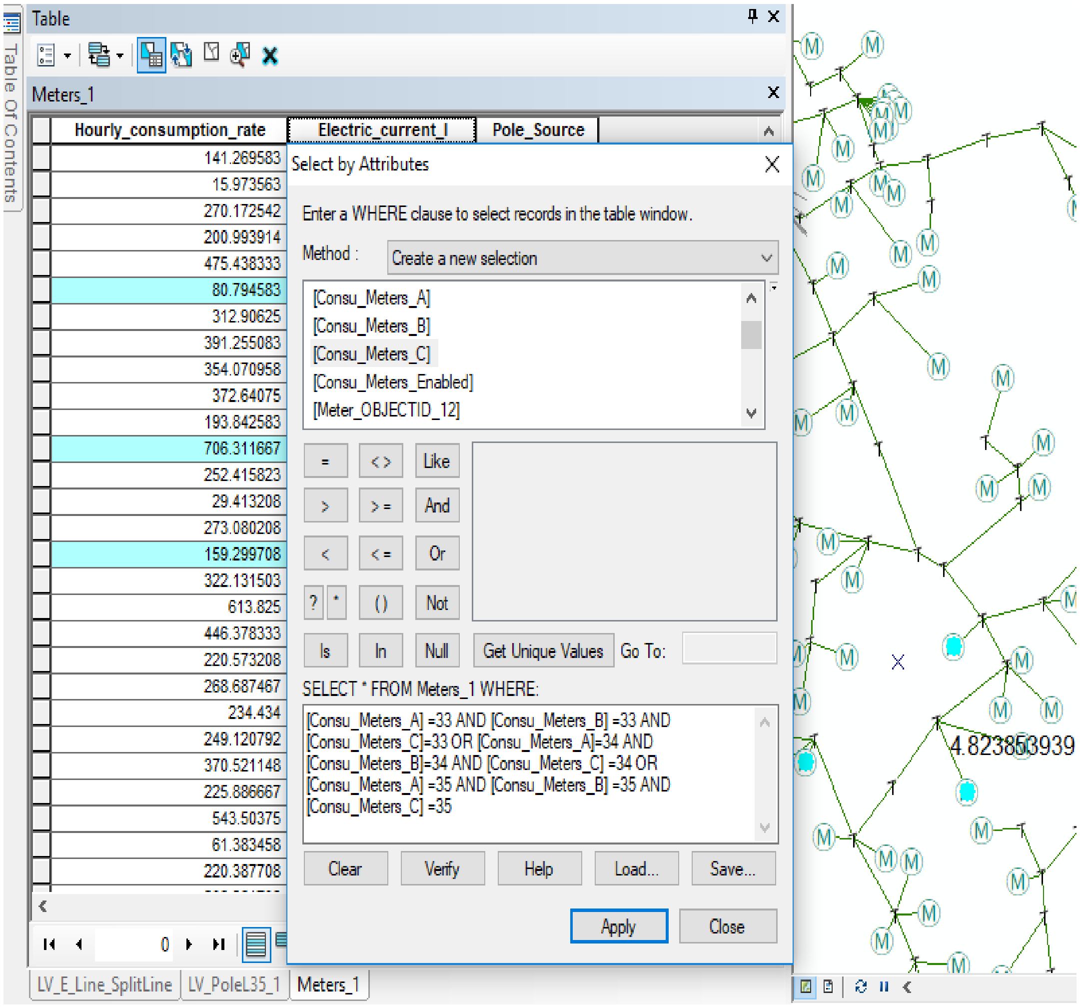


Figure 5. 77: Select 3phases meters

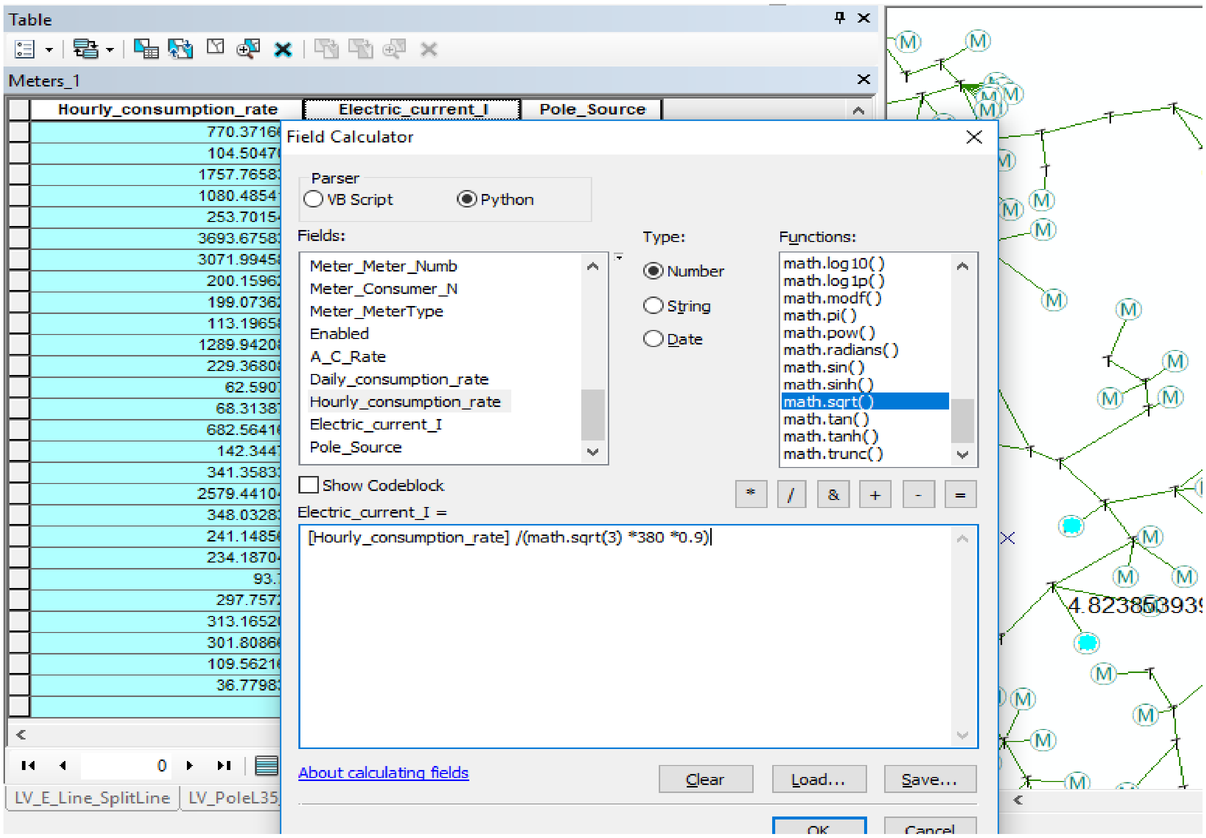


Figure 5. 78: Calculate Electric current for 3phases

- **Calculate the Electric Losses for each Lines:**

The Electric loss is calculated by the formulas no. (4 and 5) existing in third chipper.

First to get the resistance of each line, we entered a value of Cross_Sec_Area for each line by referring to the municipality engineer, where they had four types of Cross_Sec_Area, shown in the following table [5.2] and each type with its resistance that we adopted on Conductor resistance @ 20◦ C.

Table 5. 2: Electric properties (Technical Data) [66].

Cross_Sec_Area (mm^2)	**Conductor resistance @ 20◦ C (Ω/km)**
3*10 mm2	1.91
4*25mm2	1.2
4*50+2*25mm2	0.641
4*95+2*25mm2	0.32

Then we converted the value of lines lengths from meters to kilometers as shown in figure [5.65]:

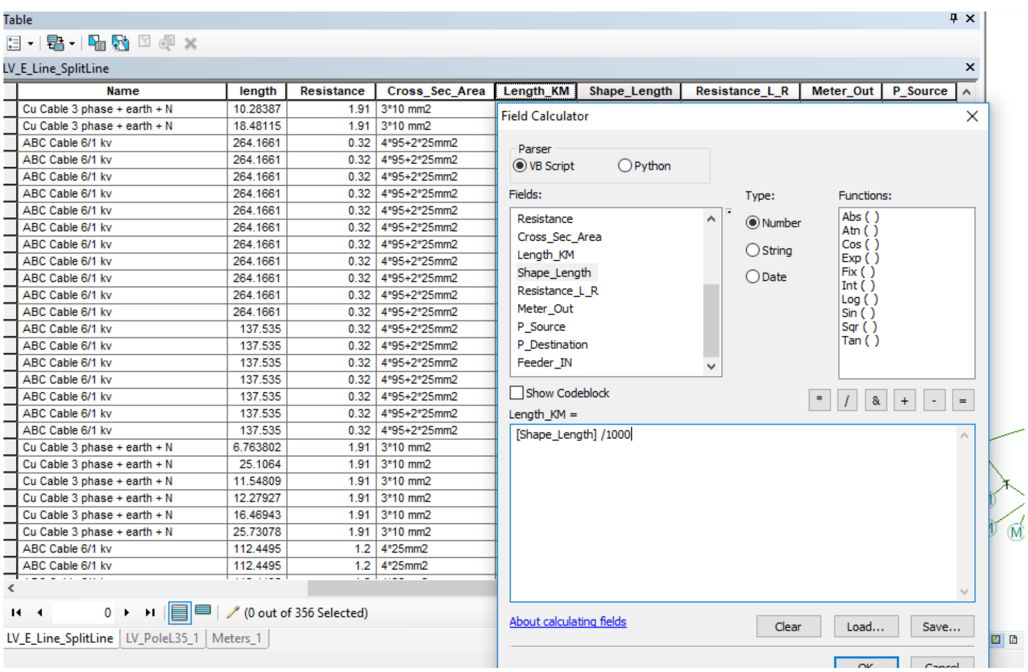


Figure 5. 79: Convert the value of lines lengths from meters to kilometers

Then we add field named by Resisitance_L_R to calculate R for each line which is the product of the resistance by the length of each line, this is illustrated by the following figure:

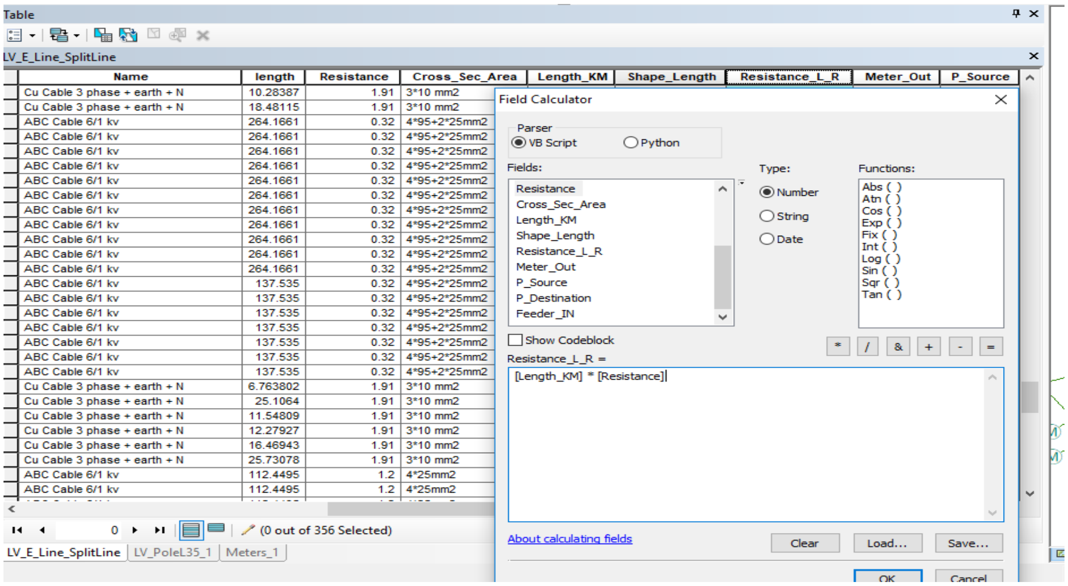


Figure 5. 80: Calculate the value of Resisitance_L_R

Geometric network for Zoon (Transformer 44_LV_ network) of study area:

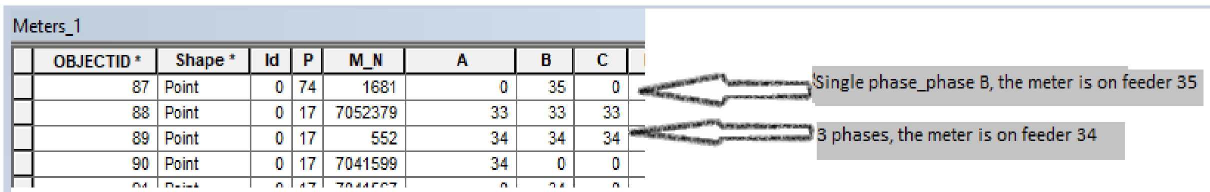
Repeat all the previous steps for building the Geometric Network, which summarized as follows:

1. Build a new shapefile for the study area, which is the transformer 44 polygon called by Tower 44 , to draw a polygon around the network of this transformer

2. Build a new feature classes based on Tower44 using clip tool, the new layers we got is as follows: ACSR_Cable, Feeders, LV_E_Line, LV_PoleL35, Meters, and MV_tower_transformer_Source

3. Built new feature dataset and import these feature classes in it.

4. Modify the three field of ABC phases where classify the phase type based on feeder id, their three feeders on tower 44 which is: 33, 34, and 35. When the value of three field of one meter are not 0 that’s means the meter is take from 3 phase otherwise if two value have zero and the other have value of feeder id then we can recognize that the meter is a single phase.


