

**UNIVERSITY OF NAIROBI**



**USE OF GEOGRAPHICAL INFORMATION SYSTEM (GIS) IN  
MANAGING UTILITY INCIDENTS.**

**A Case Study of Kenya Power Company, Roysambu Area in Nairobi County**

**By**

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**Research Project Report submitted in partial fulfilment of the requirement  
for the award of Degree in Master of Science in Geographic Information  
Systems at the University of Nairobi.**

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**Declaration**

This is my original work and has not been presented for a degree in any other University.

Signature.......... Date 23 July 2012.....  
John Wanyagia Kariuki

This project report has been submitted for the examination with my approval as the University Supervisor.

Signature.......... Date 25/7/2012.....  
Dr. Ing. I.N. Karanja

## **DEDICATION**

To my Family, Parents and Friends who gave me the support I required.

## **ACKNOWLEDGEMENT**

My heartfelt thank you to the Almighty Lord for making this Journey a success.

My appreciation goes to my supervisor Dr. –Ing F.N. Karanja for the priceless guidance given throughout the project.

Mr. Denis Ndwiga of Partechs Limited thanks for all the guidance accorded to me in designing the spatial web based system.

To my Beloved Wife Loise for her support and understanding.

## **ABSTRACT**

In pursuance of an effective incidence management within utility line of business, the businesses should ensure that spatial details and web based system are utilized in managing the incidences.

At present the Kenya Power company, does not utilize spatial details and there is no web based system utilized in incidence management.

The aim of the project was to demonstrate the role of GIS in managing utility services incidences using Kenya power as a case study.

A spatial web based system was developed and tested to address customer's location consideration and a web based solution when managing power outage incidences at Roysambu Area, Nairobi, Kenya. The system will be hosted and managed at Kenya Power company premises.

It was not possible to host the system online, and thus impossible to demonstrate use of smart phones used by field personnel's.

The project should be adopted by Kenya Power Company to enhance its incidence service management.

The method used in this project is potentially applicable in other utility industries as well as other investments not necessarily on utility line of business.

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## ABBREVIATIONS

GIS	Geographical Information Systems
KENGEN	Kenya Electricity Generating Company
CCK	Communication Commission of Kenya
IP	Internet Protocol
RAPDRP	Restructured-Accelerated Power Development and Reforms Programme
I-SRI	Environmental Systems Research Institute
IMS	Incidence Management System
USIU	United States International University
PAC	Pan Africa Christian University
MISC	Moi International Sports Centre
RAM	Read Access Memory
GB	Gigabyte
KNBS	Kenya National Bureau of Statistics
REMC	Rural Electric Membership Corporation
API	Application Programming Interface
REST	Representational State Transfer
REMC	Rural Electric Membership Corporation

## Chapter 1: INTRODUCTION

### 1.1 Background

Within the Kenyan government, performance contracting policy, its duty of citizens to "demand excellent Service as your right". (Public Sector Reforms & Performance Contracting, 2012)

Customers are always demanding for quality and excellent services from the public offices, including the utility industries. Prompt, efficient and effective incident management within the utility industries will ensure excellent service provision. This has led to utility companies to align their visions to customers' needs and satisfaction e.g. "To provide world class power that delights our customers." (Kenya Power, 2012), "Satisfaction of all our customers with water and sewerage services." (Nairobi City Water and Sewerage Company, 2012) and also the utility companies have aligned one of their core values to customer focus e.g. "Customer first" (Kenya Power, 2012), "Customer Focus" (Nairobi City Water and Sewerage Company, 2012).

The high competition existing in today's Business world, coupled by contract based and job performance evaluation done frequently have made utility companies including Kenya Power, Nairobi City water and sewerage Company, Kenya Pipeline Company Limited etc. to strive to offer timely, efficient and effective services to its customers.

The current procedure at the company is whereby a customer calls to report the problem, which is received by the company customer care staff, who then logs in the details of the problem to the system which generates a work order. The work order is allocated to the field team personnel with the accompanying customer details. In most cases the work orders are given out in the morning and the field team dispatched, all other upcoming issues after this are sometimes left pending until the following morning which causes delay on service delivery. (Kenya Power, 2012)

The field team personnel use the customer details as per the work order to try and locate the exact customer location address including the road, street, house number, plot, etc.

In most cases the field team personnel repeatedly call the customer to trace the exact location, which itself is not an effective way of undertaking the task

Moreover, when the field personnel solves the issue there is no way of updating the status of work order until they are back in the office and upload the details to update the work order status. The customers have no access of knowing and verifying the status of their issue. It's also difficult to update Field team personnel of new work order while in field.

GIS systems have shown potential to address the above shortcomings (CyberSWIFT, 2012), (ESRI, 2012). Through spatial web based system it is possible to display a map clearly showing the specific physical address of the customers including the name of the road, street, plot and house number, etc.

The customers can be able to view the status of their issues through logging in to the system. Through this system the field personnel will also be able to receive upcoming work orders while on the field, and also submit the report promptly upon completion of their work or for escalation making it easier for their supervisors to know their progress and for company and customers get the current status of the work order promptly.

The company will be able to inform and update the customers on incidence progress or other issues through short message services. The customer can freely interact with the system through a voice call, through short message service, through web based system or by walk in to the company offices to report the incidences.

## **1.2 Problem Statement**

Quality, effective and efficient customer service is a major driver for business continuity, winning trust and confidence of the customers. Customer satisfaction is the key to success. Getting your customers to tell you what's good about your products or services, and where you need improvement, helps you to ensure that your business measures up to their expectations. (SMEToolkit, 2012). Businesses all over the world are coming up with means and methods of ensuring utmost customer satisfaction. Companies are conducting researches on customer satisfaction, investing in modern technologies with the aim of achieving ways of retaining and attracting more customers which will translate to more business opportunities and hence more revenues.

The utility companies have also embarked on various ways and methods to ensure quality, timely and efficient Incidences resolutions.

The current procedure of solving incidences in utility industry, with emphasis on Kenya Power have a gap in that there is no consideration for spatial aspects and web based solution in addressing the incidences. Location based technologies and web based solutions have not been utilized to cope with increasing customer incidences. The field team personnel relies on the information keyed in by the customer care when the customer was reporting the incidence, they do not have a mechanism of locating the customer location at a glance ,direction to the customer location, plot number, etc. (Kenya Power, 2012)

The proposed system have a spatial database and it's web based, it will maintain the customer data including spatial details and attributes data, field team will be able to use smart phones to receive and update work orders, company will be able to inform and interact with their customers through short message services and customers will have a portal where they can log key in their incidences and also track the status of the reported incidences.

### **Research objective**

#### **1.3.1 Overall Objective**

The overall objective of the study was to demonstrate the role of GIS in managing utility services incidences using Kenya power as a case study.

#### **1.3.2 Specific Objectives**

The specific objectives of the proposed research included:

- i. To review the current system used to address utility services incidences.
- ii. To identify requirements for an efficient system.
- iii. To design a spatial web based incidence management system.
- iv. Implement the incidence management system.
- v. Evaluate the potential of system to improve efficiency in incidence resolutions.
- vi. To compare between new system and current system.

#### **1.4 Research questions**

The research questions to be addressed include the following:

- i. What's the current system in use in management of power utility incidences in Kenya?
- ii. What encompasses an efficient system in management of power utility incidences in Kenya?
- iii. What will be the requirement for a spatial web based system in management of power utility incidences in Kenya?
- iv. What are the requirements to implement the new system?
- v. What are the improvements and challenges brought about by the new system?
- vi. What are the indicators to apply for systems comparison?

## **1.5 Scope and Limitation of the study**

### **Scope**

This study attempted to investigate harnessing and application of GIS and web mapping technology in addressing power outage incidences at Kenya Power Company with a focus on Roysambu Area, Ksarani constituency, Nairobi north district of Nairobi County.

### **Limitation of the study**

There were several limitations registered and encountered during this study, these includes:

- The study focused on power outage incidences only.
- The study focused only on a section of Roysambu area, an area between Lumumba drive and Kamiti Road.
- Though there was a solid concept and architecture to enable publishing the system online, the system was not hosted online. This is due to the fact that to publish a system online, there are requirements to have a registered public IP address and domain name which are beyond the scope of the study.
- Though there was a solid concept and architecture to enable short message services, there was no integration between telephone service providers and the system for short messaging services. This is due to the fact that this calls for Service level agreement with telephone service providers and regulating bodies e.g. CCK etc, which are beyond the scope of the study.

## **1.6 Justification of the study**

To serve the customers effectively and efficiently it requires a reliable system which will take into account spatial element and web based solution, which is not currently available.

