Chapter One

Introduction

1.1 Statement of the Problem

The ability to consume and control energy is one of the initial contributions to the development in our life all over the years. The use of Geographic Information System (GIS) in management of electric networks has greatly enhanced the efficiency in energy sector. Problems of planning in distribution system can be solved by using new methods and specific techniques. Complexity of electrical distribution system and necessity of accurate up-to-date information of the network assets is a reasonable intention for introducing new method of information technology. GIS software breakthrough technology which help utilities discover new things about their investments and risks, reduce the cost of manual maintenance of the maps, and allows the simultaneous assessment of technical, financial, and environmental factors [1].

GIS have been proven to be a workable system to connect database information such as billing, material account, distribution analysis and outage reporting in power utility. Geographic Information Systems (GISs) are now being used widely for the mapping and modeling of utility network systems. Utilities use network models to monitor and analyze their distribution systems. Network analysis conclude network tracing which selects a particular path through the network based on user's criteria, network routing which determines the optimal path that has the shortest and the fastest distance and minimum measurements, high cost, time-consuming, low speed, elimination of information, lack of information and efficient tools.

1.2 Research Objectives

The objective of this research work is to model and manage the environment of the Electricity Network inside the College of Engineering at Sudan University of Science and Technology in terms of:

1. Build a Geometric Network for the Electricity Network in College of Engineeringat Sudan University of Science and Technology.
2. Control of the load distribution**.**
3. Performance analysis.

1.3 Related Topics

There are many researches conducted in domain of management of electricity network to sign out the suitable locations of supply, etc…

Salawudeen and Rashidat [2], conduct a research project is to locate and map all the facilities of Power Holding Company of Nigeria (PHCN). This mapping involves the collection of both the geometric and attributes data of those entities identified. This was done in collaboration with the staff at the distribution department of PHCN. The GIS technology deployed involves the use of both computer based wares. Both geometric data and attribute data collected was entered into the system via Ms Excel and later exported into Arc view GIS 3.2a. The database was created using Arc view 3.2a. Series of spatial search /query operation was carried out to provide answer to pending questions that will lead to effective management of the facilities. The end products are customized maps, tables, softcopy of the map and project report.

Khair [3], said in research project, electricity is considered as an essential need for our daily life. The power distribution companies manage the power distribution system safely and efficiently. Efficient functioning of distribution Company is important to sustain the development of power sector and economy. Hence there was a need for some latest and modern systems to be utilized for improving the reliability and efficiency of power sectors. GIS came into existence as a powerful and effective tool for management of transmission and distribution system. Use ArcGIS system to sign out the suitable locations that are to be fed with power supply, development of accurate database, monitoring of supply and its control load management.

1.4 Thesis Layout

The present research work is documented in five chapters, Chapter One introduces the research problem and objectives, the Electricity Geometric Network concepts have been discussed in Chapter Two, Chapter Three highlights the basic concepts of the Geometric Network Principles and Application, while Chapter Four describes the methodology of research work. Resulting, Analysis and Conclusion have been discussed and summarized in Chapter Five.

Chapter Two
Electricity Geometric Network

2.1 Electrical Grid

The term grid usually refers to a network, and should not be taken to imply a particular physical layout or a breadth. Grid may also be used to refer to an entire continent's electrical network, a regional transmission network or may be used to describe a sub network such as a local utility's transmission grid or distribution grid. Since its inception in the industrial age, the electrical grid has evolved from an insular system that serviced a particular geographic area to a wider, expansive network that incorporated multiple areas. At one point, all energy was produced near the device or service requiring that energy. In the early 19th century, electricity was a novel invention that competed with steam, hydraulics, direct heating and cooling, light, and most notably gas. During this period, gas production and delivery had become the first centralized element in the modern energy industry. It was first produced on customer's premises but later evolved into large gasifies that enjoyed economies of scale. Virtually every city in the U.S. and Europe had town gas piped through their municipalities as it was a dominant form of household energy use. By the mid-19th century, electric arc lighting soon became advantageous compared to volatile gas lamps since gas lamps produced poor light, tremendous wasted heat which made rooms hot and smoky and noxious elements in the form of hydrogen and carbon monoxide. An electrical grid is an interconnected network for delivering electricity from suppliers to consumers. It consists of generating stations that produce electrical power, high-voltage transmission lines that carry power from distant sources to demand centers, and distribution lines that connect individual customers, as shown in Figure 2.1.

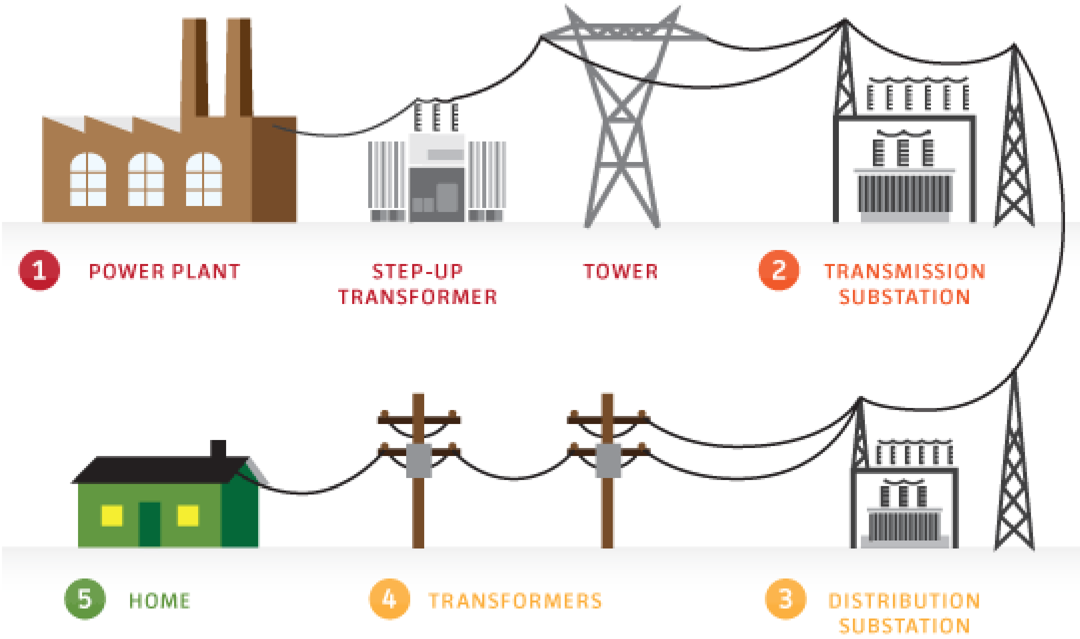

Figure 2.1: Parts and Steps of Electrical Grid

Power stations may be located near a fuel source, at a dam site, or to take advantage of renewable energy sources, and are often located away from heavily populated areas. They are usually quite large to take advantage of the economies of scale. The electric power which is generated is stepped up to a higher voltage at which it connects to the electric power transmission network. The bulk power transmission network will move the power long distances, sometimes across international boundaries, until it reaches its wholesale customer (usually the company that owns the local Electric Power Distribution Network). On arrival at a substation, the power will be stepped down from a transmission level voltage to a distribution level voltage. As it exits the substation, it enters the distribution wiring. Finally, upon arrival at the service location, the power is stepped down again from the distribution voltage to the required service voltage(s) [4].

2.2Geography of Transmission Networks

Transmission networks are more complex with redundant pathways. For example. A wide area synchronous grid or "interconnection" is a group of distribution areas all operating with Alternating Current (AC) frequencies synchronized (so that peaks occur at the same time). This allows transmission of AC power throughout the area, connecting a large number of electricity generators and consumers and potentially enabling more efficient electricity markets and redundant generation. In a synchronous grid all the generators run not only at the same frequency but also at the same phase, each generator maintained by a local governor that regulates the driving torque by controlling the steam supply to the turbine driving it. Generation and consumption must be balanced across the entire grid, because energy is consumed almost instantaneously as it is produced. Energy is stored in the immediate short term by the rotational kinetic energy of the generators. A large failure in one part of the grid - unless quickly compensated for can cause current to re-route itself to flow from the remaining generators to consumers over transmission lines of insufficient capacity, causing further failures. One downside to a widely connected grid is thus the possibility of cascading failure and widespread power outage. A central authority is usually designated to facilitate communication and develop protocols to maintain a stable grid. High-voltage direct current lines or variable frequency transformers can be used to connect two alternating current interconnection networks which are not synchronized with each other. This provides the benefit of interconnection without the need to synchronize an even wider area.

2.3 Structure of Distribution Grids

The structure, or "topology" of a grid can vary depending on the constraints of budget, requirements for system reliability, and the load and generation characteristics. The physical layout is often forced by what land is available and its geology. Distribution networks are divided into two types, radial or network. The cheapest and simplest topology for a distribution or transmission grid is a radial structure. This is a tree shape where power from a large supply radiates out into progressively lower voltage lines until the destination homes and businesses are reached.