Meters_1

OBJECTID *	Shape *	Id	P	M_N	A	B	C
87	Point	0	74	1681	0	35	0
88	Point	0	17	7052379	33	33	33
89	Point	0	17	552	34	34	34
90	Point	0	17	7041599	34	0	0

Figure 5. 81: Determine single and triple phases

5. Create a new topology to fix errors.

6. Rebuild geometric network for tower44 network called Q_electricity network, and identified MV_tower_transformer 44 as the main network source.

Build Connectivity Rules for Q_electricity network

In this stage building a connectivity rules for new geometric network is an important thing, define the relationships between network elements (features classes) in details, and where described as follow:

- Feeders is connected to MV_tower_transformer_Source_1 through ACSR cables.
- Poles connected to Feeders through LV_Lines.
- Poles connected to themselves through LV_Lines.
- Poles connected to meters through LV_Lines.
- LV_Lines connected to meters.
- LV_Lines connected to meters.

- LV_Lines connected to Feeders.
- ACSR cables connected to MV_tower_transformer_Source_1.
- ACSR cables connected to Feeders

Building these connectivity rules in ArcMap is shown in the following figures [5.68 - 5.70]]:

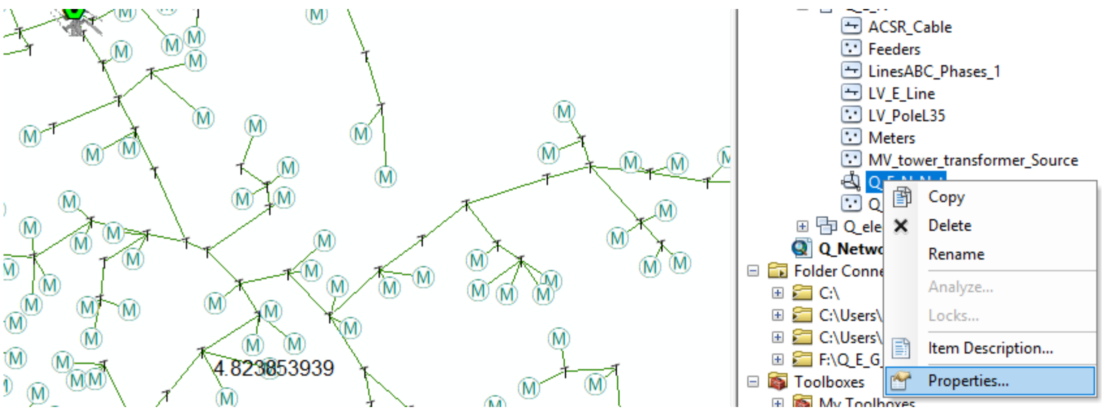


Figure 5. 82: Open connectivity rules interface through properties of geometric network

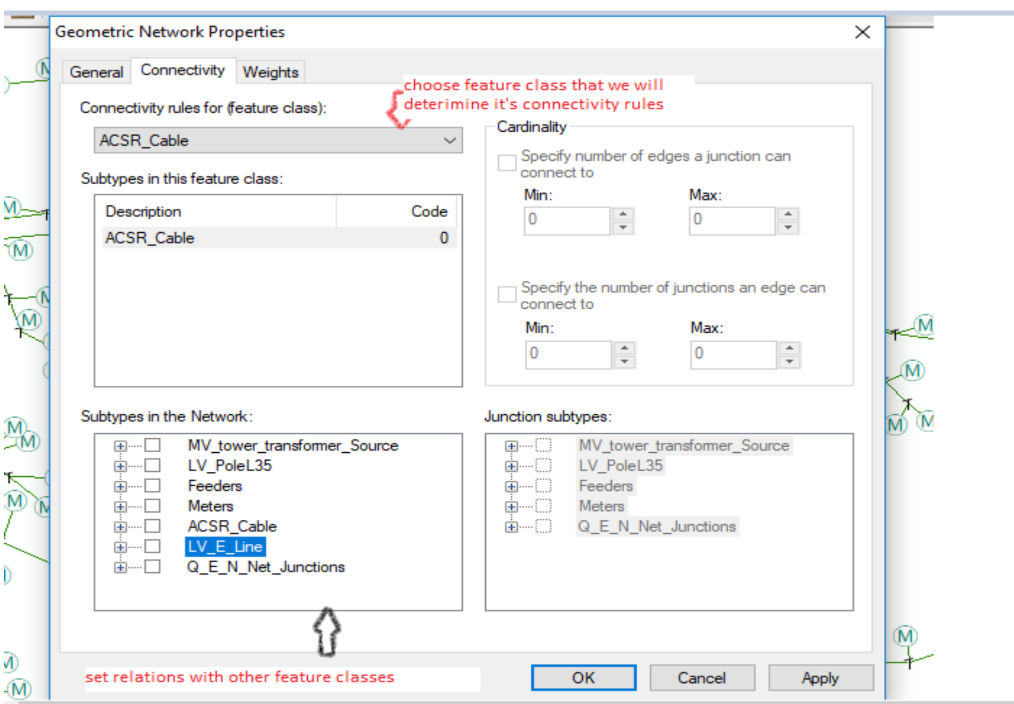


Figure 5. 83: Set connectivity rules for all feature classes

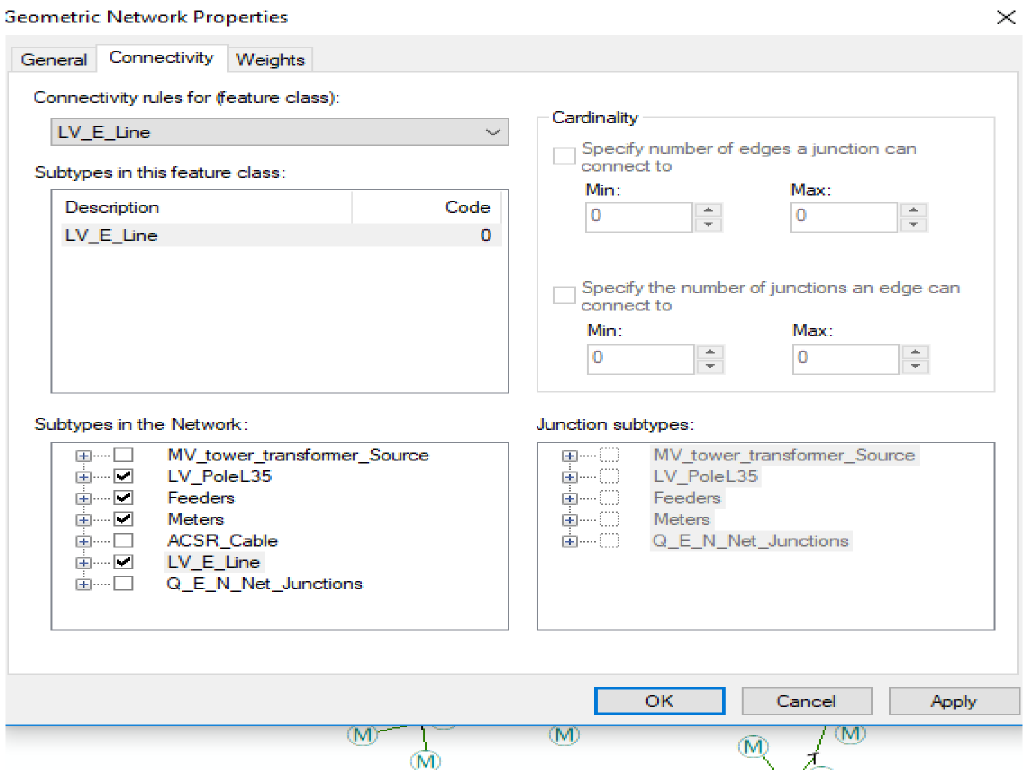


Figure 5. 84: Example of connectivity rules For LV_E_Line

Determine the direction of Electric current:

Firstly, selection a point source in the layer MV_tower_transformer_Source_1 which is Directorate of Education (Alqadima) from ancillary rule that was built automatically from geometric network which is illustrated in figure [5.71], this point linking the electricity network in each other, connect the power to all the network elements and have the keys of power outage.

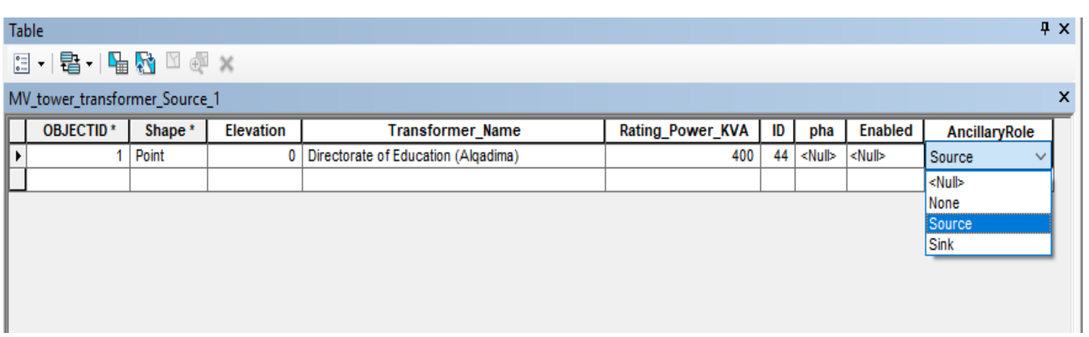


Figure 5. 85: Determine the source of network

Utility Network Analyst Tools:

After completing the construction of the electricity geometric network completely and correctly, we were able to analyze and manage the network using Utility Network Analyst Toolbar such as:

- Determine the direction of Electric current through Utility tools: as shown in following figure the electric current flows from source (Transformer 44) to all meters through LV_Line

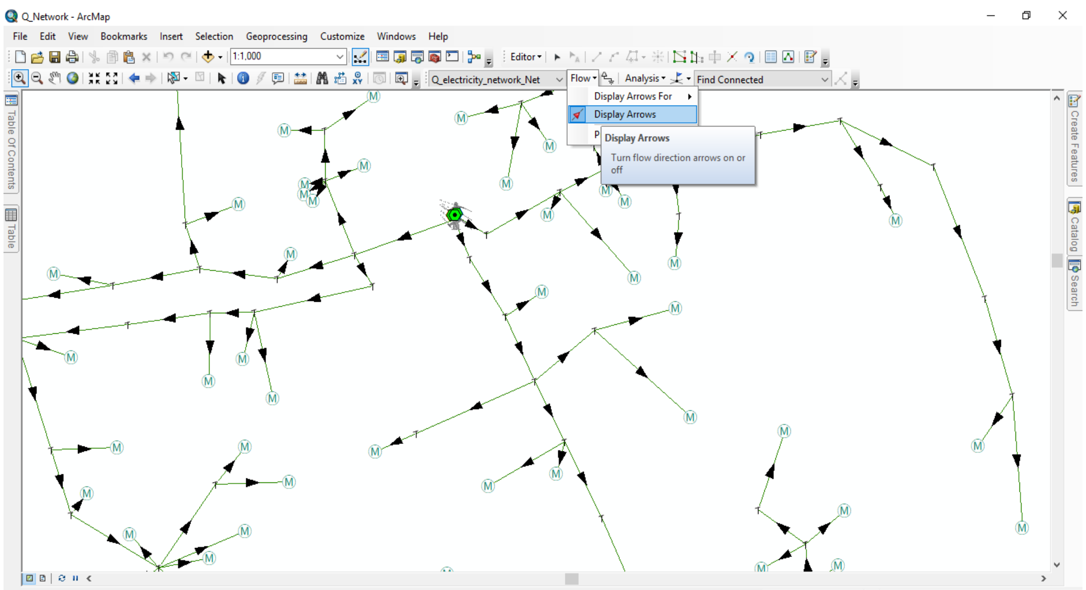


Figure 5. 86: Display the direction of Electric current

- Find disconnected: find all lines that are not connected to a specific point through the electricity network, for example Knowing the parts of the network that will be affected when a malfunction occurs in a specific place in the network
  As the example shown in the following picture, using this tool all the lines and meters that will be affected by the power outages it will be known and identified in an easy way.