The application of this technology attempted to have power outage incidences timely, effectively and efficiently addressed by taking into account spatial considerations and a web based system.

The system will be beneficial to Kenya Power Company, its customers and government at large. The company will offer customer needs and satisfaction by addressing the power outage incidences promptly and efficiently, the customers will have an interrupted power supply which is beneficial for their daily tasks and will be able to report incident promptly and monitor their status, the government will be able to offer quality and efficient power services to its citizens through its agencies, the Kenya Power company which in turn will spur growth and sustainability of the country economy and developments.

## 1.7 Organization of the Report

The organization of the report is as illustrated in Figure 1.1

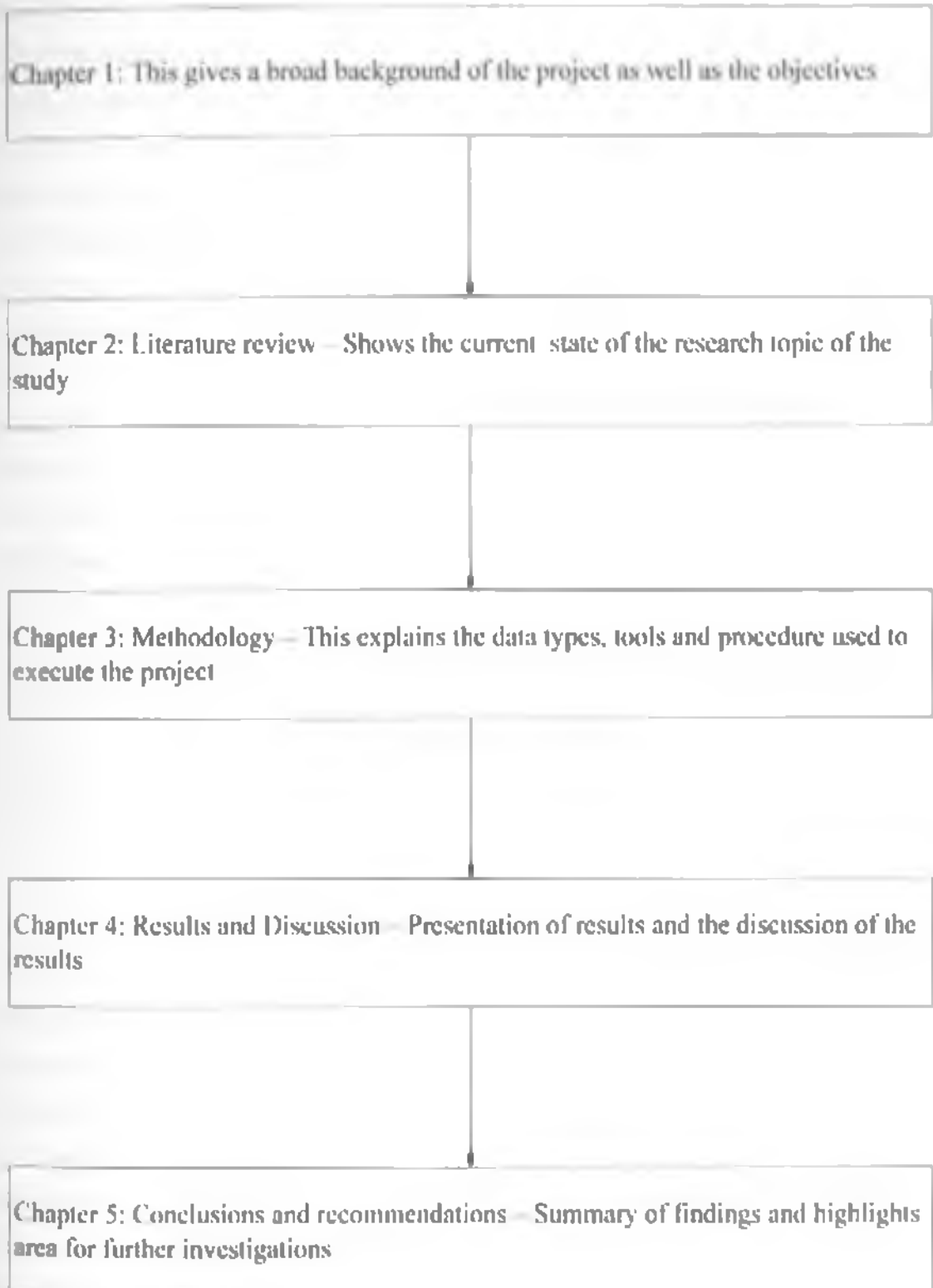


Figure 1.1 Structure of this report



## **Chapter 2: LITERATURE REVIEW**

### **2.1 Introduction**

Electrical power is the backbone of modern industrial society, and is expected to remain so for the foreseeable future. (Jones, D.A. 1991)

Electric power can refer to a quantity of electrical potential energy or to electrical energy per time that is provided commercially, by the electrical power industry. Electricity may be used to mean "wired for electricity" which means a working connection to an electric power station. Such a connection grants the user of electricity access to the electric field present in electrical wiring, and thus to electric power. (Wikipedia.org, 2012)

Electrical phenomena have been studied since antiquity, though advances in the science were not made until the seventeenth and eighteenth centuries. Practical applications for electricity however remained few, and it would not be until the late nineteenth century that engineers were able to put it to industrial and residential use. The rapid expansion in electrical technology at this time transformed industry and society. Electricity's extraordinary versatility as a means of providing energy means it can be put to an almost limitless set of applications which include transport, heating, lighting, communications, and computation. (Inventors, 2012)

#### **2.1.1 Electricity Generation**

An electric generator is a device for converting mechanical energy into electrical energy. The process is based on the relationship between magnetism and electricity. When a wire or any other electrically conductive material moves across a magnetic field, an electric current occurs in the wire. The large generators used by the electric utility industry have a stationary conductor. A magnet attached to the end of a rotating shaft is positioned inside a stationary conducting ring that is wrapped with a long, continuous piece of wire. When the magnet rotates, it induces a small electric current in each section of wire as it passes. Each section of wire constitutes a small, separate electric conductor. All the small currents of individual sections add up to one current of considerable size. This current is what is used for electric power.

An electric utility power station uses either turbine, engine, water wheel, or other similar machine to drive an electric generator or a device that converts mechanical or chemical energy to electricity. Steam turbines, internal-combustion engines, gas combustion

turbines, water turbines, and wind turbines are the most common methods to generate electricity.

Most of the electricity in the United States is produced in steam turbines. A turbine converts the kinetic energy of a moving fluid (liquid or gas) to mechanical energy.

Steam turbines have a series of blades mounted on a shaft against which steam is forced, thus rotating the shaft connected to the generator. In a fossil-fueled steam turbine, the fuel is burned in a furnace to heat water in a boiler to produce steam.

Coal, petroleum (oil), and natural gas are burned in large furnaces to heat water to make steam that in turn pushes on the blades of a turbine. Coal is the largest single primary source of energy used to generate electricity in the United States.

Natural gas, in addition to being burned to heat water for steam, can also be burned to produce hot combustion gases that pass directly through a turbine, spinning the blades of the turbine to generate electricity. Gas turbines are commonly used when electricity utility usage is in high demand. In 1998, 15% of the nation's electricity was fueled by natural gas. (Inventors, 2012)

Petroleum can also be used to make steam to turn a turbine. Residual fuel oil, a product refined from crude oil, is often the petroleum product used in electric plants that use petroleum to make steam. Petroleum was used to generate less than three percent (3%) of all electricity generated in U.S. electricity plants in 1998. (Inventors, 2012)

Nuclear power is a method in which steam is produced by heating water through a process called nuclear fission. In a nuclear power plant, a reactor contains a core of nuclear fuel, primarily enriched uranium. When atoms of uranium fuel are hit by neutrons they fission (split), releasing heat and more neutrons. Under controlled conditions, these other neutrons can strike more uranium atoms, splitting more atoms, and so on. Thereby, continuous fission can take place, forming a chain reaction releasing heat. The heat is used to turn water into steam, which, in turn, spins a turbine that generates electricity.

- Hydropower, the source for 9% of U.S. electricity generation, is a process in which flowing water is used to spin a turbine connected to a generator. There are two basic types of hydroelectric systems that produce electricity. In the first system, flowing water accumulates in reservoirs created by the use of dams. The water falls through a pipe called a penstock and applies pressure against the turbine blades to drive the generator to produce electricity. In the second system, called run-of-river, the force of the river current (rather than falling water) applies pressure to the turbine blades to produce electricity. (Inventors, 2012)

### **2.1.2 Other generating Sources**

- Geothermal power comes from heat energy buried beneath the surface of the earth. In some areas of the country, magma (molten matter under the earth's crust) flows close enough to the surface of the earth to heat underground water into steam, which can be tapped for use at steam-turbine plants

- Solar power is derived from the energy of the sun. However, the sun's energy is not available full-time and it is widely scattered. The processes used to produce electricity using the sun's energy have historically been more expensive than using conventional fossil fuels. Photovoltaic conversion generates electric power directly from the light of the sun in a photovoltaic (solar) cell. Solar-thermal electric generators use the radiant energy from the sun to produce steam to drive turbines.