Most transmission grids offer the reliability that more complex mesh networks provide. The expense of mesh topologies restricts their application to transmission and medium voltage distribution grids. Redundancy allows line failures to occur and power is simply rerouted while workmen repair the damaged and deactivated line. In cities and towns of North America, the grid tends to follow the classic radially fed design. A substation receives its power from the transmission network, Figure 2.2.

Figure 2.2: Transmission Station

The power is stepped down with a transformer and sent to a bus from which feeders fan out in all directions across the countryside. These feeders carry three-phase power, and tend to follow the major streets near the substation. As the distance from the substation grows, the fan out continues as smaller laterals spread out to cover areas missed by the feeders. This tree-like structure grows outward from the substation, but for reliability reasons, usually contains at least one unused backup connection to a nearby substation. This connection can be enabled in case of an emergency, so that a portion of a substation's service territory can be alternatively fed by another substation [4].

2.4 Interconnected Grids

Electric utilities across regions are many times interconnected for improved economy and reliability. Interconnections allow for economies of scale, allowing energy to be purchased from large, efficient sources. Utilities can draw power from generator reserves from a different region in order to ensure continuing, reliable power and diversify their loads. Interconnection also allows regions to have access to cheap bulk energy by receiving power from different sources. For example, one region may be producing cheap hydro power during high water seasons, but in low water seasons, another area may be producing cheaper power through wind, allowing both regions to access cheaper energy sources from one another during different times of the year. Neighboring utilities also help others to maintain the overall system frequency and also help manage tie transfers between utility regions.

2.5 Aging Infrastructure of Electrical Grids

Despite the novel institutional arrangements and network designs of the electrical grid, its power delivery infrastructures suffer aging across the developed world. Four contributing factors to the current state of the electric grid and its consequences are:

1. Aging power equipment – older equipment has higher failure rates, leading to customer interruption rates affecting the economy and society; also, older assets and facilities lead to higher inspection maintenance costs and further repair/restoration costs.

2. Obsolete system layout – older areas require serious additional substation sites and rights-of-way that cannot be obtained in current area and are forced to use existing, insufficient facilities.
3. Outdated engineering – traditional tools for power delivery planning and engineering are ineffective in addressing current problems of aged equipment, obsolete system layouts, and modern deregulated loading levels.
4. Old cultural value – planning, engineering, operating of system using concepts and procedures that worked in vertically integrated industry exacerbate the problem under a deregulated industry.

2.6 Modern Trends of Electrical Grids

As the 21st century progresses, the electric utility industry seeks to take advantage of novel approaches to meet growing energy demand. Utilities are under pressure to evolve their classic topologies to accommodate distributed generation. As generation becomes more common from rooftop solar and wind generators, the differences between distribution and transmission grids will continue to blur. Also, demand response is a grid management technique where retail or wholesale customers are requested either electronically or manually to reduce their load. Currently, transmission grid operators use demand response to request load reduction from major energy users such as industrial plants. With everything interconnected, and open competition occurring in a free market economy, it starts to make sense to allow and even encourage Distributed Generation (DG). Smaller generators, usually not owned by the utility, can be brought on-line to help supply the need for power. The smaller generation facility might be a home-owner with excess power from their solar panel or wind turbine. It might be a small office with a diesel generator. These resources can be brought on-line either at the utility's behest or by owner of the generation in an effort to sell electricity. Many small generators are allowed to sell electricity back to the grid for the same price they would pay to buy it. Furthermore, numerous efforts are underway to develop a "smart grid". In the U.S., the Energy Policy Act of 2005 and Title XIII of the Energy Independence and Security Act of 2007 are providing funding to encourage smart grid development. The hope is to enable utilities to better predict their needs, and in some cases involve consumers in some form of time-of-use based tariff. Funds have also been allocated to develop more robust energy control technologies. Various planned and proposed systems to dramatically increase transmission capacity are known as super, or mega grids.

2.7 Future Trends of Electrical Grids

As deregulation continues further, utilities are driven to sell their assets as the energy market follows in line with the gas market in use of the futures and spot markets and other financial arrangements. Even globalization with foreign purchases are taking place. One such purchase was the when UK'sNational Grid, the largest private electric utility in the world, bought New England's electric system for $3.2 billion. Also, Scottish Power purchased Pacific Energy for $12.8 billion. Domestically, local electric and gas firms have merged operations as they saw the advantages of joint affiliation, especially with the reduced cost of joint-metering. Technological advances will take place in the competitive wholesale electric markets, such examples already being utilized include fuel cells used in space flight; aero derivative gas turbines used in jet aircraft; solar engineering and photovoltaic systems; off-shore wind farms; and the communication advances spawned by the digital world, particularly with micro processing which aids in monitoring and dispatching. Electricity is expected to see growing demand in the future. The Information Revolution is highly reliant on electric power. Other growth areas include emerging new electricity-exclusive technologies, developments in space conditioning, industrial processes, and transportation (for example hybrid vehicles, locomotives).

2.8 Emerging Smart Grids

As mentioned above, the electrical grid is expected to evolve to a new grid paradigm-smart grid, an enhancement of the 20th century electrical grid. The traditional electrical grids are generally used to carry power from a few central generators to a large number of users or customers. In contrast, the new emerging smart grid uses two-way flows of electricity and information to create an automated and distributed advanced energy delivery network. Many research projects have been conducted to explore the concept of Smart Grid. According to a newest survey on smart grid, the research is mainly focused on three systems in smart grid- the infrastructure system, the management system, and the protection system.

The infrastructure system is the energy, information, and communication infrastructure underlying of the smart grid that supports: advanced electricity generation, delivery, and consumption; advanced information metering, monitoring, and management; and advanced communication technologies. In the transition from the conventional power grid to smart grid, we will replace a physical infrastructure with a digital one. The needs and changes present the power industry with one of the biggest challenges it has ever faced. A smart grid would allow the power industry to observe and control parts of the system at higher resolution in time and space. It would allow for customers to obtain cheaper, greener, less intrusive, more reliable and higher quality power from the grid. The legacy grid did not allow for real time information to be relayed from the grid, so one of the main purposes of the smart grid would be to allow real time information to be received and sent from and to various parts of the grid to make operation as efficient and seamless as possible. It would allow us to manage logistics of the grid and view consequences that arise from its operation on a time scale with high resolution; from high-frequency switching devices on a microsecond scale, to wind and solar output variations on a minute scale, to the future effects of the carbon emissions generated by power production on a decade scale. The management system is the subsystem in smart grid that provides advanced management and control services. Most of the existing works aim to improve energy efficiency, demand profile, utility, cost, and emission, based on the infrastructure by using optimization, machine learning, and game theory. Within the advanced infrastructure framework of smart grid, more and more new management services and applications are expected to emerge and eventually revolutionize consumers' daily lives. The protection system is the subsystem in smart grid that provides advanced grid reliability analysis, failure protection, and security and privacy protection services. We must note that the advanced infrastructure used in smart grid on one hand empowers us to realize more powerful mechanisms to defend against attacks and handle failures, but on the other hand, opens up much new vulnerability. For example, National Institute of Standards and Technology pointed out that the major benefit provided by smart grid, the ability to get richer data to and from customer smart meters and other electric devices, is also its Achilles' heel from a privacy viewpoint. The obvious privacy concern is that the energy use information stored at the meter acts as an information rich side channel. This information could be mined and retrieved by interested parties to reveal personal information such as individual's habits, behaviors, activities, and even beliefs [4].

2.9 Energy in Sudan

Sudan's electrical power sector has been subject to poor infrastructure and experiences frequent power outages. At present the country's electricity generating capacity consists of about 760 megawatts of thermal power, about 320 megawatts of hydropower capacity, and total electricity generation is 3.2 Billion Kilowatt Hours (Bow). About 70% of the electricity is consumed in the Khartoum area. Rural areas are without access to electricity, except for some large, export-oriented agricultural schemes. Electrical Power is transmitted through two interconnected electrical grids, the Blue Nile Grid and the Western grid, which encompasses a small portion of the country. Regions in Sudan that are not covered by the grid rely on small diesel-fired generators for power. Only 30 percent of Sudan’s population currently has access to electricity, the government hopes to increase that figure to 90 percent in the near future.

Civil war in the country has curtailed foreign investment in the Sudanese power sector, but it is expected to increase with the cessation of the civil conflict. In June 2004 the United Arab Emirates (UAE) pledged to invest in the Sudanese power sector following the signing of a peace accord. In January 2006, the Export/Import Bank of India extended $350 million of credit to the country for the construction of a 500-MW power plant. Sudan’s power utility is the state-owned National Electricity Corporation of Sudan (NEC). Two electric power stations have been inaugurated in June 2004 and they are estimated to have a combined capacity of 330 MW. Two facilities that would participate in the supply of power. The El-Jaili Power project is a power plant that has been constructed by the National NEC in the vicinity of Khartoum. El-Jaili combined cycle power station also known as Plant 1. The Dit Kilo X power station is powered by diesel and has a working capacity of a 257 MW. The project consisted of 7 diesel units that were interconnected at the existing Kilo X substation where bays for injection of 110 KV have been made available. It was Sudan's first Independent Power Production (IPP) project that was completed in 2004. There also exist the 300-MW Kajbar hydroelectric facilities in northern Sudan. The government has been developing the country’s hydropower potential by installing 30 megawatts of power at the Jebel Aulia irrigation project, and it has planned to add 50 megawatts to the capacity of the Sennar dam. The government also has significant expansion plans in the thermal power sector. The increased power that is generated will at the very least be used for export. A transmission link between Ethiopia and Sudan has been in place since 1996, a development initiative known as the Nile Basin Initiative has identified building an

Ethiopia-Sudan interconnection as a fast-track project of its Eastern Nile Subsidiary Action Program. The Merowe Dam project, Figure 2.3, is a multipurpose scheme for hydropower generation. It is the largest project to be undertaken in the electrical power sector.