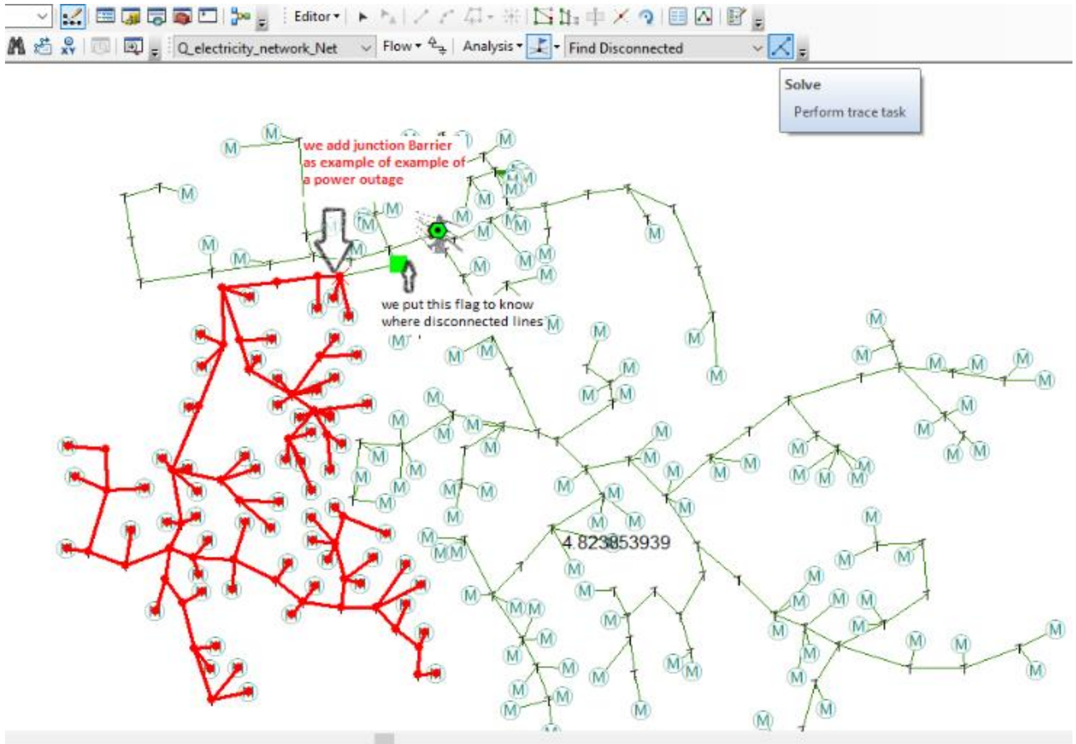


Figure 5. 87: Find disconnected

The next work was for calculate Power losses at any location in the network, for that the electric current data at this location is important where calculation of electricity loss depends on the value of the electric current, resistance and length of the line, but the electric current is known only at the meters, and through which we can know the electric current at the pole connected, which is equal to the sum of the currents at the meters connected to it, therefore so we suggested the following solution:

First, calculate the current at any line or pole using the hierarchical tree in a backward way

As we have linked each meter to the column to which it is connected by adding this information in the meter table as shown in the picture, where this column (named Pole_Source) represents pole id.

Table

Meters_1

Daily_consumption_rate	Hourly_consumption_rate	Electric_current_I	Pole_Source
3.39047	141.269583	0.642134	2
0.383366	15.973563	0.072607	141
6.484141	270.172542	1.228057	2
4.823854	200.993914	0.913609	139
11.41052	475.438333	2.161083	55
1.93907	80.794583	0.136394	53
7.50975	312.90625	1.422301	54
9.390122	391.255083	1.778432	74
8.497703	354.070958	1.609413	54
8.943378	372.64075	1.693822	40
4.652222	193.842583	0.881103	40
16.95148	706.311667	1.192366	26
6.05798	252.415823	1.147345	58
0.705917	29.413208	0.133696	78
6.553925	273.080208	1.241274	109
3.823193	159.299708	0.268923	78
7.731156	322.131503	1.464234	80
14.7318	613.825	2.790114	81
10.71308	446.378333	2.028992	73
5.293757	220.573208	1.002605	106
6.448499	268.687467	1.221307	106
5.626416	234.434	1.065609	107
5.978899	249.120792	1.132367	70

Figure 5. 88: add the pole source for each meter to the Meter table

Then add each source and destination for each line but the lines are connected to each other, because when we started drawing the lines, we used to draw the entire line from its beginning to the end, but this will not help us when will use the hierarchical tree for calculate electric current and losses, because each line has more than one source and more than one destination so we had to solve this problem by using of split line tool: it's function is dividing the lines at each point in the network (in our case the points represent the transformer, feeders, meters), and the result after using this tool is shown in the following image, this means that each part of the lines has a row in the lines table and has a special id, length and a special resistance for it.

Now after having the complete lines table named LV_E_Split lines, our need became to add the source and destination for each line by identifying each line on the network, its source and destination and taking the ID for each one and adding it in the new columns that we added in the Table of LV_E_Split lines which are:

- P_Source: source of line.
- P_Destination: destination of line.

- Meter_Out: destination of line in the end of network.
- Feeder_In: source of line in the beginning of network.

Next added a new column this table to calculate the resistance for each line, which is by multiplying the length by the resistance , but the length unit here is meters, so we added a new column to convert the meter to a kilometer called (Length_KM), using the Field calculator tool.

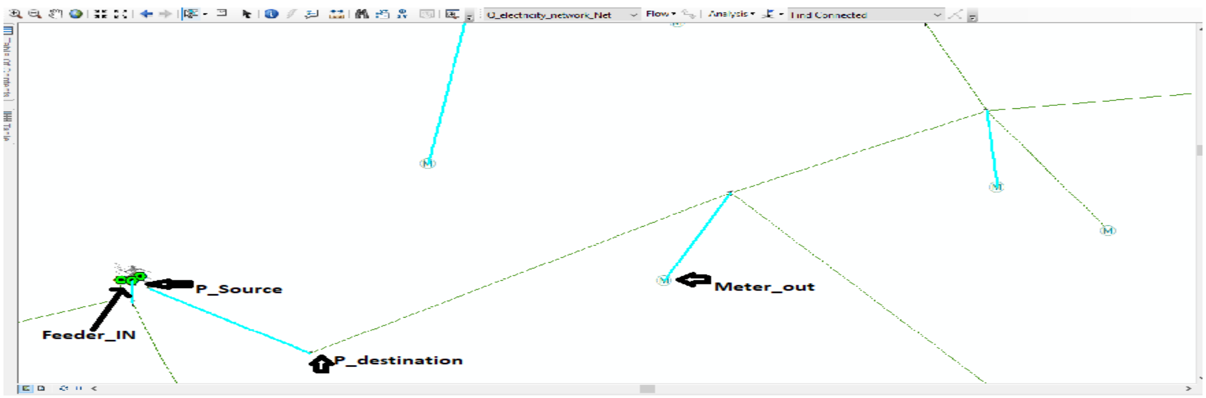


Figure 5. 89: determine for each line on the network, its source and destination

Length_KM	Shape_Length	Resistance_L_R	Meter_Out	P_Source	P_Destination	Feeder_IN
0.020058	20.057582	0.03831	88	17	<Null>	<Null>
0.008503	8.503418	0.016242	34	33	<Null>	<Null>
0.037673	37.672503	0.071954	35	33	<Null>	<Null>
0.006587	6.587056	0.012581	33	88	<Null>	<Null>
0.012588	12.588384	0.024044	37	88	<Null>	<Null>
0.0178	17.80049	0.033999	<Null>	12	89	<Null>
0.015196	15.196181	0.029025	36	89	<Null>	<Null>
0.020151	20.151058	0.038489	89	38	<Null>	<Null>
0.026336	26.335602	0.050301	91	38	<Null>	<Null>
0.014141	14.141136	0.02701	67	23	<Null>	<Null>
0.045233	45.232854	0.054279	<Null>	23	93	<Null>
0.027908	27.908395	0.03349	<Null>	93	22	<Null>
0.022959	22.958837	0.043851	69	93	<Null>	<Null>
0.024989	24.988973	0.047729	71	72	<Null>	<Null>
0.026223	26.222879	0.050086	70	93	<Null>	<Null>
0.009539	9.538773	0.018219	72	94	<Null>	<Null>
0.034213	34.213337	0.041056	<Null>	21	92	<Null>
0.019087	19.087001	0.022904	<Null>	92	5	<Null>
0.011171	11.171249	0.021337	65	21	<Null>	<Null>
0.023652	23.651651	0.045175	64	92	<Null>	<Null>
0.024986	24.985501	0.047722	63	92	<Null>	<Null>
0.011279	11.278763	0.021542	57	94	<Null>	<Null>
0.017336	17.335754	0.011112	<Null>	71	95	<Null>
0.027881	27.880587	0.017871	<Null>	95	84	<Null>
0.031587	31.586546	0.020247	<Null>	84	69	<Null>
0.023745	23.744735	0.01522	<Null>	69	66	<Null>
0.026988	26.988168	0.017299	<Null>	66	85	<Null>
0.027301	27.30126	0.052145	61	84	<Null>	<Null>

Figure 5. 90: add source and destination for each line on the network in LV_E_Split Line table.

As we note now the data has been modified and therefore we had to rebuild the network again by repeat all the steps of building the geometric network and rebuilding the connectivity rules that we mentioned earlier.

Meters and lines tables were exported to excel files to calculate electric current and loss by using SQL Navigator for Oracle (Oracle Database used for stored data), where used 4 algorithms to calculate was current and loss at each line and every pole

Then we used the Java programming language and a NetBeans IDE 8.0.1program to display the results in a website as shown in the following figures:

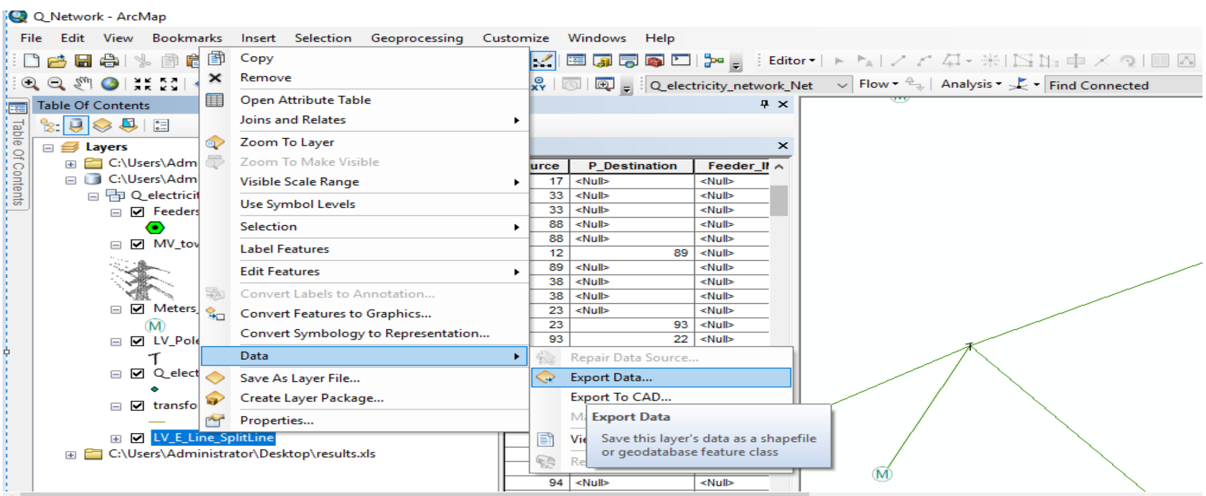


Figure 5. 91: Export LV_E_Split Line table to excel file.

Table 5. 3: Sample of the Line table stored in Oracle Database

OBJECTID	P_SOURCE	P_DESTINATION	L_R	IS_METER	IS_FEEDER
1	118		0.0396499799353072	73	
2	24		0.0422070656331209	48	
3	49		0.0373486497434277	47	
4	87	16	0.0178465401995647		
5	16	18	0.0788363197983472		
6	43		0.0175615115523377	117	
7	16		0.0364490244655363	93	
8	42	41	0.0310076990987045		
9	41	17	0.0195969123609834		

Table 5. 4: Sample of the meter table stored in Oracle Database

OBJECTID	CONSU_METERS_A	CONSU_METERS_B	CONSU_METERS_C	ELECTRIC_CURRENT_I
1	0	35	0	0.64213446969697
2	0	0	35	0.0726071022727273
3	0	0	35	1.22805700757576
4	35	0	0	0.913608700568182
5	0	0	35	2.16108333333333

```
Procedure calculate losse(pole n)
Current =0;
Length=0;
Resistance =0;
Path_value=0;
Node_value=0
For all meters m connected to pole n;
Current = Current + Current at meter m
For all node N in path from source to pole n
Loop
Nod_ value= NRisitance* NLength
Path_value= Path_value+ Node_value;
End Loop
Losse= current* Path value;
End;
```

Class 1 Calculate the loss at a particular Pole

```
Procedure calculate losse(cable n)
Current =0;
Length=0;
Resistance =0;
Path_value=0;
Node_value=0
cable n=pole destination;
For all meters m connected to pole destination;
Current = Current + Current at meter m;
For all node N in path from source to pole destination
Loop
Node_value= NRisitance* NLength
Path_value= Path_value+ Node_value;
End Loop
Losse= current* Path_value;
End;
```

Class 2 Calculate the loss at a particular Line.

```
select sum (m.electric_current_i)
from meters m
where     m.consu_meters_a <> 0
and m.objectid in (

select p.is_meter
from poles p
where p.is_meter is not null
start with p.objectid = 6
connect by prior p.p_destination = p.p_source
```

Algorithm 1: Calculates the summation of the Electric current value for all Meters connected to a specific line

```
select sum (p.l_r),
from poles p
start with p.objectid = 6
connect by prior p.p_source = p.p_destination
```

Algorithm 2: To calculate the summation of the Resistance_L_R values from the start of the feeder to a specific line

For all algorithms and full code see. Appendix A.