- Wind power is derived from the conversion of the energy contained in wind into electricity. Wind power like the sun, is usually an expensive source of producing electricity

- Biomass (wood, municipal solid waste (garbage), and agricultural waste, such as corn cobs and wheat straw, are some other energy sources for producing electricity. These sources replace fossil fuels in the boiler. The combustion of wood and waste creates steam that is typically used in conventional steam-electric plants. Biomass accounts for less than 1% of the electricity generated in the United States. (Inventors, 2012)

### **2.1.3 Electric Power Transmission**

Transmission and distribution lines link electricity generators with consumers. Transmission lines make up a large component of the electricity transportation network. These are high voltage lines, supported by large steel towers, carrying electricity from the power plants to distribution systems. Large transformers step up the voltage to carry electricity more efficiently over long distances. As the electricity nears its destination, voltages are reduced or "stepped down" at substations. Finally distribution systems move electricity to where consumers need it – in homes, industries and on farms.

Because power plants, especially hydro stations, have often been built in remote locations, transmission lines often travel over long distances. Power lines can affect land through the siting of facilities and rights-of-way, vegetation management and the disposal of waste materials. There is also public concern over potential health effects of electric and magnetic fields from power lines and electricity facilities.

There are more than 160,000 kilometers of transmission lines in Canada. (Centre for Energy, 2012)

## **2.1 Kenya Power Company**

Kenya Power is a limited liability company which transmits, distributes and retails electricity to customers throughout Kenya. Kenya Power is a public company and is listed at the Nairobi Stock Exchange (NSE).

Kenya Power was formed in the Year 2011 after rebranding of Kenya Power and Lighting Company to Kenya Power. (Kenya Power, 2012)

### **2.1.1 Sources of Power**

In Kenya, electricity is mainly generated from hydro, thermal and geothermal sources.

Wind generation accounts for less than six megawatts of the installed capacity.

Currently, hydro power comprises over 60 percent of the installed capacity in Kenya and is sourced from various stations managed by the Kenya Electricity Generating Company (KenGen). Hydro power is generated by a process whereby mechanical energy produced by falling water is transformed into electrical energy. Kenya Electricity Generating Company Limited, (KenGen) is the leading electric power generation company in Kenya, producing about 80 percent of electricity consumed in the country. The company utilizes various sources to generate electricity ranging from hydro, geothermal, thermal and wind. Hydro is the leading source, with an installed capacity of 766.88MW, which is 64.9 per cent of the company's installed capacity.

Thermal electricity is produced by the burning of fuel (fossil, nuclear, biomass etc) to produce steam or gas which turns turbines that produce electricity. Geothermal electricity is generated from underground steam that is used to drive a conventional turbine to generate electricity. (Kenya Power, 2012)

### **2.1.2 Transmission and Distribution**

Kenya Power is responsible for ensuring that there is adequate line capacity to maintain supply and quality of electricity across the country. The interconnected network of transmission and distribution lines covers about 41,486 kilometers. (Kenya Power, 2012)

- **National grid**

The national grid is operated as an integral network linked by a 220 kV and 132 kV transmission network. There is a limited length of 66 kV transmission lines. The national grid impacts on the future growth of the energy sector because any new generation capacity must take into consideration the existing network and its capacity to handle new loads.

(Kenya Power, 2012)

- **Expansion**

Kenya Power reinforces the power transmission and distribution network by constructing additional lines and substations.

- **Efficiency**

Efficiency of the transmission and distribution network continues to be enhanced in both technical and non-technical aspects.

Technical improvements include re-conductoring of lines, installation of capacitors, and construction of additional feeders and substations.

Non-technical improvements include introduction of electronic meters, improvement of meter reading accuracy, fraud control and resolution of billing anomalies.

- **Supply and Demand of Electricity**

Kenya Power has more than 1,500,000 customers who consumed over 5,432

Gigawatt hours of electricity in the financial year 2008/9. During the year, the maximum daily electricity peak demand recorded was 1,072 MW. (Kenya Power, 2012)

### 2.1.3 Company Quality Policy

Kenya Power is committed to providing high quality customer service by efficiently transmitting and distributing high quality electricity that is safe, adequate and reliable at cost effective tariffs. The Board, Management and staff of Kenya Power are committed to effective implementation and continual improvement of the Quality Management System that complies with ISO 9001:2008 in order to consistently meet its customers and other stakeholder's requirements and expectations. (Kenya Power, 2012)

## 2.2 GIS For Utility Industries

A Geographic Information System integrates hardware, software, and data for capturing, managing, analyzing, and displaying all forms of geographically referenced information.

GIS allows us to view, understand, question, interpret, and visualize data in many ways that reveal relationships, patterns, and trends in the form of maps, globes, reports, and charts.

A GIS helps one answer questions and solve problems by analyzing and visualizing data in a way that is quickly understood and easily shared. GIS are now widely accepted as powerful and integrated tools for storing, visualizing, and analyzing spatial data.

(Arca, Alkan, Bayik and Seker, 2012)

GIS technology can be integrated into any enterprise information system framework.

## 1.1.1 GIS For Electric Industries

As an electric utility professional, one recognizes the value of good data. When that is linked to a geographic location on a map, one can visualize the big picture which gives a powerful decision-making tool.

GIS provides an efficient platform for data management, planning and analysis, workforce automation, and situational awareness (ESRI, 2012). Any utility company can leverage these capabilities since they can easily integrate GIS with the existing information technology infrastructure.

GIS has been employed in Electric industries with industry focus on Electric distribution, Electric Transmission, Electric distribution, etc

A real life case scenario for GIS for electric industries application includes the RAPDRP project launched in 2008 by the Government of India (CyberSWIFT, 2012)

### a) GIS in Electric Distribution

GIS ties together all the pieces of the electric distribution system for improved customer service, better management of assets and outages, and increased accuracy of data. Large and small distribution utilities around the world rely on GIS technology as the platform for network operations and asset management.

GIS touches on all aspects of electric distribution, including Smart Grid/Asset management, Outage management, Workforce automation, Renewable energy, Regulatory compliance and Joint Use

Use of GIS in electrical distribution can be manifested as applied by Kootenai Electric, the member-owned cooperative based in Hayden, Idaho (Wyland, 2009)

### b) GIS in Electric Transmission

Transmission utilities rely on GIS for modeling, management, and communication. With GIS, you can model routes and determine rights-of-way that respect the land and landowners. You can also manage assets and vegetation while ensuring regulatory compliance.

Because one can easily link data within GIS to location, one can communicate accurate information across all departments in the organization and externally to generation and distribution companies.

GIS touches all aspects of electric transmission, including Asset Management, Field Maintenance and Inspection, Vegetation Management, Transmission Network Design and Regulatory Compliance

GIS has been applied in electric transmission, case point as in Vermont Electric Power Company (VELCO), employed geographic information system (GIS) technology from ESRI to create an innovative solution called the Vegetation Inventory Program (VIP). The solution enabled VELCO to facilitate the creation of map books of the entire system, deliver ortho-photographs and field data, and make information seamlessly accessible to workers in the field and the office. (ESRI, 2012)

#### c) **GIS in Electric Generation**

Developers and operators of electric generation plants rely on GIS for almost all tasks ranging from site selection to operations management. GIS enable consolidation of multiple data sources into one map-based platform to determine land suitability, including proximity to resources and transportation. Once the site is up and running, one can rely on GIS technology to meet licensing requirements and maintain infrastructure.

GIS touches all aspects of electric generation, including Renewable Energy, Generation Site Selection, Licensing and Environmental Analysis.

A real life case scenario on application of GIS in electrical generation can be depicted as in Danish Energy (DONG Energy) company. (Homann, 2012)

### **2.2.2 Case Study: Application of GIS in Utility industry.**

A case scenario of GIS utilization in Northeastern Rural Electric Membership Corporation (REMC), Indiana, USA describes a real scenario how GIS can be utilized in Utility industries. (ESRI, 2012)

#### **a) Improving REMC Outage Response with Mobile GIS**

REMC is a consumer-owned utility that supplies electric power to members in northeastern Indiana. More than 26,000 households and businesses receive power from Northeastern REMC. Utility linemen have traditionally navigated the service territories by memory, armed with a handful of paper maps. However, over the years, the once sparsely populated service territory has become heavily populated suburbia.