Figure 2.3: Merowe Dam

The project was previously called Hamadab Project but was later renamed the Merowe Project. Its basic function is to generate hydropower with an installed capacity of 1,250 megawatts [5].

Chapter Three

Geometric Network Principles and Application

3.1 Introduction

A geographic information system is an integrated software package specifically designed for use with geographic data that performs a comprehensive range of data handling tasks. These tasks include data input, storage, retrieval and output, in addition to a wide variety of descriptive and analytical processes. From the definition, it becomes clear that GIS handles geographic data, which include both spatial and attribute data that describe geographic features. Second, the basic functions of GIS include data input, storage, processing, and output. The basic concept of GIS is one of location and spatial distribution and relationship. The backbone analytical function of GIS is overlay of spatially referenced data layers, which allows delineating their spatial relationships [6].

3.2 Geometric Networks

A geometric network has a corresponding logical network. The logical network is the physical representation of the network connectivity, Can be visualized as a set of tables without geometry – associated with features in the network [7].A geometric network is a connectivity relationship between collections of feature classes in a feature dataset. Each feature has a role in the geometric network of either an edge or a junction. Multiple feature classes may have the same role in a single geometric network [8].

3.2.1 Building Geometric Network

The basic methodology for building a geometric network is to determine which feature classes will participate in the network and what role each will play. Optionally, a series of network weights can be specified, as can other more advanced parameters. Two methods are available for building a network: building a new, empty geometric network and building a geometric network from existing simple features.

3.2.1.1 Buildinga New, Empty Network

Geometric Networks are built inside feature datasets. Once a geometric network has been built, you must add feature classes to the feature dataset for that geometric network and assign them roles in the network. Arc Catalog lets you build a new geometric network from nothing, then design and build up the network from scratch. You can then use editing tools in Arc Map, custom Visual Basic (VB), Visual Basic for Applications (VBA), or C++ code to add features to the geometric network. New feature classes can be added to a geometric network at any time.

3.2.1.2 Building a Geometric Network from Existing Data

You may already have data from which you want to build a geometric network in your geodatabase. Arc Catalog and Arc Toolbox contain tools to build a geometric network from that data.

3.2.2 Edges and Junctions

Edges are network features similar to simple line features, Line Feature Class: water mains, electrical transmission lines, gas pipelines, telephone lines, etc... There are two types of edges:

1. Simple Edges, a simple edge in a geometric network has a 1–1 relationship with edge elements in the logical network.

2. Complex Edges, a Complex edge has a 1–M relationship with edge elements in the logical network, so one complex edge in the geometric network can represent multiple edges in the logical network.

If you snap a junction or edge along a simple edge, then the edge being snapped to is split both in the logical network and in the geometric network, giving you two edge features. If you snap a junction or an edge along a complex edge, then that edge is split in the logical network but remains a single feature in the geometric network. It will remain a single feature; however, a new vertex is built at the point where the new junction or edge connects to it [8].

Junctions - facilitates the transfer of flow between edges, similar toPoint Feature Class: fuses, switches, service taps, valves, etc…Topologically connected to each other, edges must connect to other edges at junctions. There are two Types of Junctions:

1. User defined junctions - built based on point feature classes, correspond to a single junction element in the logical network.
2. Orphan junctions - will be inserted at the endpoint of any edge at which a junction does not already exist, maintains network integrity [7].

3.2.3 Flow Direction in a Geometric Network

In utility network applications, knowing the direction of flow along network edges can be essential. Establishing the flow direction in a geometric network determines the direction in which commodities flow along each edge. The flow direction in a network is determined by:

1. The connectivity of the network.
2. The locations of sources and sinks in the network.

3. The enabled or disabled state of features.

Sources and sinks drive flow through a utility network. Sources are junction features that push flow away from themselves through the edges of the network. For example, in a water distribution network, pump stations can be modeled as sources since they drive the water through the pipes away from the pump stations. Sinks are junction features that pull flow toward themselves from the edges in the network. For example, in a river network, the mouth of the river can be modeled as a sink since gravity drives all water towards it. Flow moves away from sources or towards sinks. Because flow direction can be established with either sources or sinks, it usually suffices to specify only sources or only sinks in a network (otherwise your network may have edges with indeterminate flow). It is important to remember that disabled features are accounted for when setting flow direction. Disabling a feature makes it act as if flow cannot pass through it. Thus, disabling a feature means that the flow direction cannot be set for the disabled features or for those features that are connected to the sources or sinks exclusively through the disabled feature.

3.2.3.1 Three Categories of Flow Direction

After you set the flow direction for your network, an edge has one of three categories of flow direction:

1. Determinate flow direction, if the flow direction of an edge can be uniquely determined from the connectivity of the network, the locations of sources and sinks, and the enabled or disabled states of features, the feature is said to have determinate flow. Determinate flow for an edge is specified as either with or against the direction in which the feature was digitized.

2. Indeterminate flow direction, indeterminate flow in a network occurs when the flow direction cannot be uniquely determined from the topology of the network, the locations of sources and sinks, or the enabled or disabled states of the features. Indeterminate flow commonly occurs for edges that form part of a loop, or closed circuit. It can also occur for an edge whose flow is determined by multiple sources and sinks, where one source or sink is driving the flow in one direction through the edge, but another source or sink is driving it in the opposite direction.
3. Specifying flow direction, all geometric networks that have flow have sources and sinks. In some cases, you may not know the locations of the sources and sinks, but you may know the flow direction. If this is the case, you must choose the junctions in your network to act as sources and sinks that produce the correct flow direction [8].

3.2.4 Managing a Geometric Network

More complicated than managing a single entity, such as a table, shape file, or feature class, a geometric network is an association among several feature classes and is represented by several tables in the database [7]. Some of the standard operations on the geometric network work the same way as other items in Arc Catalog. A geometric network can be copied or deleted. Copying a geometric network persists the network connectivity and feature classes. Deleting a geometric network also deletes the network schema and causes the network feature classes to revert to simple feature classes. Geometric networks can be copied in two ways: by copying the feature dataset containing the geometric network or by copying the geometric network itself. If the geometric network is copied, the target feature dataset must have the same spatial reference and extent as the source feature dataset. Geometric networks can be deleted by deleting the containing feature dataset, which will remove the geometric network and any other object stored in the feature dataset, or by deleting the geometric network itself, which will leave the feature dataset and its containing objects intact [8].

3.3 GIS and Network Analysis

Both geographic information systems and network analysis are burgeoning fields, characterized by rapid methodological and scientific advances in recent years. A geographic information system is a digital computer application designed for the capture, storage, manipulation, analysis and display of geographic information. Geographic location is the element that distinguishes geographic information from all other types of information. Without Location, data are termed to be non-spatial and would have little value within a GIS. Location is, thus, the basis for many benefits of GIS: the ability to map, the ability to measure distances and the ability to tie different kinds of information together because they refer to the same place [9].

3.4 The Role of GIS in Distribution Networks

Database plays a central role in the operation of planning, where analysis programs form a part of the system supported by a database management system which stores, retrieves, and modifies various data on the distribution systems. The thing that distinguishes an electrical utility information system from information system - such as those used in banking, stock control, or payroll systems - is needed to record geographical information in the database. Electrical network study need two types of geographical information: details on the location of facilities, and information on the spatial interrelations between them. The integration of geographically referenced database, analytical tools and in-house developed software tools will allow the system to be designed more economically and to be operated much closer to its limits resulting in more efficient, low-cost power distribution systems. Additional benefits such as improved material management, inventory control, preventive maintenance and system performance can be accomplished in a systematic and cost-effective manner. Before graphical workstations were developed, many electric utilities have built technical information systems based on relational database management systems. Technical information system is designed to cover the requirements of power supply utilities considering network expansion and operation planning, maintenance management and system documentation. Establishing links between these information systems and geographical information system is only in defining relationship between objects in the two systems [10].

Chapter Four
Methodology

4.1 Study Area

The faculty of Engineering at Sudan University of Science and Technology was selected as a study area.The area lies between Street No 61 and ElmitdadStreet in north – south direction, and between Elsahfa East Street and Elsahfa West Street in east – west direction (Figure 4.1). It is approximately about0.37 Km². It is includes seven departments, labs, offices, halls, vegetation, workshops and underground networks.