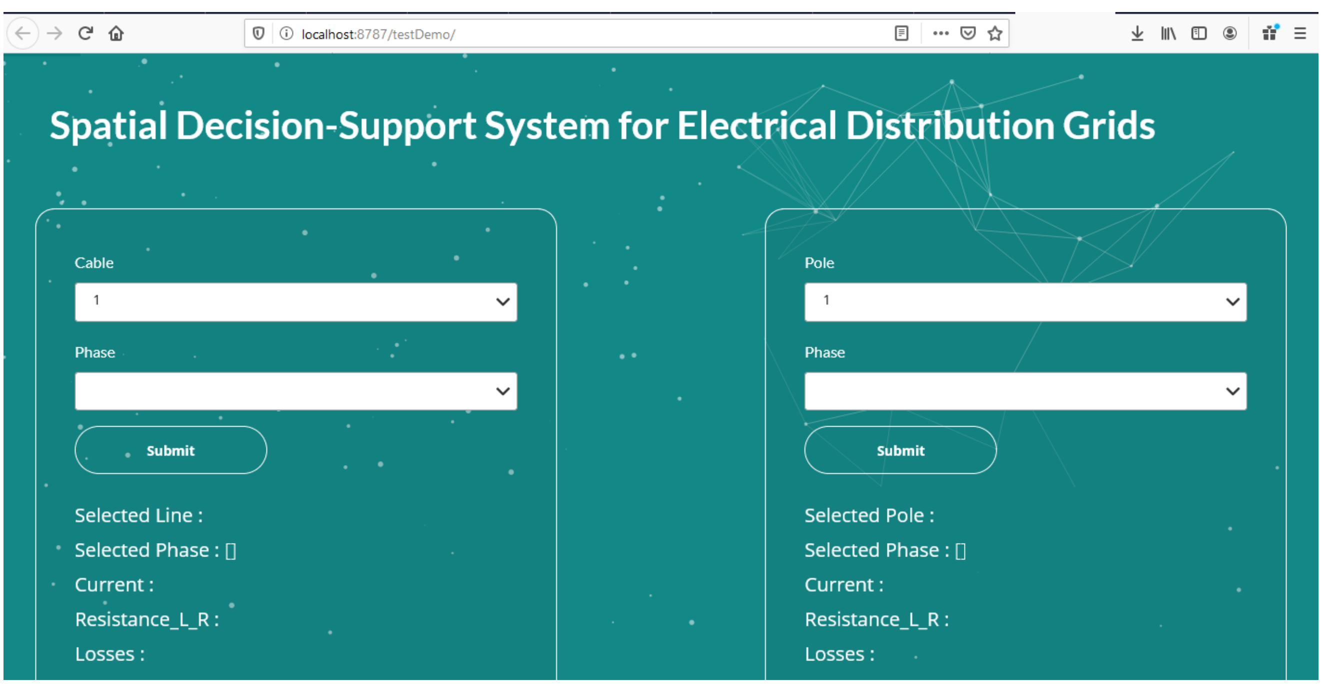


Figure 5. 92: Project web page interface to show results

On the web page, it shows us the ability to inquire about the loss, electric current, and the resistance from the feeder to determined pole or cable (line) information for a specific pole or cable by selecting the id of them from the pole and cable menus, also the selection of a specific phase (ABC), then click on submit and all necessary information will be displayed on this web page.

For web page design code see. Appendix B.

5.6 Test & Validation results

Example for test loss calculation, at pole 41 at phase B as showed in following figure [6.1]:

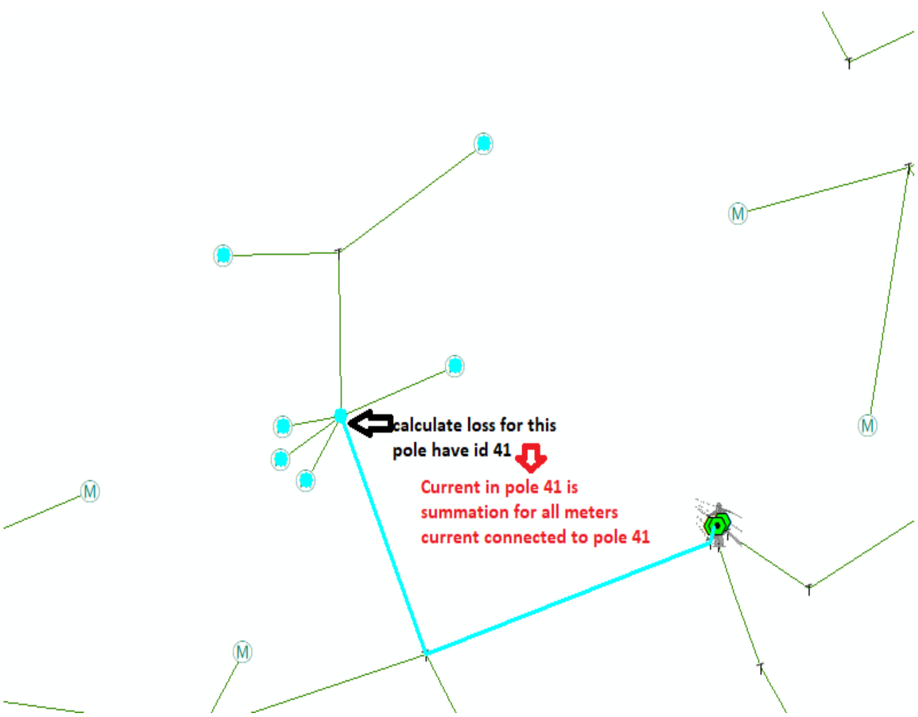


Figure 5. 93: Example of Pole 41 to calculate its loss result

First calculate current for all meters current at pole 41as follow:

First select all meters at phase B by test B attribute value that not equal zero in Meters table:

Current at pole 41 = 0.576267+ 1.828835+ 1.714952+ 1.824031

Current at pole 41= 5.944085 Ampere

Now from equation [4] and [5] we can calculate loss:

R= (0.001636*0.32) + (0.034714*0.32) + (0.02584*1.2)

R= 0.04264Ω

$P_{loss=}$ 5.944085 ^2*0.04264

$P_{loss=}$ 1.5065627 Ampere Ω

The results of Our SDSS web bage gives the same results, which that insure the reliability of our system as shown if figure [6.2].

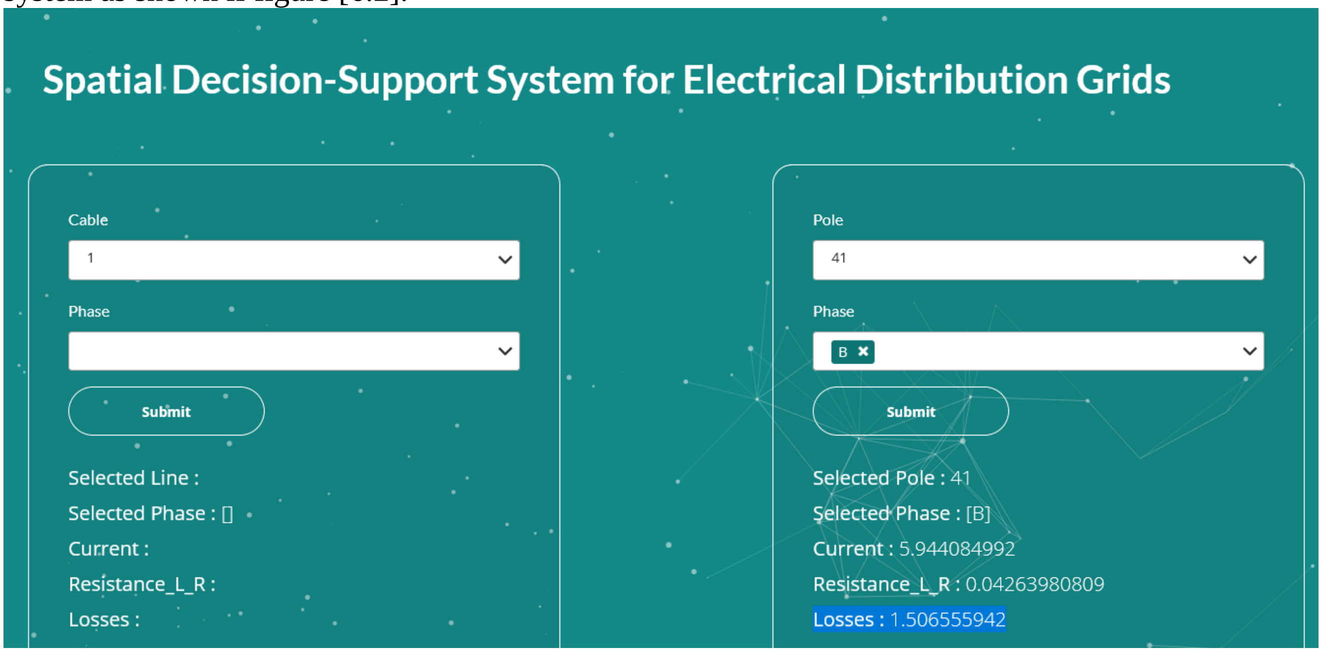


Figure 5. 94: System results for pole 41

Let take other example for test loss calculation, at line 18 (phase C) at other feeder:

First calculate current for all meters current at line 41as follow:

First select all meters at phase C by test C attribute value that not equal zero in Meters table:

Current at line 18 = 5.944085 Ampere

Now from equation [4] and [5] we can calculate loss:

R= (0.001161* 0.32) + (0.010881* 0.32) + (0.015196* 1.91) + (0.016552* 0.32) + (0.0178* 1.91) + (0.023179* 0.32) + (0.028229* 0.32)

R= 0.088624Ω

$P_{loss=}$ 1.464396^2* 0.088624

$P_{loss=}$ 0.190050237 Ampere Ω

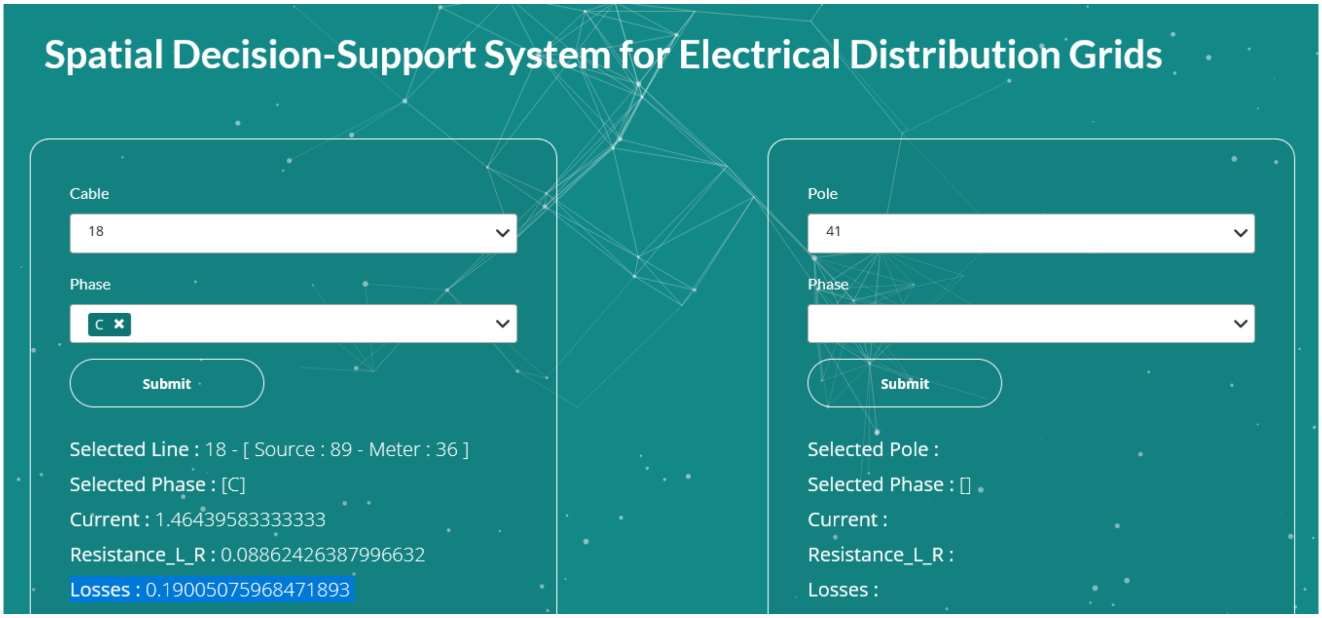


Figure 5. 95: System results for cable 18

As we notice that the results of manual calculations exactly the same as our system results. Let this data be made a geographic and graphical meaning, we need to represent it in the ArcMap, so first we extracted the line table as an Excel file from the oracle database, as it contains additional information which is the loss and electric current for each line and, but the extracted line table had no coordinates, so we do the following steps to get coordination's for this data:

- Add this table to ArcMap
- Select by attribute the lines of phase A, which determined by this query:

  Select Consumer_Meter_A=1

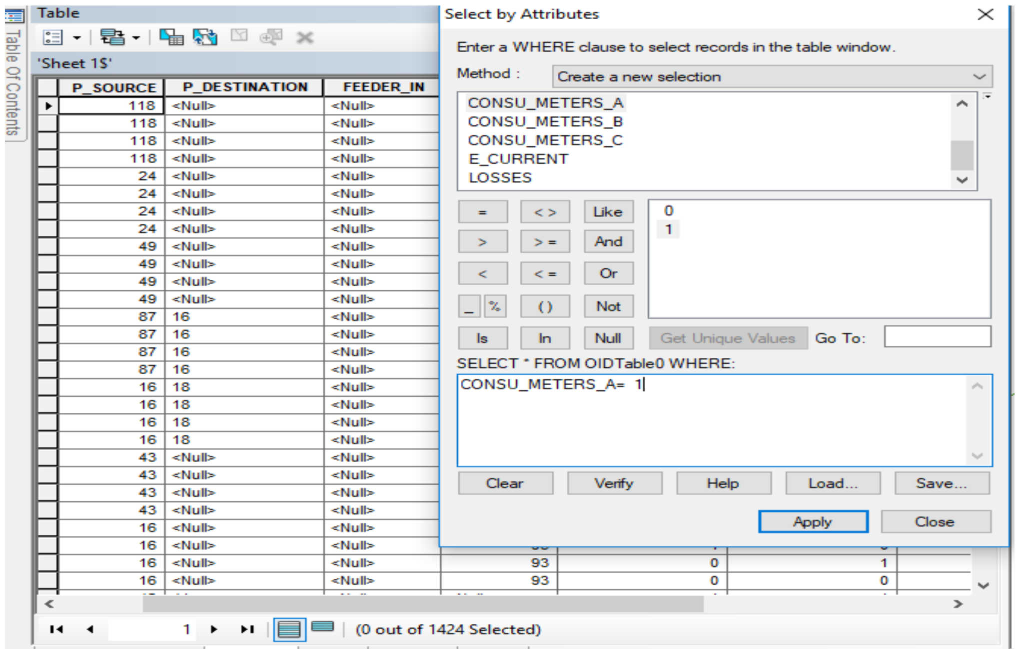


Figure 5. 96: select all lines for phase A

- This query get all lines on phase A, so we export this selected data to new layer.

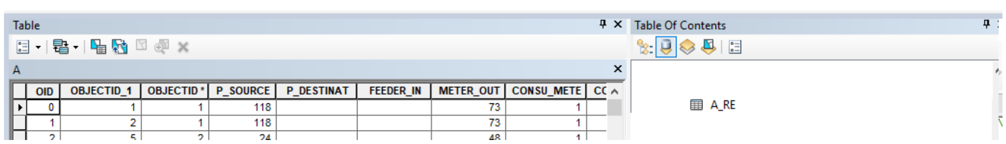


Figure 5. 97: phase A table results

- then join it to the main LV_E_Split Line, by objected id, which is have coordinates for each line, then export this data to new shapefile.

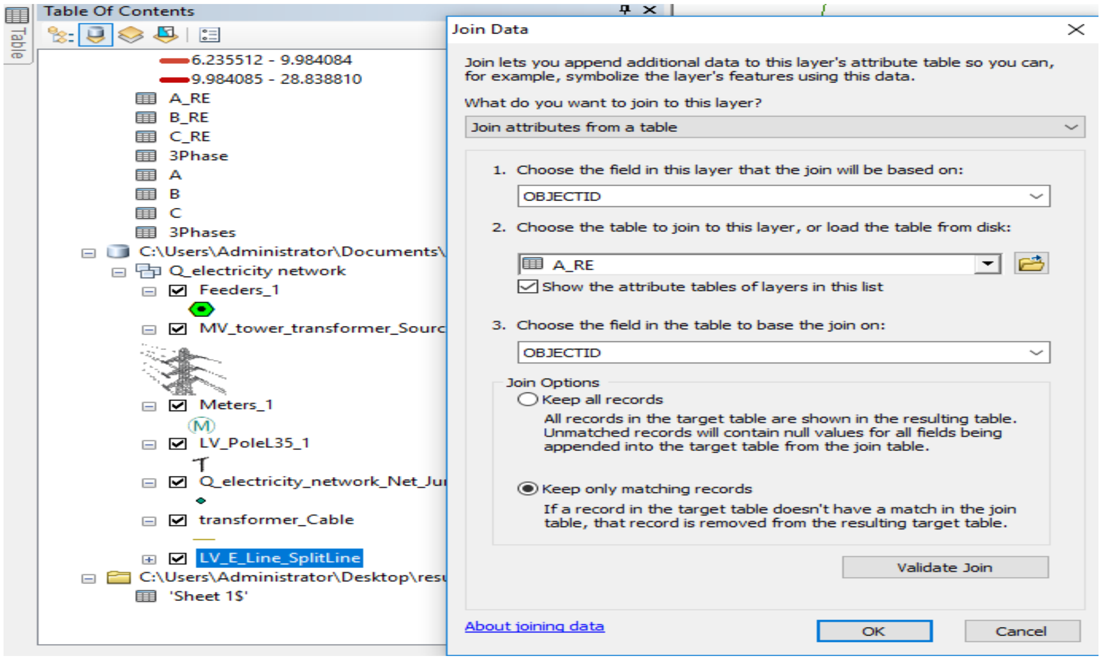


Figure 5. 98: join between A_RE and LV_E_Split Line

- Use the sympology (Quantities_ Graduated Colors) for it, where we can clarify the gradations of loads in phase_A network by representing it colors from lighter to darker.