## **b) REMC Challenge**

Northeastern REMC field crews were working with outdated paper maps of the service territory, and the company had not yet mapped a single meter. The utility needed to create accurate, digital maps of its entire network. To satisfy the needs of its growing suburban customer base, Northeastern REMC was also tasked with enabling field crews to improve outage response time. To keep its customers and staff better informed, the utility had to improve network data accuracy as well.

Northeastern REMC needed to create digital maps of its entire network, to enable field crews to respond more quickly to outages, and improve network data accuracy to keep customers and staff informed.

## **c) REMC Solution**

Northeastern REMC selected GIS technology from ESRI. Using GIS, the utility company was able to map the entire network. Field crews would then have access to digital maps, up-to-date data, and new routing functionality. Mobile GIS would enable updates from the office and the field to ensure that customers and staff members would have the most accurate data.

To remap its entire service territory, including every customer meter, the utility took its GIS to the field. A mobile GIS application allowed the utility to transfer data to and from the field, keeping information updated throughout the organization. To ensure that GIS data is automatically updated to the mobile application, the utility deployed GO! Sync<sup>®</sup> Mapbook by IC Technology.

To speed field crew response during outages, Northeastern REMC employed new routing functionality with road centerline data from local counties. Utility field crews now use a GPS device built into their laptops to search for facilities or equipment and generate the optimal driving route.





*Figure 2.1 Color-coding facilities by their electrical phase and tracing functionality allows field personnel to quickly assess the severity of an outage.*

(Source: <http://www.esri.com/library/casestudies/northeast-remc.pdf> accessed online, March 2012).

#### **d) REMC Results**

The utility's entire service territory was mapped, increasing the accuracy of information for customers and staff. Field crews now use mobile GIS to update from the field, ensuring up-to-date network data. Crews have improved outage response with routing functionality and GPS capabilities. GIS data is now accessible throughout the enterprise, with approximately 43 users on different devices in several departments.

It was established that using GIS technology, we can deliver the right information to the right hands at the right time. Field crews can view, search, and revise GIS data and use GPS for facility locating and routing. This improves the flow of accurate information from the field to the office to the customers.

By integrating its other systems with GIS, the utility is able to use meter status information from its advanced metering infrastructure (AMI) to create a network health report map. The map is used as a troubleshooting aid and to help ensure that the network is reporting the expected configuration. GIS-based electric network data also contains intelligence on power source and feed direction. A tracing functionality within GIS enables field staff to quickly determine tie points and load information during outage situations.

### 2.2.3 Critique

At Indiana case study they apply GIS technology which enabled its field crews to improve outage response time, keep its customers and staff better informed.

Likewise this research endeavours to apply the same idea and address the existing gap to bring efficiency at Kenya power in addressing power outage incidences.

### 2.2.3 Research Gap

Hydro generated electricity is the main source of power in Kenya.(Kenya Power, 2012). However it highly prone to vagaries of weather especially the droughts that lowers the generation capacity. The Kenya Power company is overwhelmed by many emergency responses to manage power outages. However, to locate the locations where response is needed, the field personnel's relies on phone calls made to the customers. This delays the response time and waste other resources like fuel. There is need to design efficient tool that will facilitate fast response and proper allocation of resources (personnel and materials). Although the potential of GIS in improving efficiency in utility management has been demonstrated mostly in developed countries, such tools has not been developed or tested in Kenya. This research therefore designs and evaluates the efficiency of a GIS and web-based application tool for power outages response management. The potential of a web-based GIS system in efficient management of power response operations is evaluated.

The research gaps that this study attempted to fill were lack of location based considerations and web based solution when addressing power outage incidences, which can be achieved by application of GIS and web mapping technology at Kenya Power Company, to address spatial consideration as well as web based solution when addressing power outages.

This will ensure reliable system is in place which will ensure timely, efficient and effective power outage incidences resolutions have a portal where the company will interact with their customers and a system which can be used for report generations to aid in decision making during addressing power outages.

The system will be of beneficial to Kenya Power company, its customers and Kenyan government as customers will have steady power supply, be able to timely and efficiently report incidences and track their status, the company will be able to meet customer needs and satisfaction which will translate to growth and sustainability of the country economy.

## Chapter 3: METHODS

The methodology used included creation of spatial web based system which makes use of ASP.NETMvc4 web framework and RavenDB database as described in section 3.3.

The system included details about customer's, customer locations, a web based solution to display customer's location and other information and also ways to customize the system.

The web displayed maps were used to show the customers location, the direction to customer locations among others.

### 3.1 Study Area

The study focused on a section of Roysambu area, Kasarani constituency, Nairobi North district, in Nairobi County, an area between Lumumba Drive and Kamiti Road. The study area lies between latitude  $1^{\circ} 12' 50''$  S and  $1^{\circ} 13' 0''$  S and longitude  $36^{\circ} 53' 10''$  E and  $36^{\circ} 53' 30''$  S.

Nairobi North district had a population of 1,062,086 as per Kenya population census of 2009. (KNBS, 2012)

The Kasarani area encompasses an urban residential area, International stadium (MISC Kasarani), Various industries including central glass industries and others, various schools and universities including USIU, PAC and others, various hotels including Safari park and others, Various businesses, etc.

Kenya Power has both three-phase and single-phase electrical power connection in this area, they also have a power substation located at Roysambu area.

The study area was selected due to proximity to Roysambu power sub-station and knowledge of the area.

The study area is as shown in figure 3.1

## Area of Study



Figure 3.1 Area of Study Map.

### 3.2 Data and Tools

Various data and tools were applied in development of the web based spatial system.

#### 3.2.1 Data Sources

To design a reliable and effective spatial web based system, there were various data sets that were utilized for the research project, as shown in table 3.1.

The project utilized secondary data from various sources.

Table 3.1 Data sources

GIS Data Name	Data Source	Data Characteristics	Year
Urban area	Google earth	Raster Image	2012
Electric Meter population	Kenya Power	attribute	2011
streets	Ministry of Roads	Vector	2009
Aerial Photograph	Ramani Geosystems	Raster image 25 cm resolution	2010
Power Customers	Kenya power	attribute	2011

#### 3.2.2 Tools

There were various tools that were applied during this study, these included but not limited to:

- i. Computer – This was used as the tool to develop the system, it also housed the system and the acquired data. The computer used was Dell model, with the following specifications 320 GB harddisk, 2GB RAM, windows 7 professional operating system, 17 inch monitor, MS Office 2007 Professional
- ii. Printer – This was used to print the study report, the printer used was HP Deskjet 3000-j310a model.
- iii. Google Maps API – These enabled to embed Google Maps site into our web based system.
- iv. Raven Database management system – this is an open source 2<sup>nd</sup> generation document Database. It was used to develop the spatial database.
- v. ASP.NETMVC 4 – This was used as framework for building scalable, standards-based web based applications using well-established design patterns and the power of ASP.NET and the .NET Framework. Was used to develop the web based systems. Beta version was used which was a free copy.
- vi. ArcGIS 10 software (evaluation copy) – This was used for map projections.

### 3.3 Developing GIS based incidence system for power outage

The system included the development of a web based spatial system to aid in effective addressing of Kenya power incidences with emphasis on the power outage.