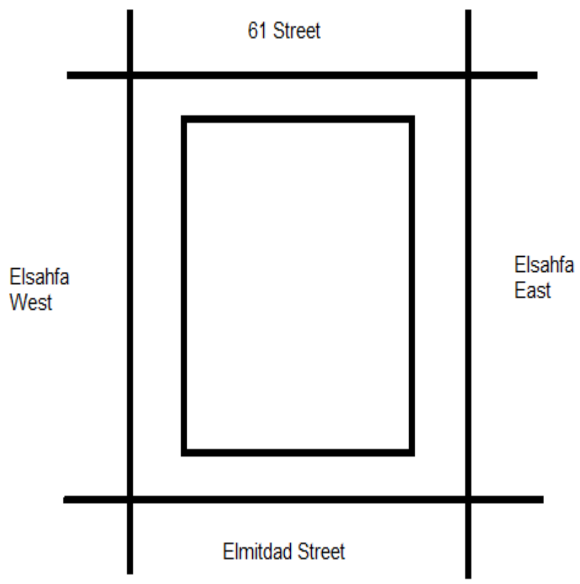

Figure 4.1: Bounders of Study Area

4.2 Test Data

The primary source data is an aerial photograph covering the study area with 10 cm spatial resolution, descriptive data for the built areaand the electrical network parts. This is in addition to the data collected from the field using different survey methods.

4.3 Hardware and Software Used

Arc GIS program used in this study to link between spatial and descriptive data, build geometric network and conduct analysis.In January 1997, Esri decided to revamp its GIS software platform, creating single integrated software architecture. ArcGIS is a geographic information system (GIS) for working with maps and geographic information. It is used for: creating and using maps, compiling geographic data, analyzing mapped information, sharing and discovering geographic information, using maps and geographic information in a range of applications, and managing geographic information in a database.

4.4 Procedures

This study consists of three phase. Phase one concern with the data acquisition and management. A geometric network for the study area has been built in phase two. In phase three a spatial analysis and an assessment have been carried out.

4.4.1 Data Acquisition and Management

The test data have been collected, acquired and managed by different means and from various resources (Figure 4.2). Aerial photograph (Resolution: 10 cm, Date: 2008) which cover the college boundary and all details of the college.The coordinates of the ground control points inside the study area were observedusing a Global Position System (GPS) receiver based on UTM Projection and WGS 1984 Datum.

Field surveying for electrical network parts, which include the place of transformers, supply sub-stations, distribution keys, and cables, also descriptive data had been collected include the available load, used load taken by Digital Clamp Meter device (Figure 4.3).

Data has been managed to conduct the analysis. Process of converting the aerial photograph to geometric network model in GIS environment.

Georeferencing aerial photograph by using Coordinates of Ground Control Points have been taken by GPS (Table 4.1).

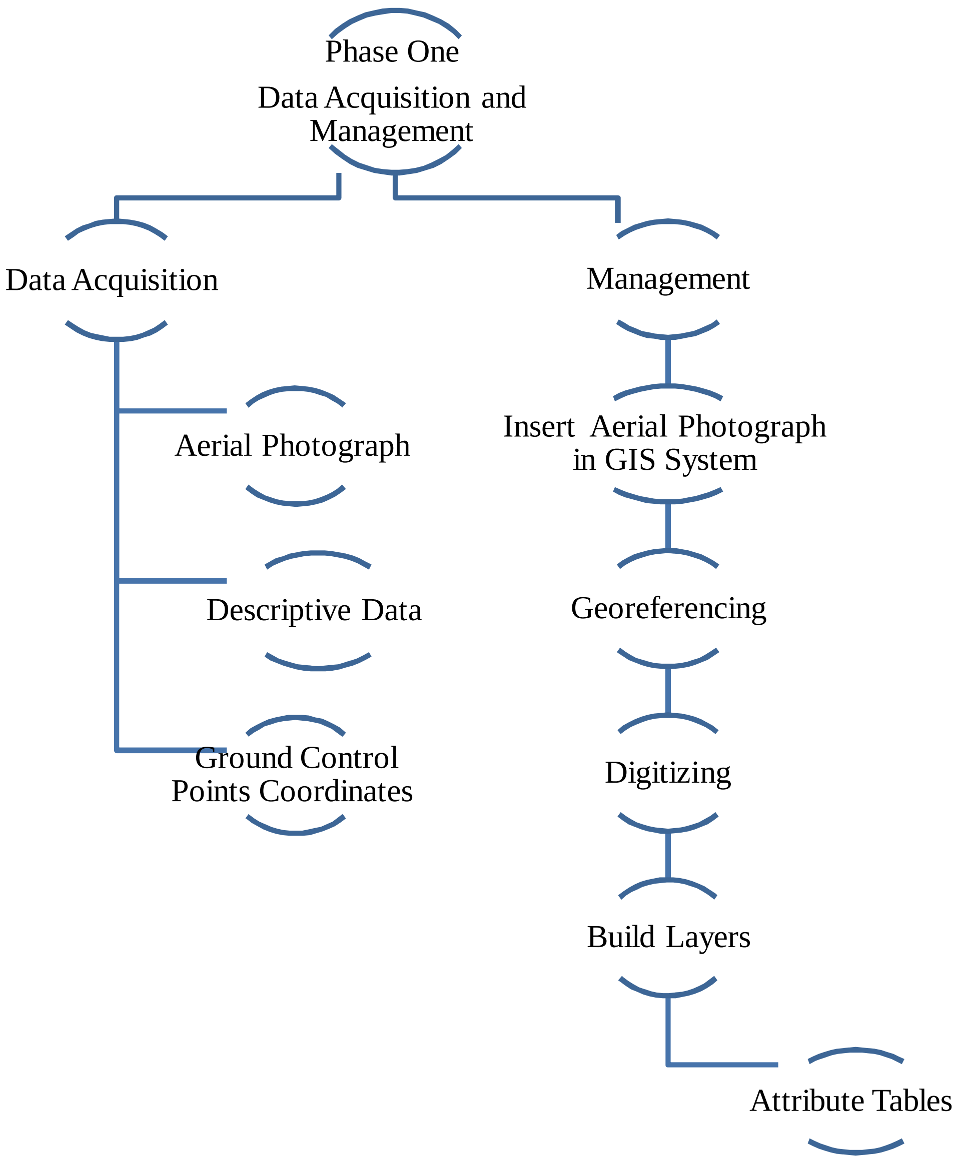

Figure 4.2: Phase one (Data Acquisition and Management)

Figure 4.3: Digital Clamp Meter Device to Measure the Loads

Table 4.1: Coordinates of Ground Control Points by GPS

No of Point	East (meter)	North (meter)
1	450586.716	1720168.969
2	450369.167	1720514.066
3	450455.828	1720479.422
4	450767.619	1720363.413

College and electrical network layers had been built in Arc Map using collected data above (these layers include: Frame, Halls, Vegetation, Departments, Labs, Workshops, Toilets, Services, Offices, Transformers, Cooling Support Stations, Cooling Control Points, Cooling Tabloons, Cooling Cables, Light Support Stations, Light Control Points, Light Tabloons and Light Cables).

Attribute Tables of all layers and all fields that relate to have been edited and all the data for each object had been entered in their own field.

4.4.2 Building a Geometric Network

Geometric network from existing data was built inside feature datasets in Arc Catalog (Figure 4.4). Connectivity rules have been conducted from properties of geometric network. And then a geometric networkhas been called in Arc Map.

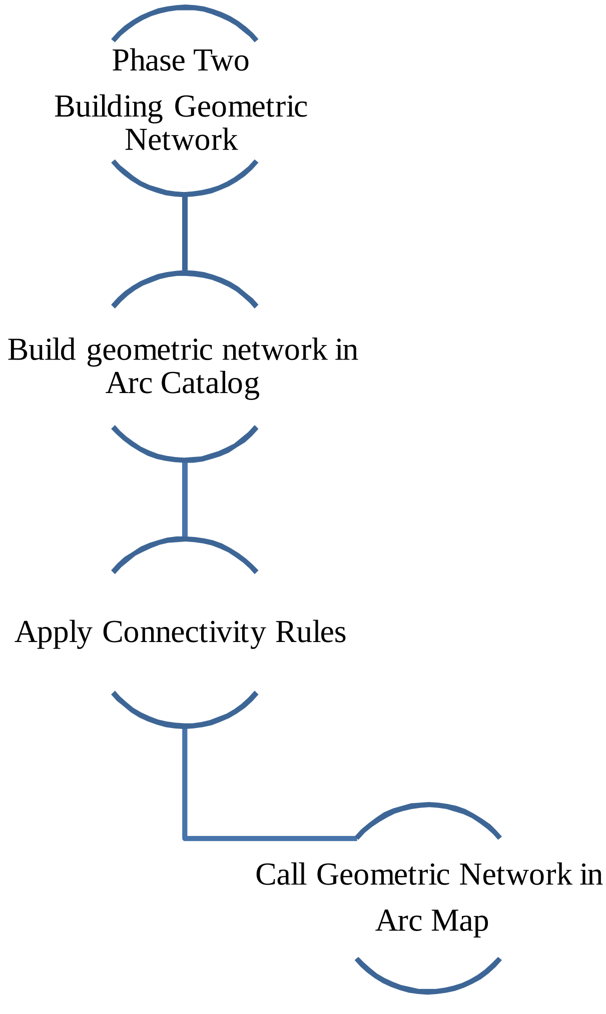

Figure 4.4: Phase Two (Building a Geometric Network)

4.4.3 Analysis and Assessment

The analysis using the Geometric Network module in ArcGIS system has been performed (Figure 4.4).