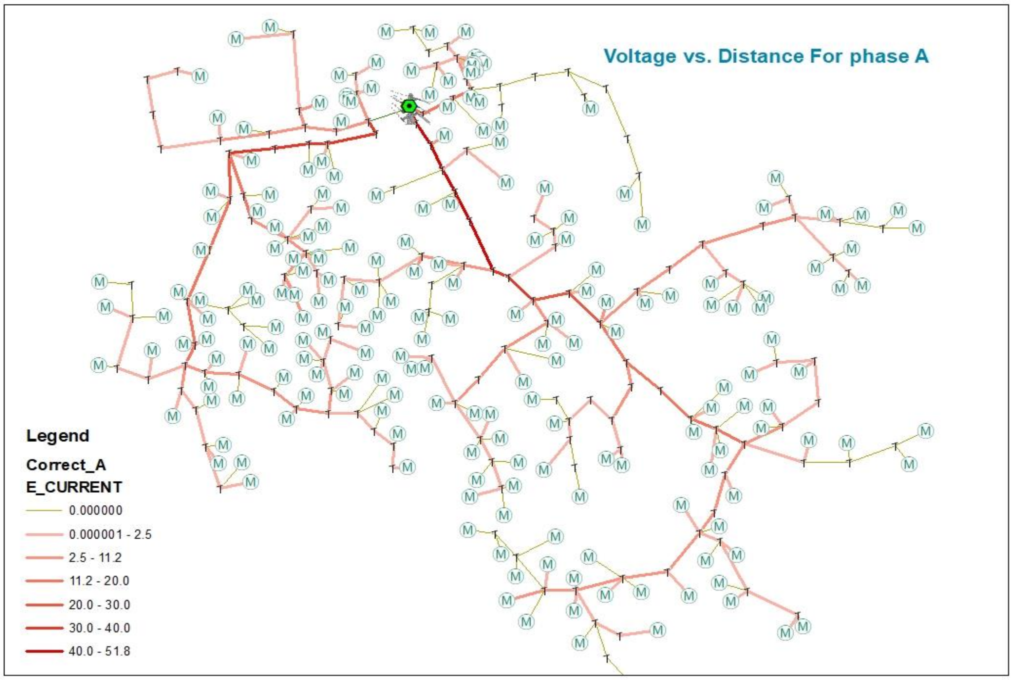


Figure 5. 99: phase (A) network

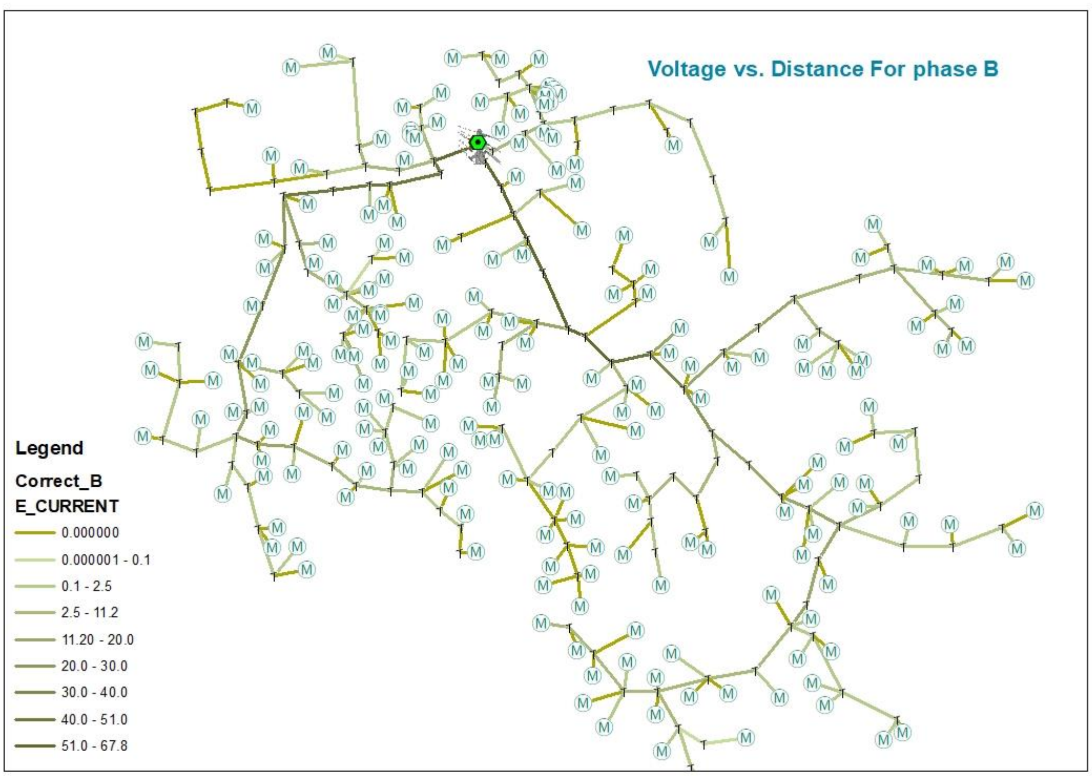


Figure 5. 100: phase (B) network

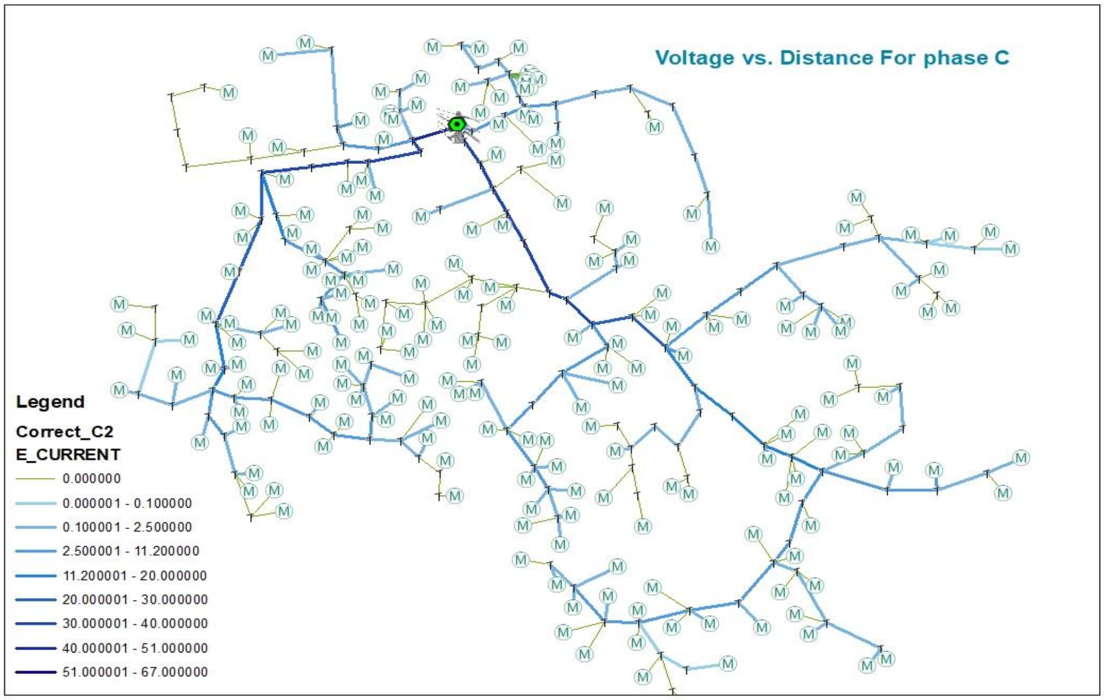
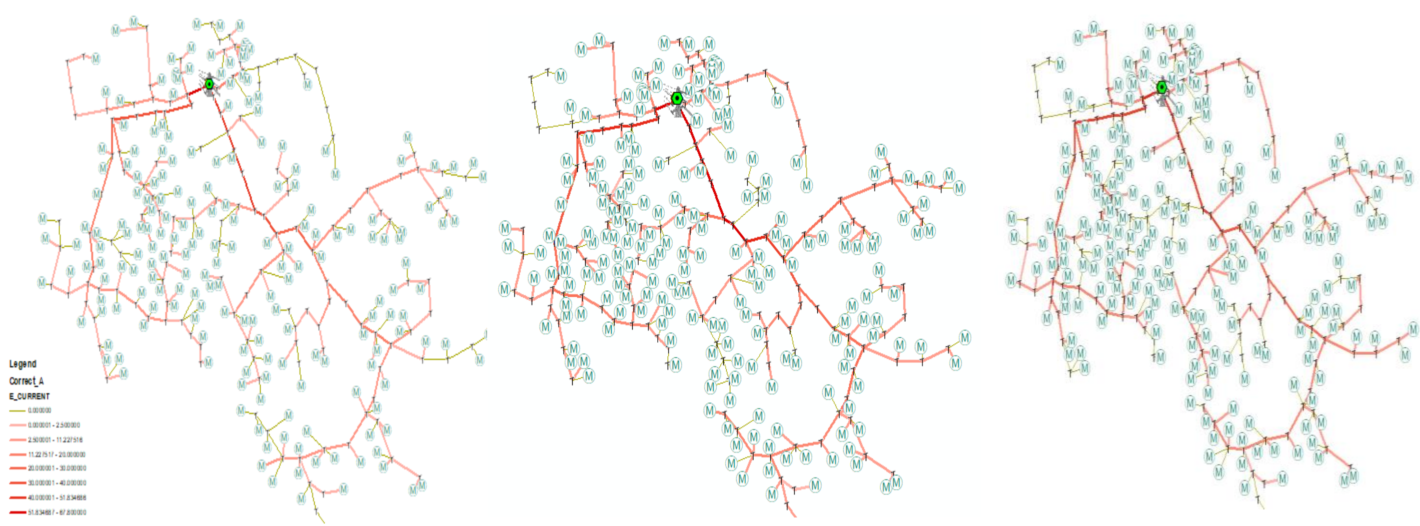


Figure 5. 101: phase (C) network

5.6.1 Comparison and Smart Decisions



(A) **(B)** **(C)**

Figure 5. 102: Comparison between the 3 Phases results

As demonstrated in figure [6.10] results for each phases presented by graduated color using the same classification classes range in order to highlight the deference between 3 phases voltage distribution, that will help the decision maker to manage and design new connections more effectively by distribute the network connections in such way trying to balance between 3 phases distribution for each feeder.

5.6.2 3D Model Results

After 3D model created and designed , it present to give a virtual really image of the system in the study area to help the decision makers to understand, watch the results of the reality to be able to manage it smartly and making right decisions. The results of 3D model for all 3 phases (A, B, C) are shown in figure [6.8].

The results of 3D model for all phase A are shown in figure [6.9]. And figure [6.10] to show the flow of electric current in phase A low voltage network.

The results of 3D model for all phase B are shown in figure [6.11]. And figure [6.12] to show the flow of electric current in phase B network.

The results of 3D model for all phase C are shown in figure [6.13]. And figure [6.14] to show the flow of electric current in phase C network.

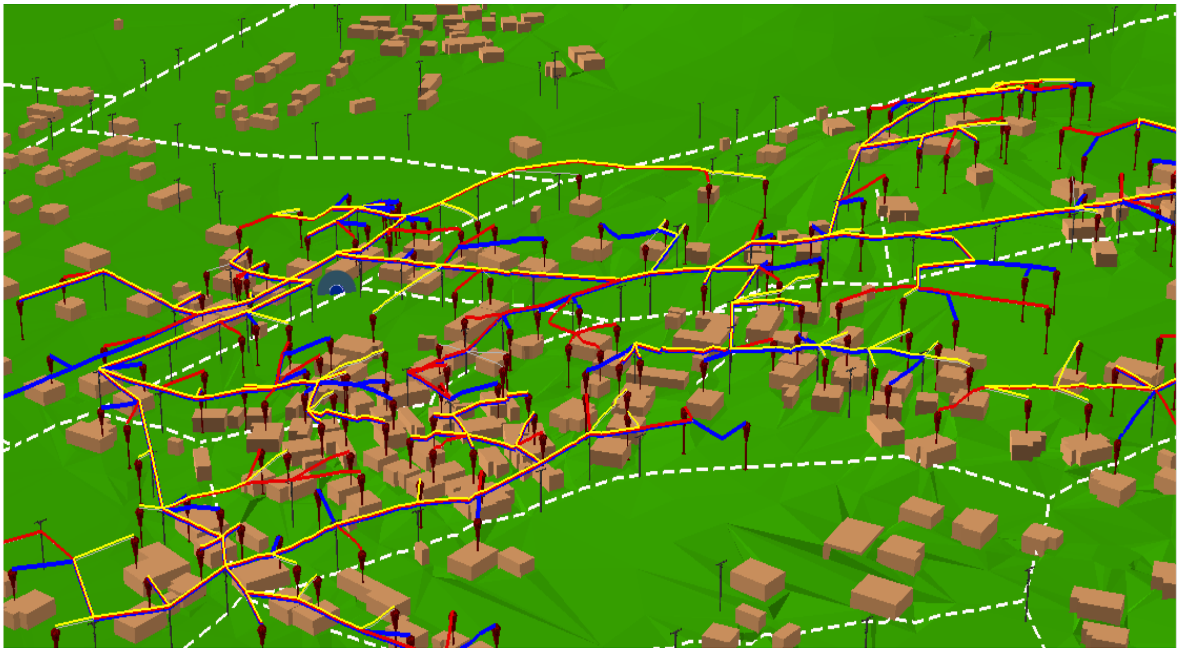


Figure 5. 103: The results of 3D model for all 3 phases (A, B, C)

Figure 5. 104: The results of 3D model for all phase A

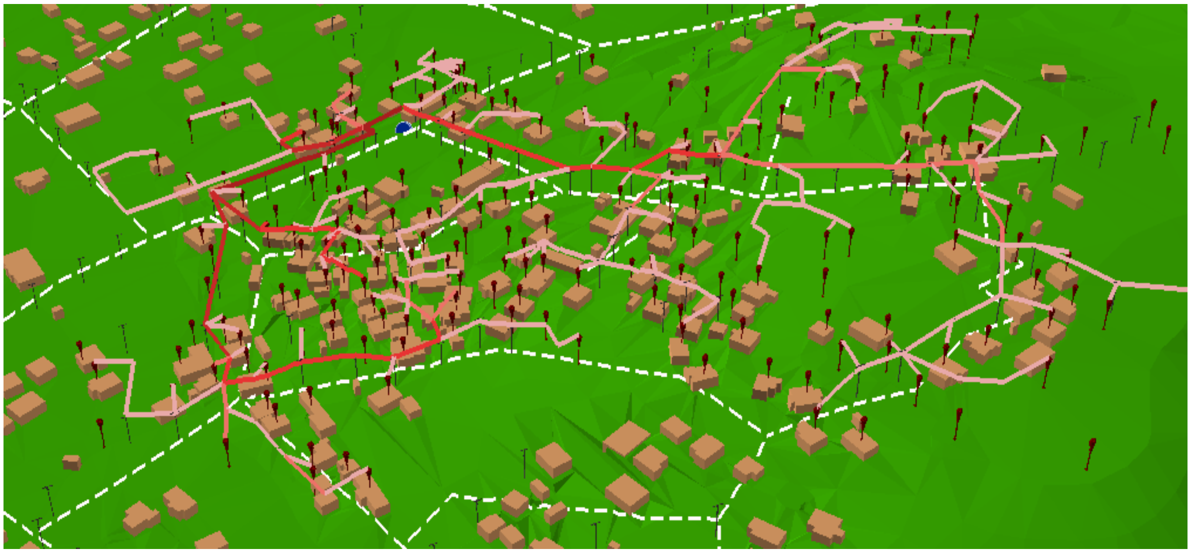


Figure 5. 105: Result of the flow of electric current in phase A low voltage network.