#### 3.3.1 Conceptual Framework

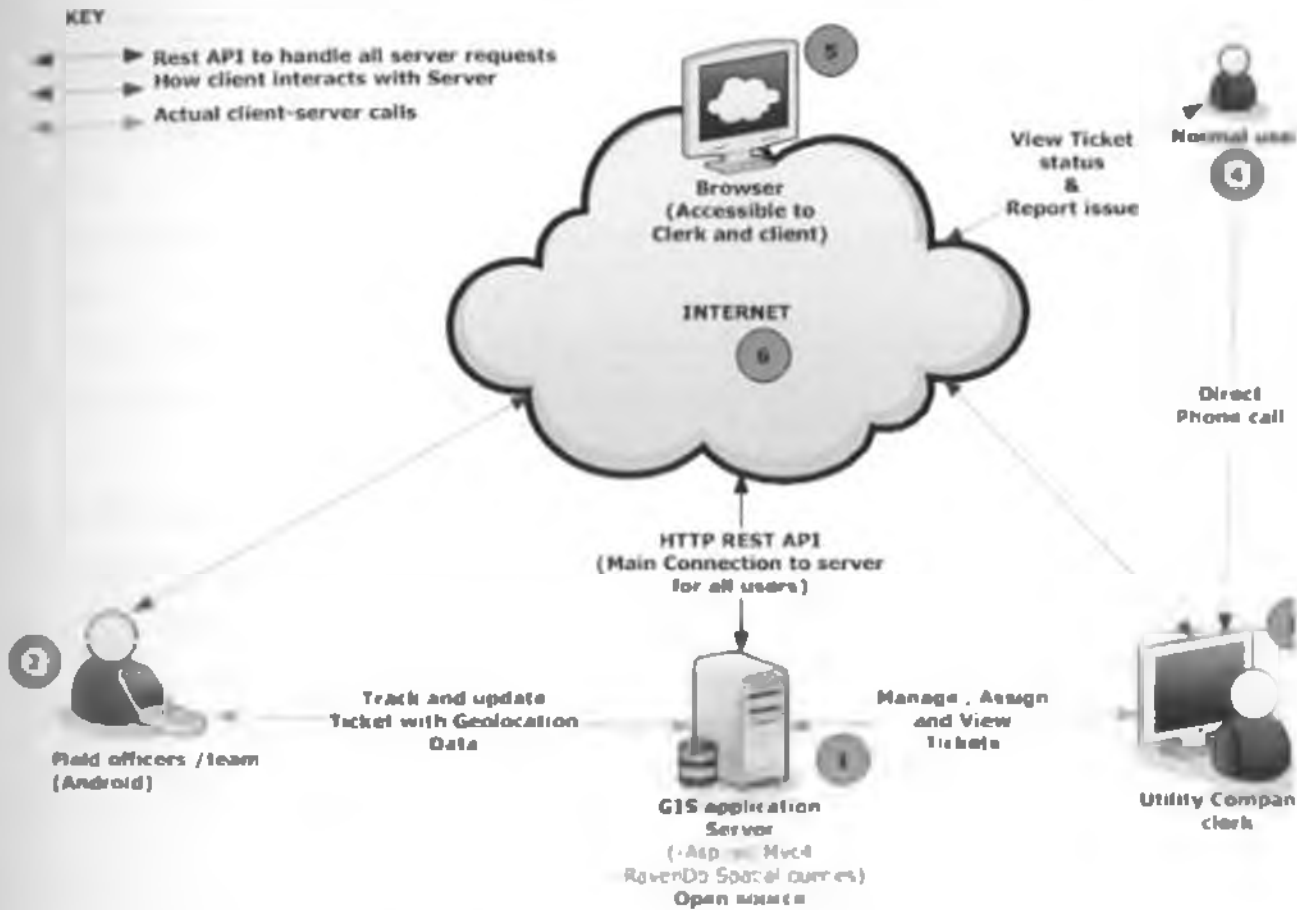


Figure 3.3 Conceptual Framework of Spatial web based system

#### System entities

##### 1 The main GIS server

This server will host the entire application and the database that will be used to store the utility meter geo location and other relevant data. It will make use of RavenDB for the database while ASP.NET MVC4 will be used to create the application that will allow users and the various devices to communicate with the database. This server will publish its interface via the browser (5) and via the HTTP REST architecture to allow devices (2) to communicate with the server. It will also handle authentication of the various users.

##### 2 Field officers mobile clients

This client running on android mobile operating system, will allow designated personnel to be able to query the GIS server (1) and get information regarding various tickets and utility meter availability within a given geographic region.

3. Utility company clerk

These are personnel who will be charged with the responsibility of managing utility meters by creating, updating and managing queries submitted by client  
They will interact with the system via the web browser interface.

4. Normal user

The normal user will be able to create/ submit tickets to the system and be able to track the progress of the same.

5. Browser

Main interface to the system. All clerks will be able to access the system via this.

6. Internet

The main infrastructure that will be required to allow for this system to operate effectively and allow devices to interconnect and share information

### 3.3.2 Data Collection

The data was collected from Kenya power offices, Ministry of roads, Ramani Geosystems and also downloading from Google earth.

The data was sampled using cluster sampling method, whereby the data was clustered by geographical area, an area with various blocks of building and various road networks was selected to ensure optimal presentation of the area

### 3.3.3 Data Presentation

The project takes into account secondary data from the utility company, ministry of roads, Ramani geosystem and from Google company.

The data was presented using the web based system and also by use of google maps.

### 3.3.4 GIS database development

The GIS database application makes use of Raven Database which is a document based database management system. Document databases are known for their ability to scale well and the quick and robust mapping of the business logic.

The spatial database was developed using RavenDB Database, a document based database management system. RavenDB is an open source 2<sup>nd</sup> generation document database. Document databases are known for their ability to scale well and the quick and robust mapping of the business logic.

RavenDB is a transactional, open-source Document Database written in .NET, offering a flexible data model designed to address requirements coming from real-world systems. RavenDB allows you to build high-performance, low-latency applications quickly and efficiently.

Data in RavenDB is stored schema-less as JSON documents, and can be queried efficiently using Linq queries from .NET code or using RESTful API using other tools. Internally, RavenDB make use of indexes which are automatically created based on your usage, or were created explicitly by the consumer.

RavenDB is built for web-scale, and is offering replication and sharding support out-of-the-box.