By using Utility Network Analysthas been found Path between twoFlags, Flags have been placed on any feature.

Path Upstream has been found. Appears red line shows the flow of electricity lines in the direction of Flag.

All lines that are pour in the point have been found by using Upstream Accumulation.

Some enquires have been conducted. Calculation of the least used load of Cooling Control Points to establish new extension for new buildings, to find out,openAttributeTable of Cooling Control Points layer and from field which represents Used Loadselect Statistics.

From Attribute Table of Light Support Stations Layerwe note weakness presence in the network.

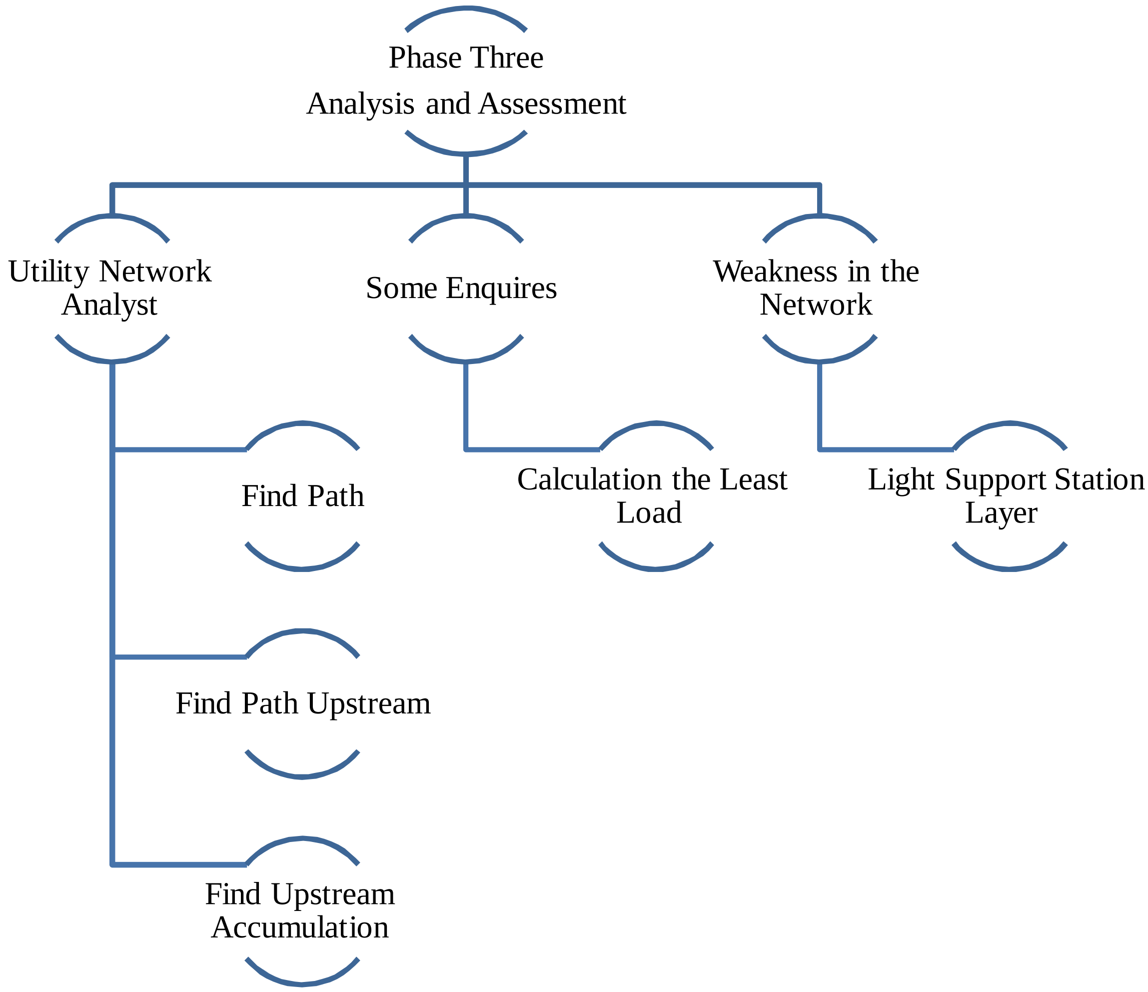

Figure 4.5:Phase Three(Analysis and Assessment)

Chapter Five

Resulting, Analysis and Conclusion

5.1 Resulting and Analysis

Attribute Tables of all layers have been generated and data for each object has been entered in their own field. Table 5.1 shows an example of thedescriptive data of the Cooling Control Points Feature-class.

Table 5.1:Attribute Table of Cooling Control Points

* OBJECTID	* SHAPE	NAME	LOCATION	SOURCE	AVAILABLE_LOAD_AMP	USED_LOAD_AMP
13	Point	CCP 8	PRODUCTION	T2	1200	512
10	Point	CCP 7	NEAR OF SOUTH DEPARTMENT	T1	600	263
20	Point	CCP 13	LH 3	CSS 7	600	171
21	Point	CCP 14	LH 11	CSS 7	600	324
15	Point	CCP 10	STUDENTS UNIT	CSS 6	600	118
37	Point	CCP 6	HALLS OF PROF HASHM	CSS 5	1200	142
36	Point	CCP 5	HALLS OF PROF HASHM	CSS 4	1200	102
5	Point	CCP 3	READING LIBRARY	CSS 3	600	291
7	Point	CCP 4	ELECTRONICS DEPARTMENT	CSS 3	1200	544
2	Point	CCP 2	SOUTH DEPARTMENTS	CSS 1	600	374
23	Point	CCP 1	NORTH DEPARTMENTS	CSS 1	600	370
14	Point	CCP 9	LABS OF BAKREY	CCP8	600	240
18	Point	CCP 12	E _ATELIER OF ARCHITECTURE	CCP 8	450	122
22	Point	CCP 15	LH 12	CCP 14	300	180
17	Point	CCP 11	LH 9	CCP 10	300	118

After georeferencing, insert all descriptive data in Attribute Tables of layers and build a geometric network, electrical network of the study area has been built(Figure 5.1).