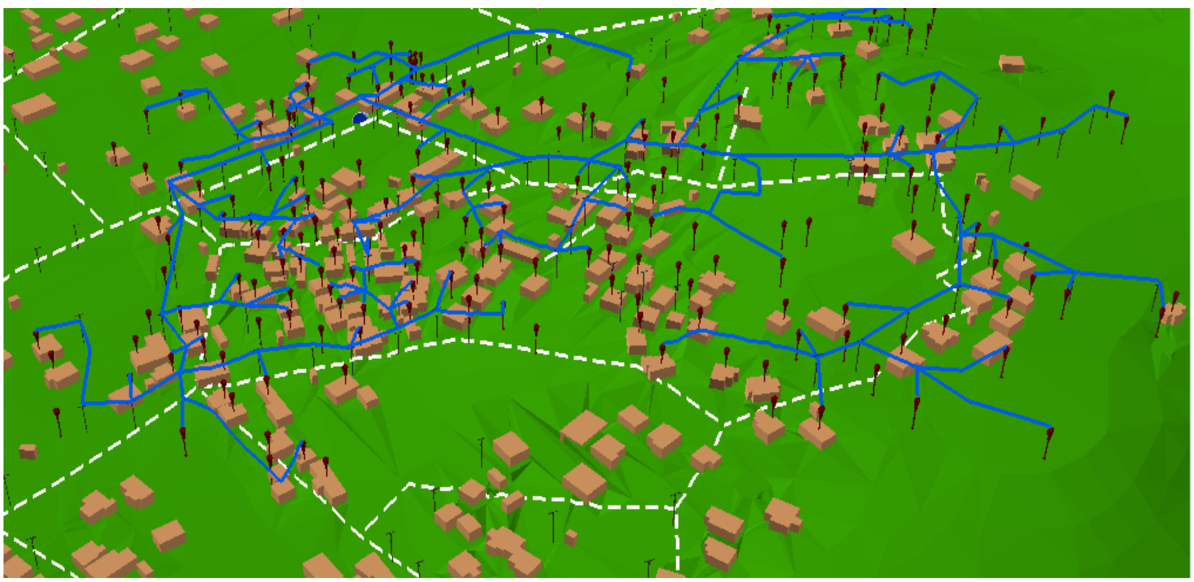


Figure 5. 106: The results of 3D model for all phase B

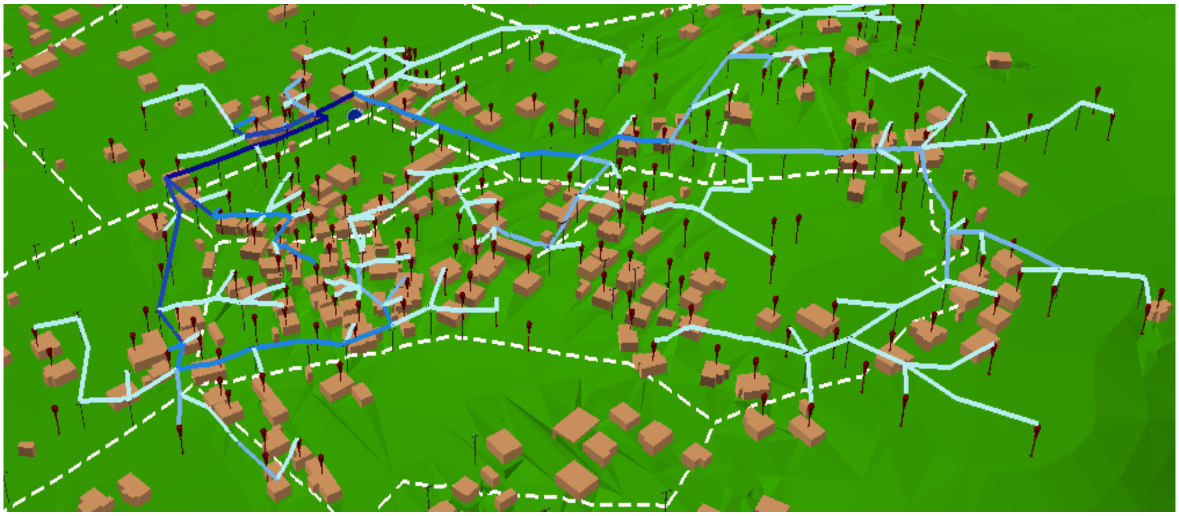


Figure 5. 107: The results of 3D model for all phase B

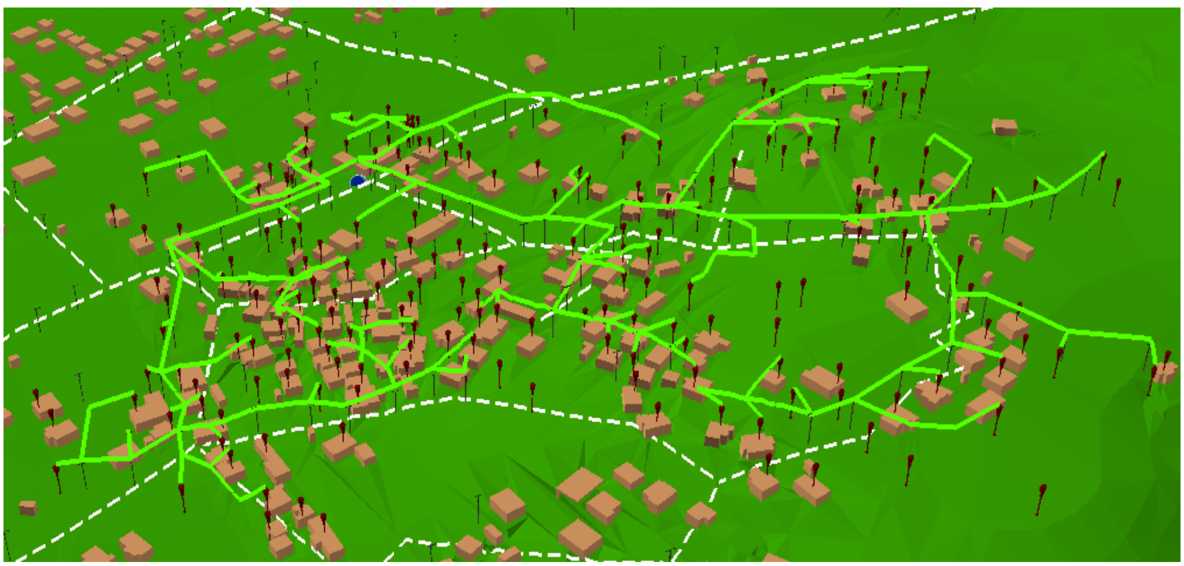


Figure 5. 108: The results of 3D model for all phase C

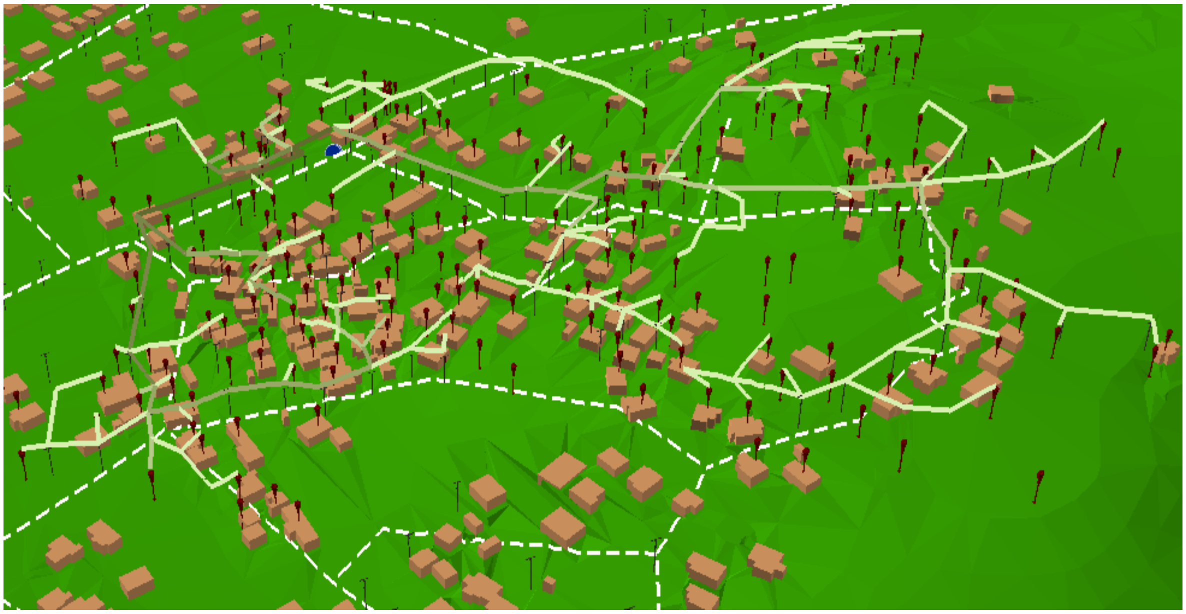


Figure 5. 109: The results of 3D model for all phase.

CONLUTION

This chapter illustrated the system implementation, study area, data collection preparing, and the obstacles we faced to get them, used tools, additionally it presents the building of Geometric network for hall Qabatya electrical grid initially then the low voltage network in particular taking into account the 3 phases networks, then we showed our SDSD system which is developed based on SQL to calculate electric losses depending in calculated electric current data by using the hierarchical tree. Codes and results also presented in this chapter using and java platform. The next section illustrate how we built 3D Model for Qabatya electrical distributed network especially for 3 phase’s networks. Finally all thesis results.

Chapter 6: Discussion and conclusion

The electricity sector in Palestine in general and the city of Qabatya in particular face serious challenges to manage electricity networks and the increased complexity of the network has led to the difficulty of managing the network as a whole. The restrictions imposed by Israel on Palestine prevent the development of electrical network equipment, such as smart meters that read the current and other electrical data, in Our research faced the difficulty of collecting data and the lack of it made us suggest a system that helps in obtaining this missing data to build a spatial SDSS to calculate electrical technical losses using the capabilities of GIS where we worked on integrating computer science with GIS and as we were able to produce a system that helps to manage complex Electricity distribution network and help decision-makers to take the right measures to solve some technical problems such as power loss, power cuts and management of the network.

In this thesis, spatial data was collected, Digitized and prepared for GIS geodatabase for creating geometric network to connect the relevant geometric layers in order to express the complex electric system components.

Medium and low voltage network were considered, transformers and feeders were also taken into account. Cables at 3 phases were digitized and relevant attributes were added just as material and cross section area, length was calculated geometrically counting on the spatial abilities of GIS, and the resistance was calculated mathematically. We have introduced the SDSS is to demonstrate the distribution of electric system as geometric network in GIS.

We applied electric theories and equations to calculate the current and technical losses using backward and forward approach to express the electric flow and its distribution in the network. Our results were exported to attribute table that was joined to the spatial data. This enrichment data helped to present them spatially on the map, presenting, semantic maps using graduated color sympology for the electric current for each cable at any phase to help the decision makers to understand, watch the results of the reality were satisfactory and to be able to manage it smartly and making right decisions.

Future Work

As further steps for the suggested model developed in this thesis's research more data can be included and considered such as medium voltage distribution network layer in order to build a complete combined geometric network that will take into account all the electric system components.

Smart meters can be added and online reading electric current data will be considered and analyzed for SDSS and so we can calculate not only technical loss but also non-technical losses, in addition to that, the data mining assumptions will applied to see the relationships between the data so we can predict electricity problems before It happens like a power outage and power theft.

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Appendix A.

```
// parameters: pole, phase
// build SQL query to calculate the SUM of electric current for all meters
connected to the pole (parameter)
        String ele_curr = "select NVL(sum (m.electric_current_i),0)   sum_ele_curr "
              + "  from meters m where";
// select the phase depending on the user selection
        if (this.phases.contains("A")) {
           ele_curr += "     m.consu_meters_a <> 0 and ";
        }
        if (this.phases.contains("B")) {
           ele_curr += "     m.consu_meters_b <> 0 and ";
        }
        if (this.phases.contains("C")) {
           ele_curr += "     m.consu_meters_c <> 0 and ";
        }
// retrieve all meters connected to the pole using hierarchical query
        ele_curr += "       m.objectid in (    select p.is_meter "
              + "                            from poles p "
              + "                           where p.is_meter is not null "
              + "                       start with p.p_source = '" + this.pole + "' "
              + "                       connect by prior p.p_destination = p.p_source)";
         // Query is ready
       // create a new connection to the database and send the query to be
      //    executed
        conn = new Conn();
        conn.executeQuery(ele_curr);
     // retrieve the result from the query and get the value of electrical current
        if (conn.get().next()) {
           this.sumEleCurr = conn.get().getBigDecimal("sum_ele_curr").round(m);
        }
        conn.reuse();
// build a query to find the summation of the resistance
        String l_r = " select NVL(sum (p.l_r),0)    as sum_l_r "
              + "      from poles p "
          + "start with p.p_destination = '" + this.pole + "' "
     + "connect by prior p.p_source = p.p_destination";
// execute the qu.3
ery then retrieve the result of the resistance
/////////////////////////////////////////////////////
        conn.executeQuery(l_r);
        if (conn.get().next()) {
           this.sumLR = conn.get().getBigDecimal("sum_l_r").round(m);
        }
// calculate the value of losses
        this.loseValue = this.sumEleCurr.pow(2).multiply(sumLR).round(m);
```

```
          conn = new Conn();
           conn.executeQuery(ele_curr);
       // retrieve the result from the query and get the value of electrical current
          if (conn.get().next()) {
              this.sumEleCurr = conn.get().getBigDecimal("sum_ele_curr").round(m);
           }
           conn.reuse();
// build a query to find the summation of the resistance
           String l_r = " select NVL(sum (p.l_r),0)    as sum_l_r "
                  + "      from poles p "
             + "start with p.p_destination = '" + this.pole + "' "
                  + "connect by prior p.p_source = p.p_destination";
// execute the query then retrieve the result of the resistance
           conn.executeQuery(l_r);
           if (conn.get().next()) {
              this.sumLR = conn.get().getBigDecimal("sum_l_r").round(m);
           }
// calculate the value of losses
           this.loseValue = this.sumEleCurr.pow(2).multiply(sumLR).round(m);
// SQL query to find all meters connected to the line the calculate the
summation
// of electrical current
select sum (m.electric_current_i)
from meters m
where
/* if the user select phase A then the condition:  m.consu_meters_a <> 0 */
   m.consu_meters_a <> 0
and m.objectid in (
select p.is_meter
from poles p
where p.is_meter is not null
/* objected = (the line parameter) */
start with p.objectid = 6
  connect by prior p.p_destination = p.p_source
  )

/* SQL query to find the summation of the resistance of all lines using
hierarchical query   */
select sum (p.l_r),
from poles p
/* objected = (the line parameter) */
start with p.objectid = 6
  connect by prior p.p_source = p.p_destination
  // build SQL query to retrieve results from the results table
String ele_curr = "select objectid,p_source,p_destination,feeder_in,meter_out,"
                + "        consu_meters_a,"
                + "        consu_meters_b,"
                + "        consu_meters_c,"
```

```
            + "        e_current,"
            + "        losses"
            + "    from results"
            + "   where ";
// condition depending on the phase parameter
        if (this.phases.contains("A")) {
           ele_curr += "      consu_meters_a = 1 and ";
        } else {
           ele_curr += "      consu_meters_a = 0 and ";
        }
        if (this.phases.contains("B")) {
           ele_curr += "      consu_meters_b =1   and ";
        } else {
           ele_curr += "      consu_meters_b =0  and ";
        }
        if (this.phases.contains("C")) {
           ele_curr += "      consu_meters_c = 1 and ";
        } else {
           ele_curr += "      consu_meters_c  = 0 and ";
        }
// line = parameter
ele_curr += " objectid = " + line;
// execute the query
        conn = new Conn();
        conn.executeQuery(ele_curr);
// retrieve the query results
 if (conn.get().next()) {
           this.losess = conn.get().getDouble("losses");
           this.curr = conn.get().getDouble("e_current");
           this.source = conn.get().getString("p_source");
           this.dest = conn.get().getString("p_destination");
           this.feeder = conn.get().getString("feeder_in");
           this.meter = conn.get().getString("meter_out");           }
```

Appendix B.