The classes and schema for the database is as shown in figures 3.4 and 3.5



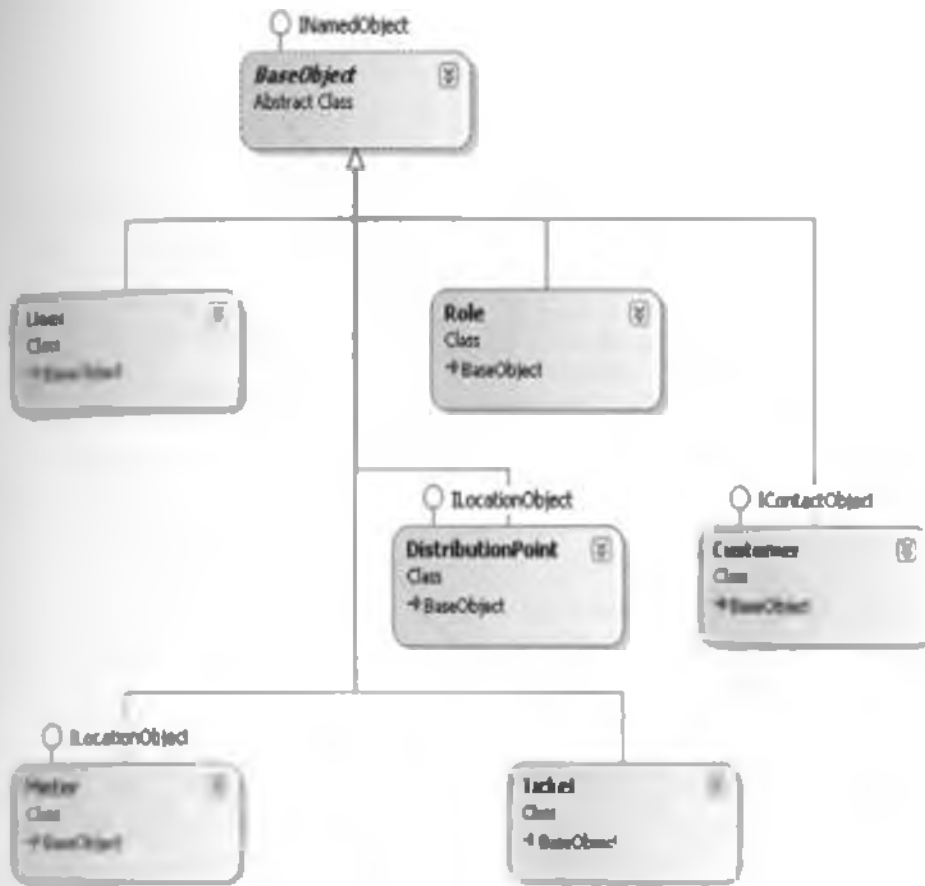


Figure 3.4 Database classes

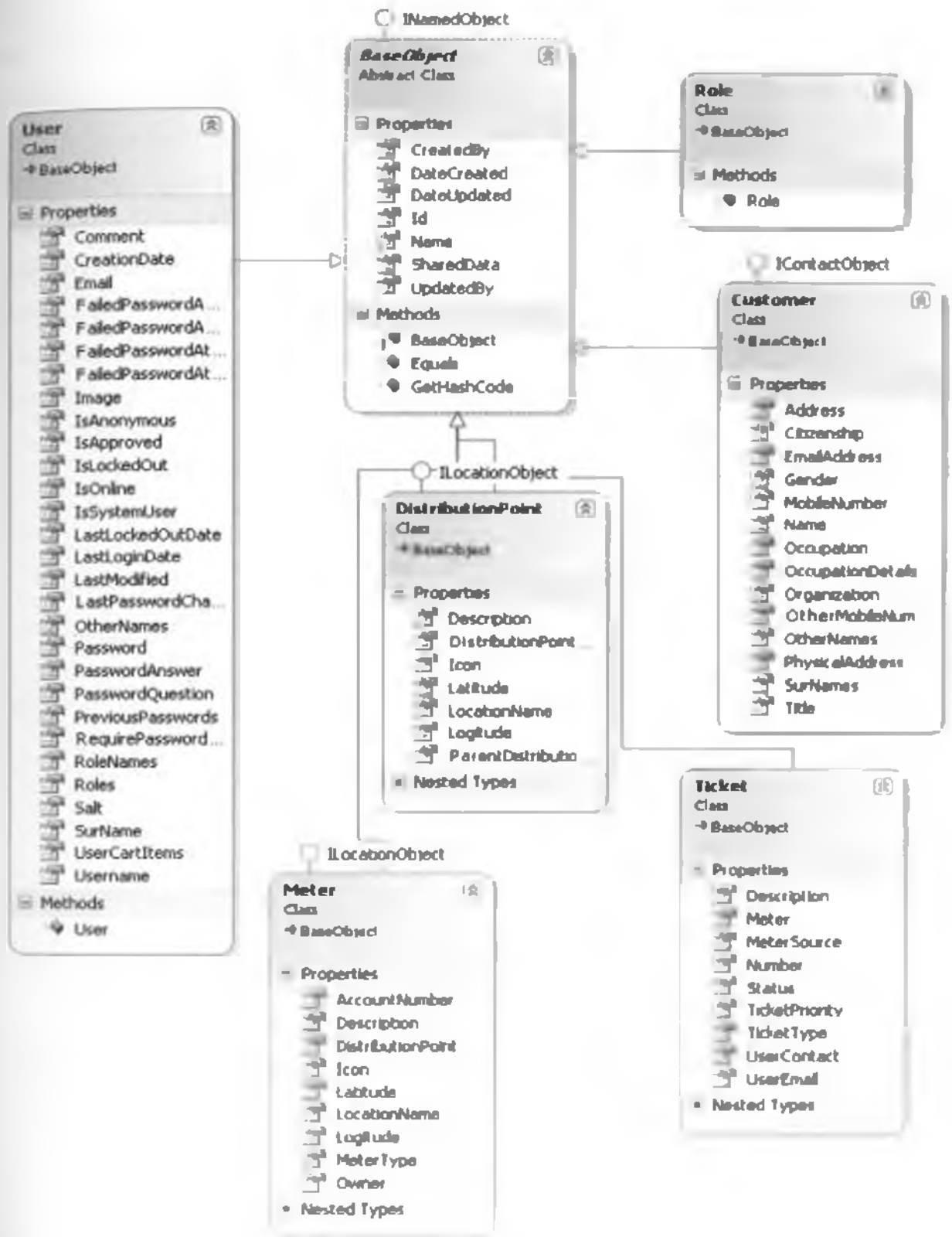


Figure 3.4 Database schemas

### 3.3.5 Web based system development

The system made use of ASP.NET Mvc4 web framework to publish data which is made available via a REST API for all mobile clients to access and via the web interface to allow for user access to the system functionality. The REST API will allow the ability to enable plugin and add new clients without having to modify the existing core e.g. it makes it possible to add mobile phone application which can be used in smart phones e.g. Android phones apps.

This design allows for decoupling and hence easier extensibility of the application core. The system can be used in different platforms including the smart phones applications

## Chapter 4: RESULTS AND DISCUSSION

In this chapter outputs of the spatial web based system are discussed.

### 4.1 Web based system

The Utility Mapper System, a spatial web based solution comprising of a spatial database and web based system to address spatial considerations and web based solutions for addressing power outage incidences was developed and tested.

The system uses ASP.NET MVC4 web framework to publish data which is made available via a REST API for all mobile clients to access and via the web interface to allow for user access to the system functionality.

The Utility Mapper System allowed customers to login and create ticket online.

One can login in to the system or can create a ticket to report the power outage incidence. On the left hand side of the Utility Mapper System, there is the create ticket and login section.

The figure 4.1 shows the system display page.

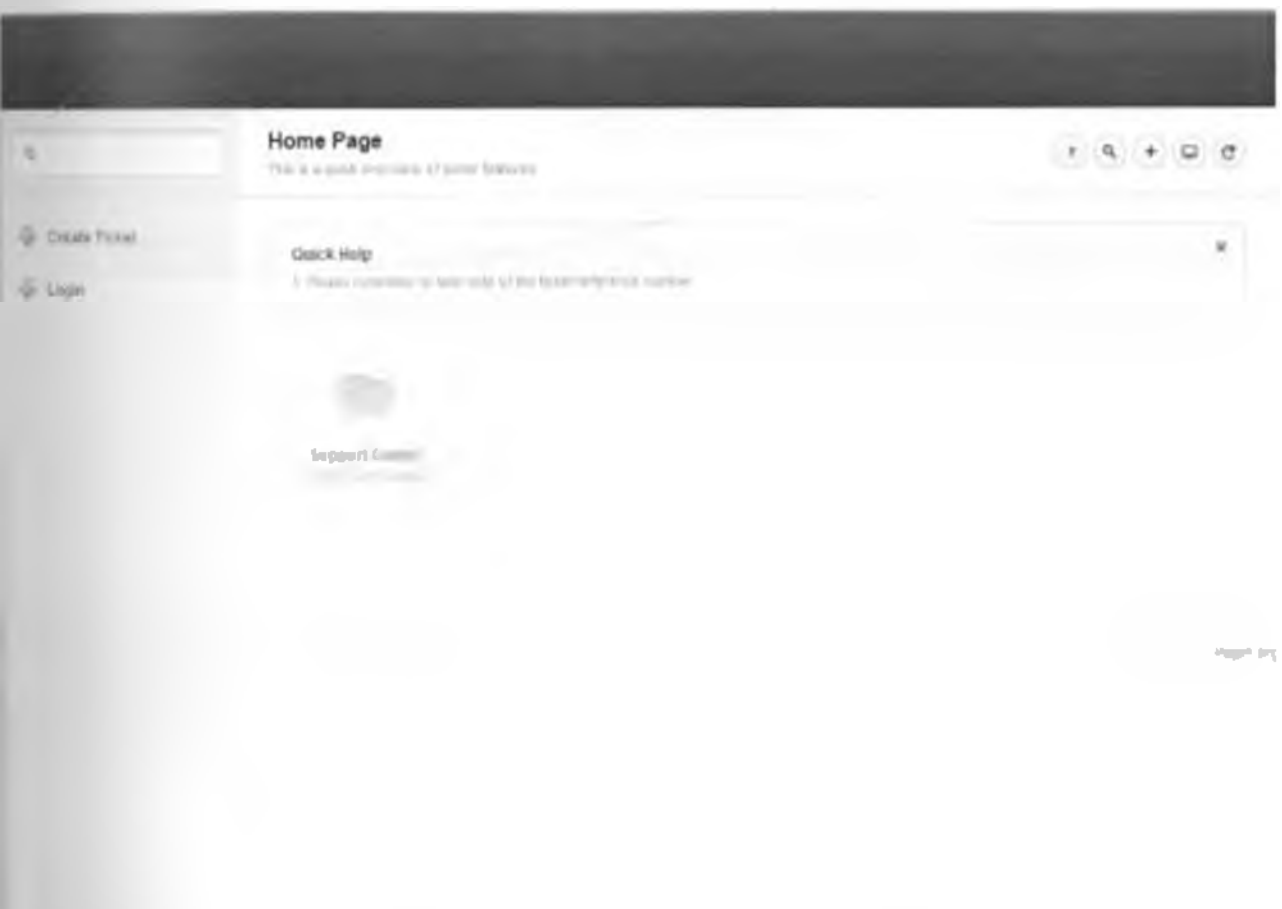


Figure 4.1 system display page; showing the system display page

For one to use the system one has to be logged into the system.

The system login requires the user name and user password.

The password has to be alphanumeric and minimum of seven characters.

After keying in the username and password, one has to click on log in, so as to get access to the system.

The login page is shown in figure 4.2



**Figure 4.2 System login page; showing user login page, requires username and password**

The web based system was designed to display the tickets, meters, customers, users and distribution points i.e. transformers, power stations and others.

After login to the system, on the left hand side, there is dashboard and management section.