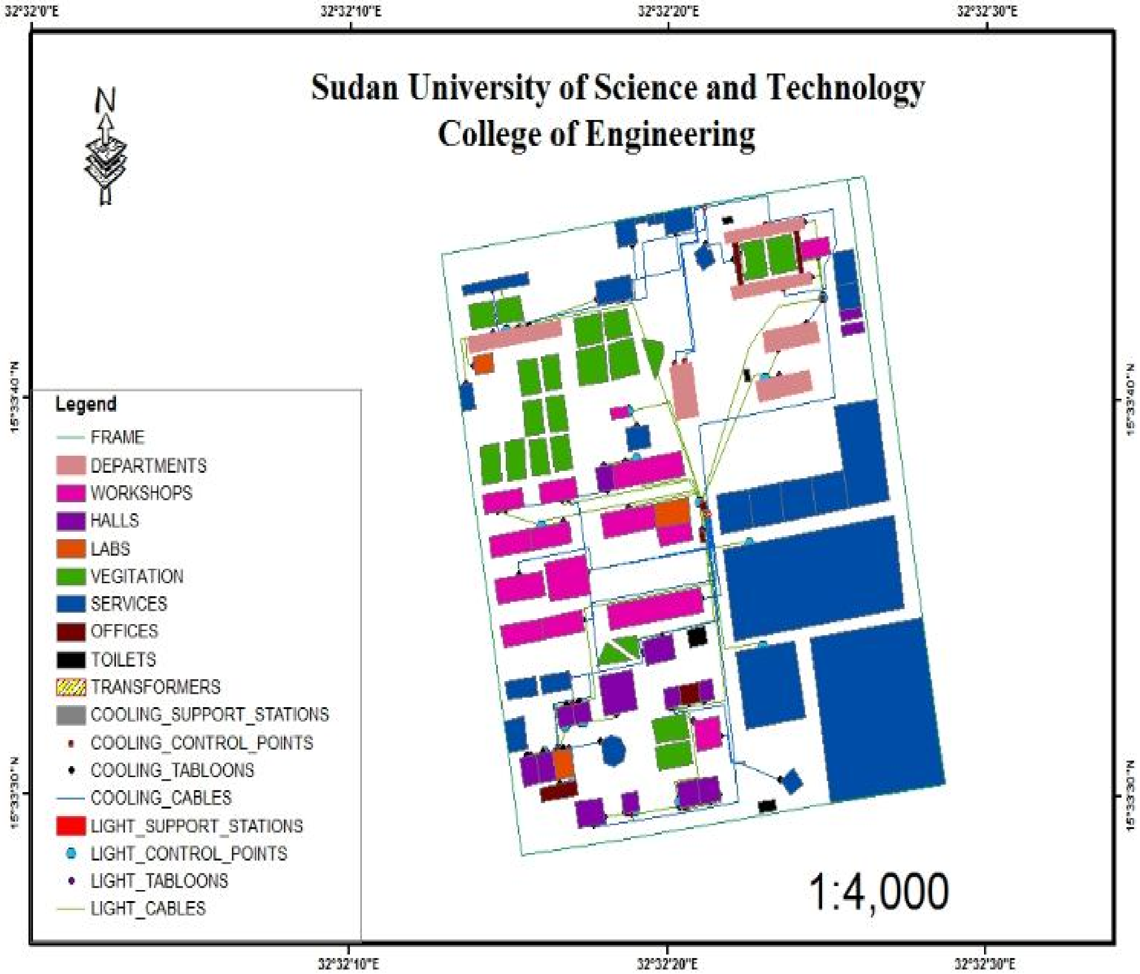

Figure 5.1: Electrical Network of the Study Area

Find path between Light Support Station (LSS) and Light Tabloon4 (LT4), to find out, from Utility Network Analyst select Add Junction Flag Tool from Analysis and put the Flag in LSS and LT4, and then select find path from Trace Task. Appears red line shows the path between LSS and LT4(Figure 5.2).

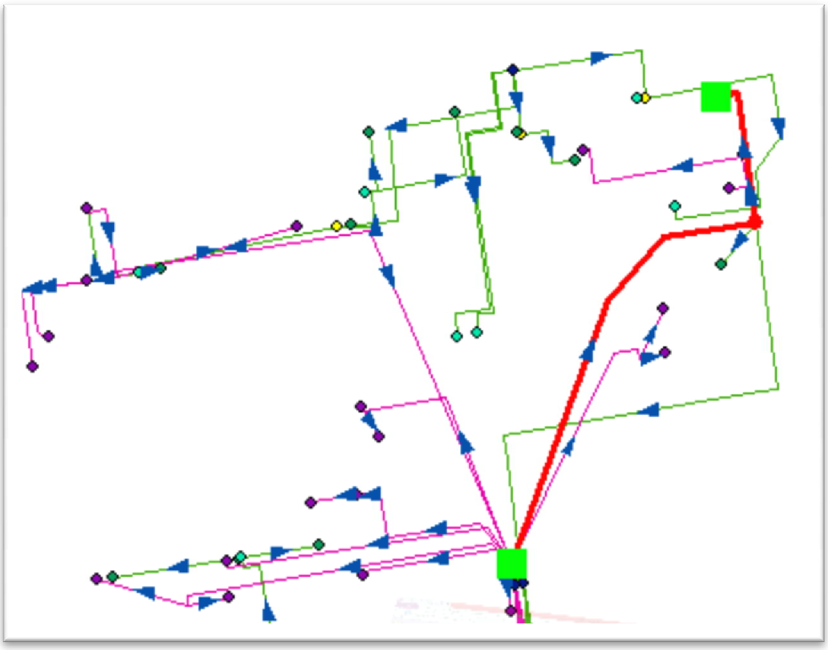

Figure 5.2: Pass between Light Support Stationand Light Tabloon4

Path upstream for Cooling Tabloon 5 (CT5) has been found by put the Flag in CT5, select find path upstream. Appears red line shows the flow of electricity lines in the direction of CT5(Figure 5.3).

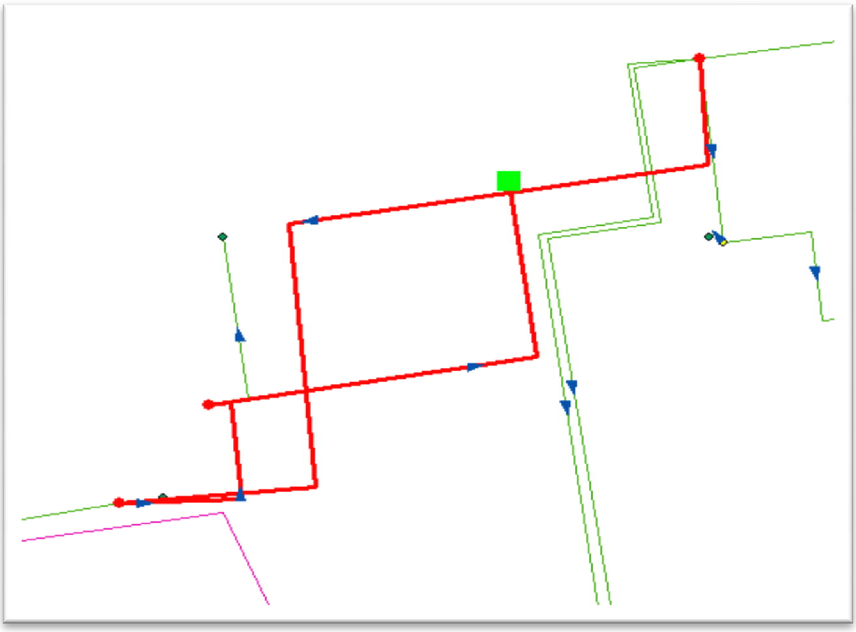

Figure 5.3: Path Upstream for Cooling Tabloon 5

All lines that are pour in Cooling Control Point 2 (CCP2) have been found by put the Flag in CCP2 and select Find Upstream Accumulation(Figure 5.4).

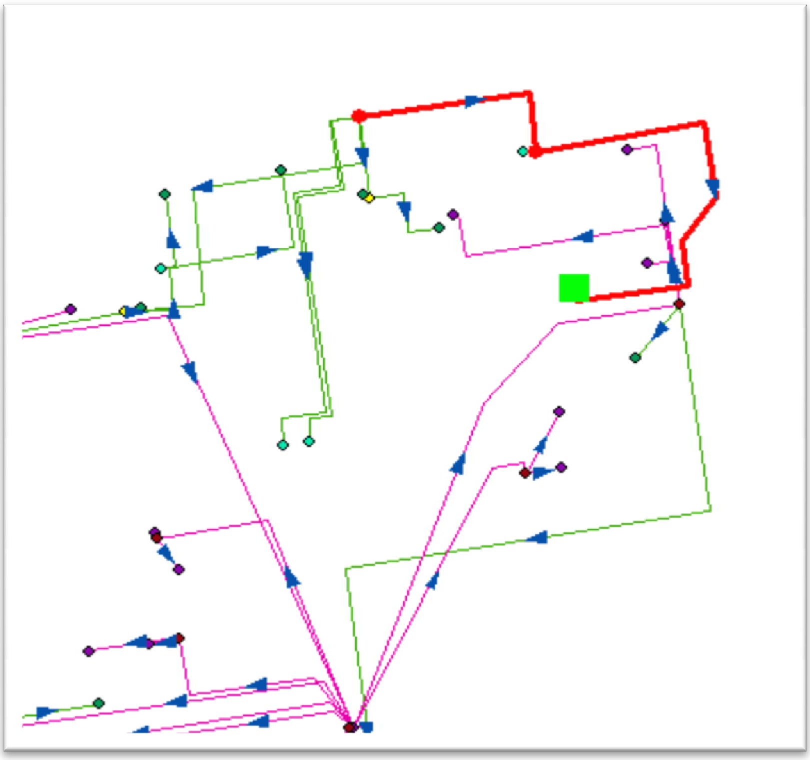

Figure 5.4: Upstream Accumulation for Cooling Control Point 2

Some enquires have been conducted. To find outleast used loadof Cooling Control Points to establish new extension for new buildings, from Statistics in AttributeTable of Cooling Control Points (CCP), the Cooling Control Point 5 (CCP5) in it least used load(Figure 5.5), and from then, establish the new cable to new builds from it.

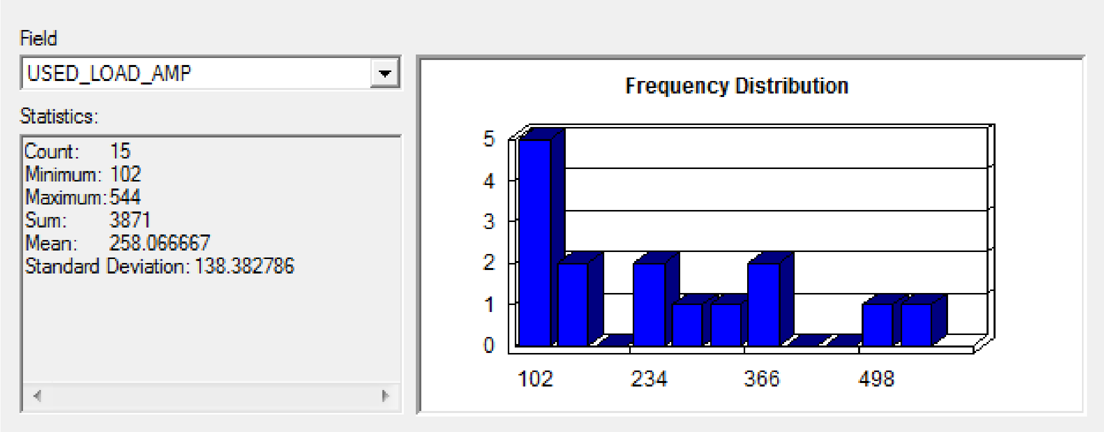

Figure 5.5: Determination Least Used Load of Cooling Control Points

From Attribute Table of Light support stations (Table 5.2), There is one Support Station only for all lighting in the college, whichmeans that there isweaknessin the network, where if occurs malfunction in the Support Station drop down all lighting, propose solution of this by establishing a new Support Stations of lighting.