Web xml

```xml
<?xml version="1.0" encoding="UTF-8"?>
<web-app version="3.1" xmlns="http://xmlns.jcp.org/xml/ns/javaee"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="http://xmlns.jcp.org/xml/ns/javaee
http://xmlns.jcp.org/xml/ns/javaee/web-app_3_1.xsd">
    <context-param>
        <param-name>javax.faces.PROJECT_STAGE</param-name>
        <param-value>Development</param-value>
    </context-param>
    <context-param>
        <param-name>primefaces.THEME</param-name>
        <param-value>nova-light</param-value>
    </context-param>
    <context-param>
        <param-name>primefaces.FONT_AWESOME</param-name>
        <param-value>true</param-value>
    </context-param>
    <session-config>
        <session-timeout>
            480
        </session-timeout>
    </session-config>
    <mime-mapping>
        <extension>eot</extension>
        <mime-type>application/vnd.ms-fontobject</mime-type>
    </mime-mapping>
    <mime-mapping>
        <extension>otf</extension>
        <mime-type>font/opentype</mime-type>
    </mime-mapping>
```

```xml
    <mime-mapping>
        <extension>ttf</extension>
        <mime-type>application/x-font-ttf</mime-type>
    </mime-mapping>
    <mime-mapping>
        <extension>woff</extension>
        <mime-type>application/x-font-woff</mime-type>
    </mime-mapping>
    <mime-mapping>
        <extension>svg</extension>
        <mime-type>image/svg+xml</mime-type>
    </mime-mapping>
    <mime-mapping>
        <extension>woff2</extension>
        <mime-type>application/x-font-woff2</mime-type>
    </mime-mapping>
    <servlet>
        <servlet-name>Faces Servlet</servlet-name>
        <servlet-class>javax.faces.webapp.FacesServlet</servlet-class>
        <load-on-startup>1</load-on-startup>
    </servlet>
    <servlet-mapping>
        <servlet-name>Faces Servlet</servlet-name>
        <url-pattern>*.jsf</url-pattern>
    </servlet-mapping>
    <welcome-file-list>
        <welcome-file>index2.jsf</welcome-file>
    </welcome-file-list>
</web-app>
```

Index2.xhtml code

```xml
<?xml version='1.0' encoding='UTF-8' ?>
<!DOCTYPE html PUBLIC "-//W3C//DTD XHTML 1.0 Transitional//EN"
```

```
"http://www.w3.org/TR/xhtml1/DTD/xhtml1-transitional.dtd">
<html xmlns="http://www.w3.org/1999/xhtml"
      xmlns:h="http://xmlns.jcp.org/jsf/html"
      xmlns:p="http://primefaces.org/ui"
      xmlns:f="http://xmlns.jcp.org/jsf/core"
      xmlns:c="http://xmlns.jcp.org/jsp/jstl/core">
    <h:head>
        <title>Facelet Title</title>
        <meta charset="utf-8" />
        <meta http-equiv="X-UA-Compatible" content="IE=edge" />
        <meta name="viewport" content="width=device-width, initial-scale=1"
/>        <!-- Site title -->
        <!-- Bootstrap CSS -->
        <link href="style1/bootstrap.min.css" rel="stylesheet" />
        <!-- Icofont CSS -->
        <link href="style1/icofont.css" rel="stylesheet" />
        <!-- Animate CSS -->
        <link href="style1/animate.css" rel="stylesheet" />
        <!-- Main/Custom CSS -->
        <link href="style1/style.css" rel="stylesheet" />
        <style>
            .ui-selectonemenu label.ui-selectonemenu-label, body .ui-
selectcheckboxmenu .ui-selectcheckboxmenu-multiple-container.ui-
inputfield{
                padding-top: 0 !important;            }
            body .ui-selectcheckboxmenu{
                height: 40px !important;            }
            body .ui-selectcheckboxmenu .ui-selectcheckboxmenu-multiple-
container .ui-selectcheckboxmenu-token{
                background: #0e7573; }
                        body .ui-chkbox .ui-chkbox-box.ui-state-active{
                border-color:
                    #0e7573;
```

```
                background-color:
                    #0e7573;  }
                    </style>
    </h:head>
    <h:body>
        <p:growl   life="3000" >
            <p:autoUpdate />
        </p:growl>
        <div class="hero-area">
            <canvas class="constellation" width="1536" height="410"></canvas>
            <div class="container" style="max-width: 1300px !important;">
                <div class="row">
                    <div class="col-lg-12 col-md-12">
                        <h2 style="font-size:40px">Spatial Decision-Support System
for Electrical Distribution Grids</h2>                                    <br/>
                <div class="row">
                    <div class="col-5" style="padding : 40px;border:1px solid
white;border-radius: 20px;background-color: #0000000f">
                        <div class="row">
                            <div class="col-12">
                                <h:form>
                                    <div class="form-group">
                                        <label  >Cable</label>
                                        <p:selectOneMenu styleClass="form-control"
value="#{lineBean.line}" filter="true">
                                            <f:selectItems value="#{lineBean.lines}" var="l"
itemLabel="#{l}" itemValue="#{l}" />
                                        </p:selectOneMenu>
                                    </div>
                                    <div class="form-group">
                                        <label  >Phase</label>
                                        <p:selectCheckboxMenu multiple="true"
value="#{lineBean.phases}" styleClass="form-control" label="Phase"
```

```
required="true" requiredMessage="Phase is required ">
                                <f:selectItem itemLabel="A" itemValue="A" />
                                <f:selectItem itemLabel="B" itemValue="B" />
                                <f:selectItem itemLabel="C" itemValue="C" />
                            </p:selectCheckboxMenu>
                        </div>
                        <p:commandLink value="Submit"
styleClass="borderd-btn" update="pnl1" action="#{lineBean.findLose()}" />
                    </h:form>
                    <br/>
                    <p:outputPanel id="pnl1">
                        <div class="row" style="font-weight: bold">
                            <div class="col-12">
                                <p class="lead">
                                    <label>
                                        <b>
                                            Selected Line  :
                                        </b>
                                        #{lineBean.line}
                                        <c:if test="#{lineBean.line ne null}">
                                            - [<c:if test="#{lineBean.source eq null}">
                                                Feeder :  #{lineBean.feeder}
                                            </c:if>
                                            <c:if test="#{lineBean.source ne null}">
                                                Source :  #{lineBean.source}
                                            </c:if>
                                            -
                                            <c:if test="#{lineBean.dest eq null}">
                                                Meter :  #{lineBean.meter}
                                            </c:if>
                                            <c:if test="#{lineBean.dest ne null}">
                                                Destination :  #{lineBean.dest}
```

```
        </c:if>
        ]
    </c:if>
</label>
<br/>
<label>
    <b>
        Selected Phase  :
    </b>
    #{lineBean.phases.toString()}
</label>
<br/>
<label>
    <b>
        Current  :
    </b>
    #{lineBean.curr}
</label>
<br/>
<label>
    <b>
        Resistance_L_R  :
    </b>
    #{lineBean.r_l}
</label>
<!--   aaaa  -->
<br/>
<label>
    <b>
        Losses  :
    </b>
    #{lineBean.losess}
```

```
                                        </label>
                                    </p>
                                </div>
                            </div>
                        </p:outputPanel>
                    </div>
                </div>
            </div>
            <div class="col-2  ">
            </div>
            <div class="col-5  " style="padding : 40px;border:1px solid
white;border-radius: 20px;background-color: #0000000f">
                <div class="row">
                    <div class="col-12">
                        <h:form>
                            <div class="form-group">
                                <label  >Pole</label>


                                <p:selectOneMenu styleClass="form-control"
value="#{demoBean.pole}" filter="true">
                                    <f:selectItems value="#{demoBean.ploes}"
var="p" itemLabel="#{p}" itemValue="#{p}" />
                                </p:selectOneMenu>
                            </div>
                            <div class="form-group">
                                <label  >Phase</label>
                                <p:selectCheckboxMenu  multiple="true"
value="#{demoBean.phases}" styleClass="form-control" label="Phase"
required="true" requiredMessage="Phase is required ">
                                    <f:selectItem itemLabel="A" itemValue="A" />
                                    <f:selectItem itemLabel="B" itemValue="B" />
                                    <f:selectItem itemLabel="C" itemValue="C" />
                                </p:selectCheckboxMenu>
```

```
                    </div>
                     <p:commandLink value="Submit"
styleClass="borderd-btn" update="pnl2" action="#{demoBean.findLose()}"
/>
                </h:form>
                <br/>
                <p:outputPanel id="pnl2">
                    <div class="row" style="font-weight: bold">
                        <div class="col-12" >
                            <p class="lead">
                                <label>
                                    <b>
                                        Selected Pole  :
                                    </b>
                                    #{demoBean.pole}
                                </label>
                               <br/>
                                <label>
                                    <b>
                                        Selected Phase  :
                                    </b>
                                    #{demoBean.phases.toString()}
                                </label>
                                <br/>
                                <label>
                                    <b>
                                        Current  :
                                    </b>
                                    #{demoBean.sumEleCurr}
                                </label>
                                <br/>
                                <label>
```

```
                                    <b>
                                      Resistance_L_R  :
                                    </b>
                                    #{demoBean.sumLR}
                                  </label>
                                  <br/>
                                  <label>
                                    <b>
                                      Losses  :
                                    </b>
                                    #{demoBean.loseValue}
                                  </label>
                                </p>
                              </div>
                            </div>
                          </p:outputPanel>
                        </div>
                      </div>
                      <script src="style1/popper.min.js"></script>
        <!-- Bootstrap JS -->
        <script src="style1/bootstrap.min.js"></script>
        <!-- Isotope JS -->
        <script src="style1/isotope-3.0.4.min.js"></script>
        <!-- WoW JS -->
        <script src="style1/wow-1.3.0.min.js"></script>
        <!-- stars JS -->
        <script src="style1/stars.js"></script>
        <!-- Main/Custom JS -->
        <script src="style1/main.js"></script>
      </h:body>
    <html/>
```

الملخص

هذه الرسالة تعبر عن نموذج مقترح لنظام دعم القرار المكاني (SDSS) لإظهار توزيع النظام الكهربائي كشبكة هندسية في نظام المعلومات الجغرافية (GIS). تم جمع البيانات المكانية لمدينة قباطية كمنطقة الدراسة المقترحة ، وتم تحويلها رقميا وإعدادها لقاعدة البيانات الجغرافية وتحليلها. تم تطبيق شبكة هندسية بعد جمع وإعداد البيانات الهندسية والسمات المتصلة بالطبقات الهندسية ذات الصلة. من أجل تقديم وتحليل واتخاذ قرارات ذكية ، تم إنشاء الطبقات ذات الصلة للتعبير عن مكونات النظام الكهربائي المعقد. تم الأخذ في الاعتبار شبكة الجهد المتوسط والمنخفض ، كما تم أخذ المحولات والمغذيات في الاعتبار. تم رقمنة الكبلات وأضيفت السمات ذات الصلة تمامًا مثلا المادة والمقطع العرضي للاسلاك ، وتم حساب الطول هندسيًا استنادًا إلى القدرات المكانية لنظام المعلومات الجغرافية ، وتم حساب المقاومة رياضيا. تم النظر في عدادات المستهلك وتم تصدير بياناتهم المحدثة حول استهلاك الكهرباء من نظام البلدية الخاص. تم استخدام النظريات والمعادلات الكهربائية وتطبيقها لحساب معدل استهلاك الطاقة اليومي والساعي ، حيث ساعدت في حساب التيار الكهربائي لكل عداد للمستهلك. تم استخدام أدوات وأساليب تحليل الشبكة الهندسية لفحص وتقديم اتجاه الخلل للتيار الكهربائي.

من أجل حساب الخسائر الفنية لكل كابل في أي مرحلة وفقًا لخصائصه والمقاومة والطول والتيار الكهربائي ، تم تصميم الشبكة الهندسية بما في ذلك جميع النتائج المحسوبة كشجرة هرمية من خلال بناء هيكل البيانات واستخدام قاعدة بيانات أوراكل لتخزين البيانات المصدرة و SQL_quarries لحساب الخسائر الحالية والتقنية باستخدام نهج الوراء والأمام للتعبير عن التدفق الكهربائي وتوزيعه في الشبكة. كما تم تقديم النتائج في موقع خاص مبرمج باستخدام لغة برمجة جافا. تم تصدير النتائج إلى جدول السمات الذي تم ربطه بالبيانات المكانية. ساعدت هذه البيانات الغنية على تقديمها مكانيًا على الخريطة ، حيث قدمت خرائط دلالية باستخدام رموز الألوان المتدرجة للتيار الكهربائي لكل كابل. من أجل مساعدة صانع القرار ، تم فصل الشبكة وتم تقديم كل مرحلة على حدة. تم تقديم نتائج مرضية للشبكة الكهربائية والجهد مقابل الطول ، وتم تسليط الضوء على الفازات لكل كابل

تم إنشاء نموذج ثلاثي الأبعاد وتصميمه وتقديمه لإعطاء صورة فعلية حقًا للنظام في منطقة الدراسة لمساعدة صناع القرار على فهم ومراقبة نتائج الواقع حتى يتمكنوا من إدارته بذكاء واتخاذ القرارات الصحيحة.