The figures 4.3 and 4.4 shows customer meter locations, distribution point

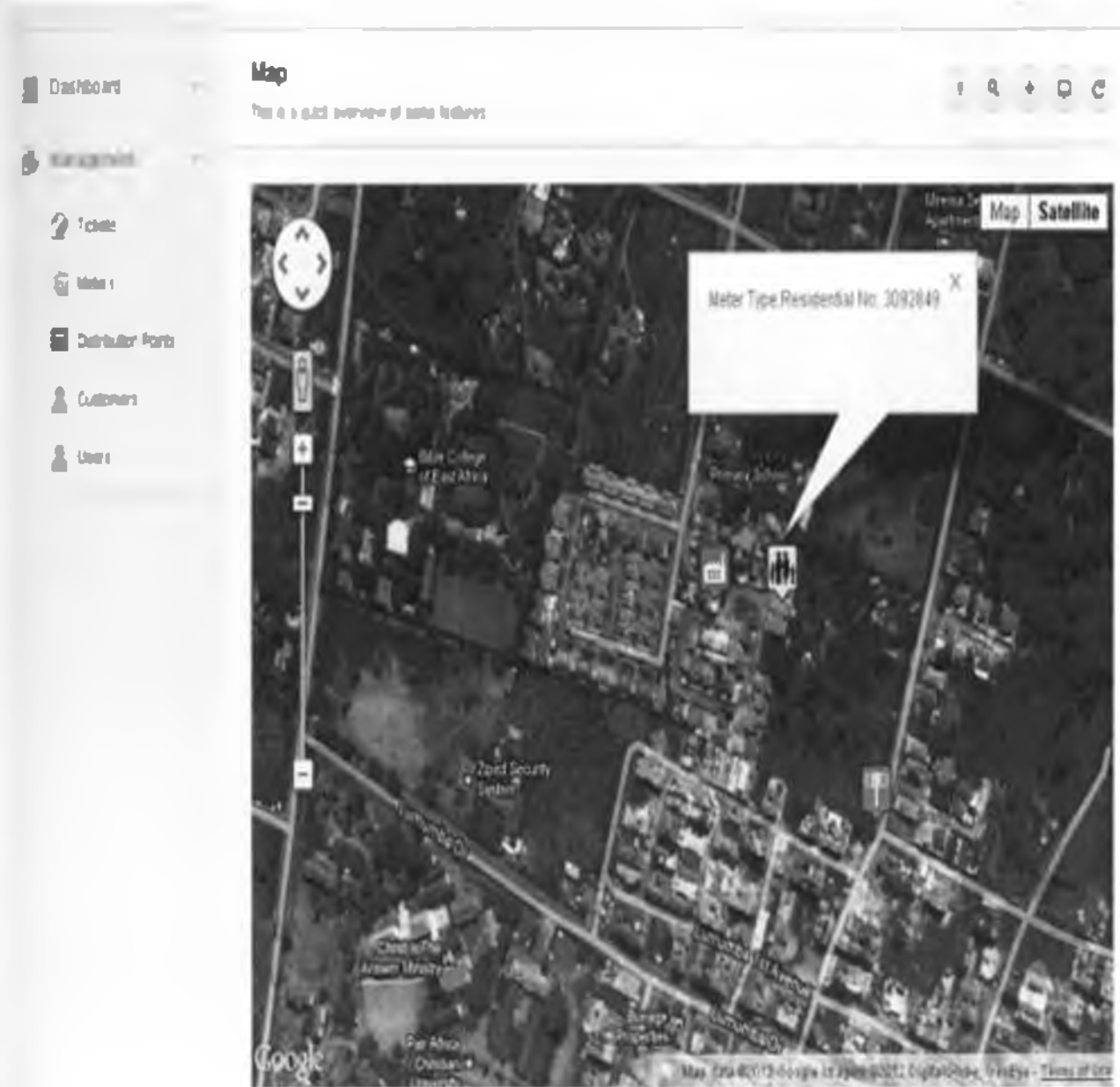


Figure 4.3 showing residential meter location on the Utility Mapper system

The Figure 4.4 shows the location of a specific main transformer on spatial web based system.

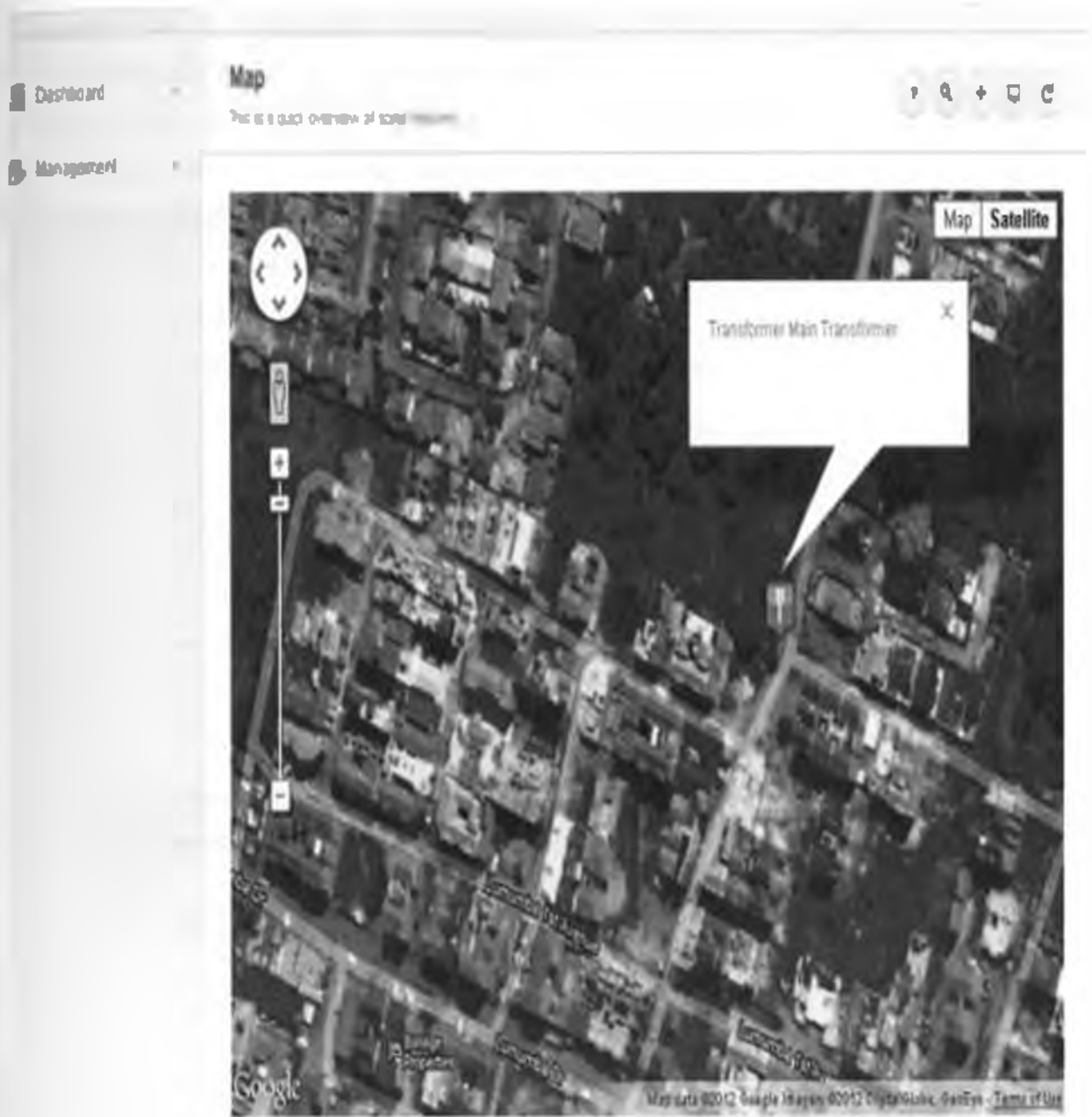


Figure 4.4 showing transformer location on the Utility Mapper system

## 4.1.1 Creating meters

Customer location will be captured by creating power meters on the system –

To create a meter, details including the name, description, location name, meter type, customer and nearest distribution point i.e. transformer will have to be captured.

The location will be captured by selecting the location on the Google map which will display the location coordinates.

To create a meter on the Utility Mapper system, click on meter under management section.

This is as shown in figures 4.5 and 4.6.