Table 5.2: Attribute Table of Light Support Stations

* OBJECTID	* SHAPE	NAME	FROM_WHERE	LOCATION	AVAILABLE_LOAD_AMP	LOAD_AMP
1	Point	LSS	T2	near of office of electrical tech	3600	1755

5.2 Conclusion

According to the test carried out in this study, it could be concluded that:

1. A geometric network has been designed and built for the study area.
2. The network model was found to be able to detect the weakness in the network performance, whereis one Support Station only for all lighting in the college
3. The model helps to choice of an appropriate load for new extensions.
4. The flow directions of the electricity power in network can be managed based on the developed model.

5.3Recommendations

For future similar works, it is recommenced that:

1. Extend the study to include water and sewers networks to complete the spatial database of the college.
2. Expand the use of connectivity rules in geometric network.
3. Conduct more analysis to take advantage ofUtility Network Analyst tools in ArcGIS system.
4. Generalization of work to include all states of the Sudan to avoid conflicts that occurs.

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Appendix

Database of the Study Area

All descriptive data for electricity network have been edited in Attribute Tables in GIS system.

Table 1: Attribute Table of Transformers

* OBJECTID	* SHAPE	SHAPE_Length	SHAPE_Area	NAME	CAPACITY_KVA
1	Polygon	11.926427	8.831101	T2	1000
2	Polygon	11.969858	8.895404	T1	1000
4	Polygon	12.096336	9.046092	T3	1000

Table 2: Attribute Table of Cooling Support Stations

* OBJECTID	* SHAPE	SHAPE_Length	SHAPE_Area	NAME	SOURCE	LOCATION	AVAILABLE_LOAD_AMP	USED_LOAD_AMP
2	Polygon	8.988459	4.958851	CSS 1	T3	north departments	1200	744
4	Polygon	9.272172	5.324047	CSS 2	T3	n_mosque	1200	111
5	Polygon	9.26808	5.328335	CSS 3	T3	reading library	1200	1007
6	Polygon	9.179661	5.19379	CSS 4	T3	halls of prof Hashm	1200	102
7	Polygon	9.034116	5.00994	CSS 5	T3	halls of prof Hashm	1200	142
9	Polygon	9.045291	5.042939	CSS 6	T1	LH2	1200	210
10	Polygon	9.717856	5.858188	CSS 7	T1	near of the new atelier	1200	633

Table 3: Attribute Table of Cooling Tabloons

* OBJECTID	* SHAPE	NAME	LOCATION	SOURCE	AVAILABLE_LOAD_AMP	USED_LOAD_AMP
2	Point	CT 4	KASLA CAFETERIA	CCP 3	300	54
3	Point	CT 5	ALMOHANDES1 CAFETERIA	CCP 3	300	89
4	Point	CT 2	W_TEACHERS OFFIICESS	CSS 2	300	35
6	Point	CT 7	THE ADMINISTRATION	CCP 4	600	173
7	Point	CT 8	PETROLEUM DEPARTMENT	CCP 7	600	263
9	Point	CT 14	WELDER	T2	1200	109
12	Point	CT 13	TURNERY	T2	1200	85
13	Point	CT 11	W _ATELIER OF ARCHITECTURE	CCP 12	300	48
14	Point	CT 12	LH 5	CCP 12	300	14
15	Point	CT 29	S_MOSQUE	CSS 7	300	120
20	Point	CT 24	NEW ATELIER	CSS 7	600	48
21	Point	CT 22	LH 4	CCP 13	300	60
22	Point	CT 23	TEACHERS OF TECH	CCP 13	300	58
23	Point	CT 26	LH 10	CCP 14	300	72
24	Point	CT 28	LH 13	CCP 15	300	120
25	Point	CT 6	ELECTRONIC DEPARTMENT	CCP 4	600	371
26	Point	CT 9	PRODUCTION	CCP 8	600	150
27	Point	CT 10	E _ATELIER OF ARCHITECTURE	CCP 12	300	60
28	Point	CT 15	LH 2	CSS 6	300	92
29	Point	CT 21	LH 3	CCP13	300	53
30	Point	CT 25	LH 11	CCP 14	300	72
31	Point	CT 27	LH 12	CCP 15	300	60
32	Point	CT 17	LH 9	CCP 11	300	58
33	Point	CT 16	LH 8	CCP 11	300	60
34	Point	CT 20	LABS OF BAKREY	CCP 9	300	100
35	Point	CT 18	LH 6	CCP 9	300	40
36	Point	CT 19	LH 7	CCP 9	300	41
37	Point	CT 1	N_MOSQUE	CSS 2	750	76
38	Point	CT 3	READING LIBRARY	CSS 3	600	148
39	Point	CT 30	CARS	T2	1200	83
41	Point	CT 31	ALKOTHER CAFETERIS	CCP 9	300	21
42	Point	CT 32	OFFICES OF TEACHERS	CCP 9	300	38

Table 4: Attribute Table of Cooling Cables

* OBJECTID	* SHAPE	SHAPE_Length	NAME	TRACK	CABLE_DIAMETER_MM²
8	Polyline	32.187737	CC 11	CPP 3_CT 4	16
36	Polyline	14.725402	CC 38	CCP 13_CT 23	16
37	Polyline	29.278893	CC 39	CCP 13_CT 22	16
50	Polyline	2.945592	CC 40	CCP 13_CT 21	16
56	Polyline	14.467154	CC 32	CCP 9_CT 18	16
57	Polyline	28.860672	CC 33	CCP 9_CT 19	16
4	Polyline	37.331032	CC 9	CSS 2_CT 2	25
7	Polyline	75.943118	CC 12	CCP 3_CT5	25
26	Polyline	59.937871	CC 28	CCP 12_CT 11	25
27	Polyline	36.505193	CC 29	CCP 12_CT 12	25
34	Polyline	38.167497	CC 36	CSS 7_CT 24	25
39	Polyline	20.72565	CC 45	CCP 14_CT 26	25
43	Polyline	43.637522	CC 48	CCP 15_CT 28	25
48	Polyline	1.328081	CC 30	CCP 12_CT 10	25
51	Polyline	2.666781	CC 44	CCP 14_CT 25	25
52	Polyline	2.57658	CC 47	CCP 15_CT 27	25
53	Polyline	5.639119	CC 24	CCP 11_CT 17	25
54	Polyline	6.937017	CC 23	CCP 11_CT 16	25
58	Polyline	5.576439	CC 31	CCP 9_CT 20	25
60	Polyline	1.657667	CC 8	CSS 2_CT1	25
65	Polyline	5.708089	CC 13	CSS 3_CT 3	25
74	Polyline	3.632777	CC 20	CSS 6_CT 15	25
76	Polyline	40.642876	CC 50	CCP 9-CT 31	25
77	Polyline	52.437167	CC 51	CCP 9-CT 32	25
15	Polyline	25.264797	CC 18	CCP 7_CT 8	35
24	Polyline	21.060402	CC 22	CCP 10_CCP 11	35

Table 5: Attribute Table of Cooling Cables

* OBJECTID	* SHAPE	SHAPE_Length	NAME	TRACK	CABLE_DIAMETER_MM²
25	Polyline	66.126316	CC 27	CCP 8_CCP 12	35
29	Polyline	35.484131	CC 41	CSS 7_CT 29	35
42	Polyline	63.874223	CC 46	CCP 14_CCP 15	35
21	Polyline	179.23813	CC 30	CCP 8_CCP 9	50
35	Polyline	107.232679	CC 37	CSS 7_CCP 13	50
38	Polyline	85.625792	CC 43	CSS 7_CCP 14	50
73	Polyline	34.693247	CC 10	CSS 3_CCP 3	50
10	Polyline	52.432791	CC 16	CCP 4_CT 7	70
16	Polyline	79.966278	CC 49	T2_CT 30	70
1	Polyline	168.150448	CC 7	CSS 1_CCP 2	90
3	Polyline	27.250134	CC 2	T3_CSS 2	90
9	Polyline	96.507495	CC 14	CSS 3_CCP 4	90
13	Polyline	148.176812	CC 5	T3_CSS 4	90
23	Polyline	103.866155	CC 21	CSS 6_CCP 10	90
44	Polyline	9.849936	CC 15	CCP 4_CT 6	90
62	Polyline	3.748845	CC 6	CSS 1_CCP1	90
11	Polyline	157.906269	CC 4	T3_CSS 5	120
14	Polyline	278.479909	CC 17	T1_CCP 7	120
19	Polyline	230.47636	CC 34	T2_CT 13	120
20	Polyline	142.563956	CC 25	T2_CCP 8	120
28	Polyline	200.216245	CC 42	T1_CSS 7	120
75	Polyline	0.7019	CC 26	CCP 8_CT 9	120
2	Polyline	78.532536	CC 1	T3_CSS 11	180
5	Polyline	145.072254	CC 3	T3_CSS 3	180
17	Polyline	189.957505	CC 35	T2_CT 14	180
22	Polyline	138.04046	CC 19	T1_CSS 6	180

Table 6: Attribute Table of Light Control Points

* OBJECTID	* SHAPE	NAME	LOCATION	SOURCE	AVAILABLE_LOAD_AMP	USED_LOAD_AMP
1	Point	LCP 1	FLIGHT DEPARTMENT	LSS	600	311
2	Point	LCP 2	NEAR OF SOUTH DEPARTMENTS	LSS	600	325
3	Point	LCP 3	ELECTRONICS DEPARTMENTS	LSS	750	386
6	Point	LCP 4	MAINTENANCE	LSS	300	63
7	Point	LCP 6	REFRIGERATION AND ADAPTATION	LSS	300	152
8	Point	LCP 5	BUILDS AND DRAIN	LSS	300	90
10	Point	LCP 9	LABS OF BAKREY	LSS	600	180
11	Point	LCP 10	LH 6	LCP 9	300	19
13	Point	LCP 11	LH 8	LCP 9	300	22
14	Point	LCP 13	LH 3	LSS	600	168
15	Point	LCP 14	LH 11	LCP 13	300	84
16	Point	LCP 15	LH 12	LCP 14	300	44
17	Point	LCP 12	LH 9	LCP 11	300	21
18	Point	LCP 7	N_HOME OF TEACHERS	T1	1200	250
19	Point	LCP 8	S_HOME OF TEACHERS	T1	1200	166
20	Point	LCP 16	ELECTRICAL TECH	LSS	300	39

Table 7: Attribute Table of Light Tabloons

* OBJECTID	* SHAPE	NAME	LOCATION	SOURCE	AVAILABLE_LOAD_AMP	USED_LOAD_AMP
2	Point	LT 1	FLIGHT DEPARTMENTS	LCP 1	300	163
3	Point	LT 2	PETROLEUM DEPARTMENTS	LCP 1	300	148
4	Point	LT 4	NORTH DEPARTMENTS	LCP 2	300	100
5	Point	LT 5	ATELIER OF CLUB	LCP 3	300	29
6	Point	LT 3	SOUTH DEPARTMENTS	LCP 2	300	179
7	Point	LT 32	W_TEACHERS OFFICESS	LCP 2	300	17
10	Point	LT 11	QUICK CAFETERIA	LCP 3	300	40
11	Point	LT 10	ELECTRICAL LAB	LCP 3	300	24
12	Point	LT 7	ELECTRONIC DEPARTMENTS	LCP 3	300	105
18	Point	LT 33	BREATHER	LCP 4	300	23
19	Point	LT 34	W_ATELIER OF ARCHITECTURE	LCP 6	300	38
20	Point	LT 13	LH 5	LCP 5	300	21
21	Point	LT 14	E_ATELIER OF ARCHITECTURE	LSS	300	40
23	Point	LT 15	JOINERY	LSS	300	35
24	Point	LT 8	READING LIBRARIES	LCP 3	300	92
26	Point	LT 17	LH 2	LSS	300	45
28	Point	LT 23	LH 7	LCP 10	300	20
30	Point	LT 21	LH 1	LCP 12	300	48
31	Point	LT 27	NEW ATELIER	LCP 13	300	20
32	Point	LT 29	LH 10	LCP 14	300	21
34	Point	LT 31	LH 13	LCP 15	300	25
35	Point	LT 25	LH 4	LCP 13	300	23
36	Point	LT 26	TEACHERS OF TECH	LCP 13	300	19
38	Point	LT 24	LH 3	LCP 13	300	22
39	Point	LT 30	LH 12	LCP 15	300	19
46	Point	LT 6	MAINTENANCE	LCP 4	300	40
47	Point	LT 12	BUILDS AND DRAIN	LCP 5	300	69
49	Point	LT 18	LABS OF BAKREY	LCP 9	300	50
50	Point	LT 22	LH 6	LCP 10	300	19
51	Point	LT 19	LH 8	LCP 11	300	22
52	Point	LT 20	LH 9	LCP 12	300	21
54	Point	LT 28	LH 11	LCP 14	300	19
55	Point	LT 9	THE ADMINISTRASTION	LCP 3	300	125
56	Point	LT 16	REFRIGERATION AND ADAPTATION	LCP 6	300	114
57	Point	LT 35	SECURITY	LCP 16	300	18
58	Point	LT 36	ELECTRICAL TECH	LCP 16	300	21

Table 8: Attribute Table of Light Cables

* OBJECTID	* SHAPE	SHAPE_Length	NAME	TRACK	CABLE_DIAMETER_MM²
7	Polyline	12.631713	LC 50	T2_LSS	220
8	Polyline	122.171041	LC 1	LSS_LCP 1	120
9	Polyline	12.568839	LC 2	LCP 1_LT 1	25
10	Polyline	25.716201	LC 3	LCP 1_LT 2	50
11	Polyline	211.087744	LC 4	LSS_LCP 2	120
12	Polyline	70.242681	LC 7	LCP 2_LT4	35
13	Polyline	31.79378	LC 5	LCP 2_LT 5	16
15	Polyline	24.823345	LC 6	LCP 2_LT3	35
16	Polyline	117.899446	LC 8	LCP 2_LT 32	25
17	Polyline	287.352504	LC 14	LSS_LCP 3	120
18	Polyline	13.686333	LC 15	LCP 3 _LT 7	35
21	Polyline	66.84085	LC 18	LCP 3_LT 8	25
22	Polyline	79.909528	LC 19	LCP 3_LT 11	25
26	Polyline	41.560772	LC 17	LCP 3_LT 9	35
29	Polyline	158.336239	LC 25	LSS_LCP 6	35
30	Polyline	43.886626	LC 26	LCP 6_LT 34	25
31	Polyline	86.283215	LC 20	LSS_LCP 5	35
33	Polyline	33.682591	LC 21	LCP 5_LT 13	25
34	Polyline	143.682867	LC 24	LSS_LT 14	25
35	Polyline	71.237597	LC 23	LSS_LT 15	25
36	Polyline	87.137913	LC 16	LCP 3_LT 10	35
37	Polyline	144.642691	LC 10	T1_LCP8	120
42	Polyline	63.83205	LC 9	T1_LCP 7	120
43	Polyline	205.914321	LC 29	LSS_LCP 13	35
44	Polyline	176.113147	LC 28	LSS_LT 17	25
45	Polyline	326.020251	LC 40	LSS_LCP 9	35

Table 9: Attribute Table of Light Cables

* OBJECTID	* SHAPE	SHAPE_Length	NAME	TRACK	CABLE_DIAMETER_MM²
46	Polyline	13.84195	LC 41	LCP 9_LCP 10	25
47	Polyline	15.703849	LC 49	LCP 10_LT 23	16
48	Polyline	19.25972	LC 44	LCP 9_LCP 11	25
50	Polyline	17.847336	LC 46	LCP 11_LCP 12	25
52	Polyline	33.052237	LC 48	LCP 12_LT 21	16
53	Polyline	21.742298	LC 33	LCP 13_LT 27	25
54	Polyline	105.933735	LC 34	LCP 13_LCP 14	25
55	Polyline	49.785876	LC 35	LCP 14_LT 29	16
57	Polyline	47.394134	LC 37	LCP 14_LCP 15	25
58	Polyline	28.620877	LC 38	LCP 15_LT 31	25
59	Polyline	14.684151	LC 32	LCP 13_LT 26	16
60	Polyline	30.320176	LC 31	LCP 13_LT 25	16
61	Polyline	3.452024	LC 30	LCP 13_LT 24	16
63	Polyline	2.120863	LC 13	LCP 4_LT 6	16
64	Polyline	10.793453	LC 22	LCP 5_LT 12	25
65	Polyline	9.161635	LC 43	LCP 9_LT 18	16
66	Polyline	2.017235	LC 42	LCP 10_LT 22	16
67	Polyline	1.810831	LC 45	LCP 11_LT 19	16
68	Polyline	3.846201	LC 47	LCP 12_LT 20	16
70	Polyline	4.352982	LC 36	LCP 14_LT 28	16
71	Polyline	19.517998	LC 27	LCP 6_LT 16	25
72	Polyline	8.166677	LC 39	LCP 15_LT 30	16
73	Polyline	120.68871	LC 11	LSS_LCP 4	25
74	Polyline	14.033993	LC 12	LCP 4_LT 33	16
75	Polyline	2.096182	LC 51	LSS_LCP 16	25
79	Polyline	23.125229	LC 52	LCP 16_LT 35	16
80	Polyline	1.794357	LC 53	LCP 16_LT 36	16