One can select either map or satellite option on the google map



Figure 4.5 how to create customer meter selecting satellite option on Google map



The figure 4.6 shows how to create a customer meter and details to fill, when selecting Map option on the Google map



Figure 4.6 how to create customer meter selecting map option on Google map

Through the system it's possible to display the location of the meter on the map, both the residential or commercial meter as shown in figures 4.7 and 4.8

The figure 4.7 shows location of a residential meter Number 3092849 on the Utility Mapper System

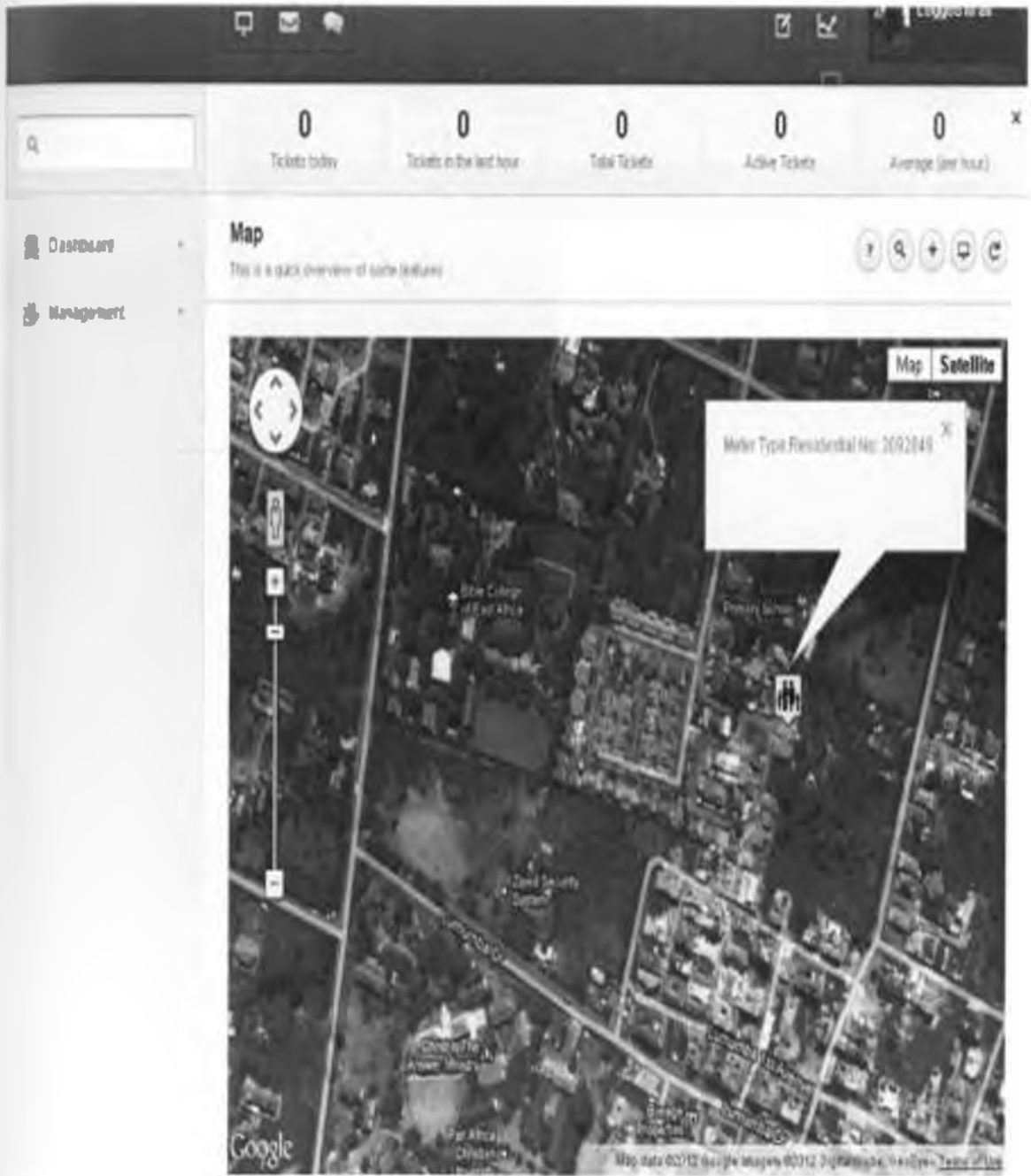


Figure 4.7 showing location of a specific residential power meter

The figure 4.8 shows location of a commercial meter Number 3092849324 on the Utility Mapper System.

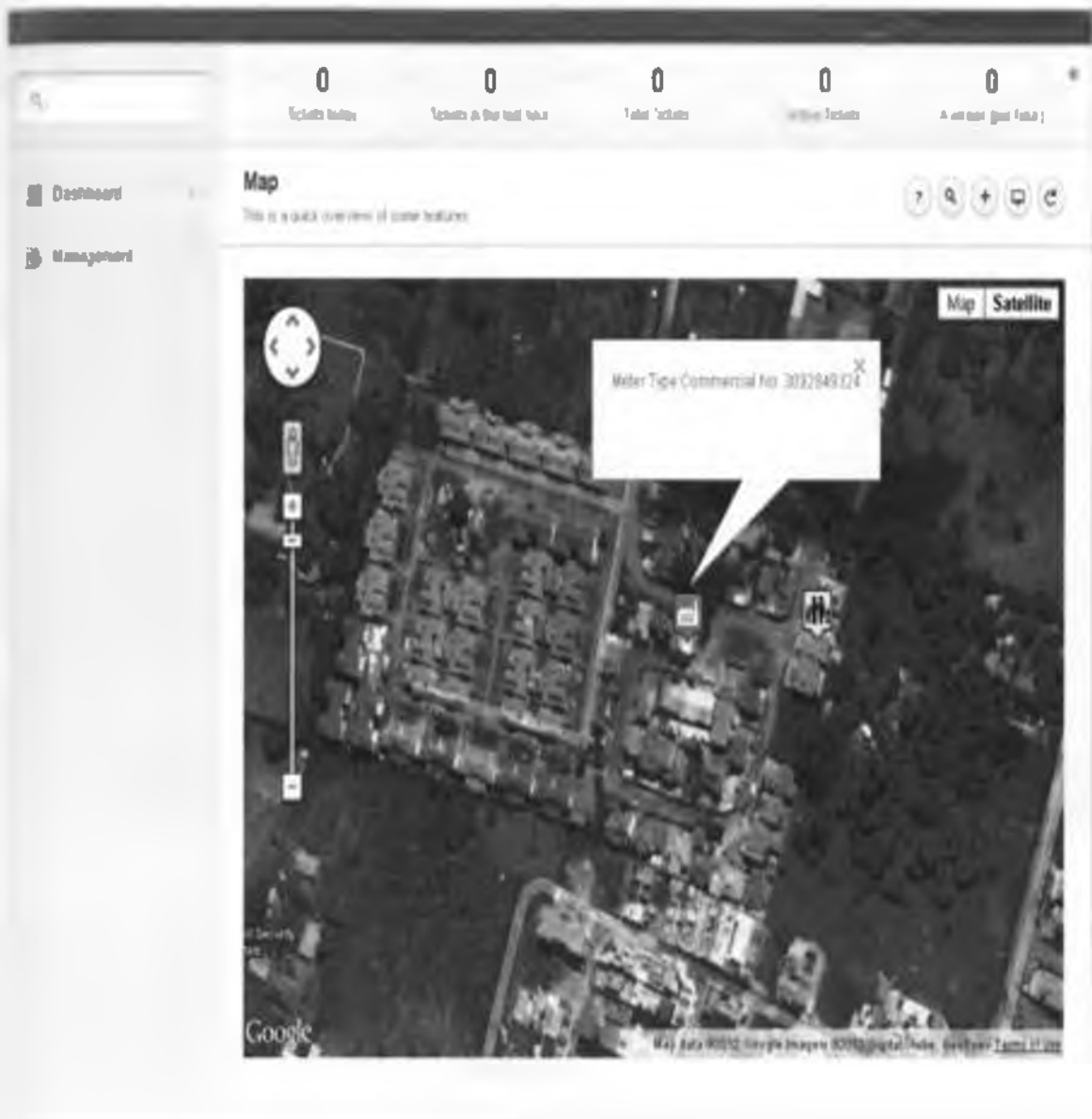


Figure 4.8 showing location of a specific commercial meter

## 4.1.2 Raising a ticket

The system will be used to manage power outage incidences by raising tickets for all reported incidences.

A ticket will be raised by the customer care personnel after receiving the customer incidence either through a phone call, walk in customer or a customer can report the incidence by raising the ticket through the system.

To raise a ticket one has to be logged into the system and fill details as in figure 4.9.



Figure 4.9 showing how to create/raise a ticket

After raising the ticket, the ticket number are forwarded to field team personnel who gets the ticket number through the Utility Mapper System or through the company android enabled phones.

The customer will receive the ticket number through a phone call, direct from customer care, short message service or through an E-mail.

The system can also show the number of tickets, active tickets, tickets by day and hours, average tickets per hour, spatial details of items e.g. transformer as shown in figures 4.10 and 4.11

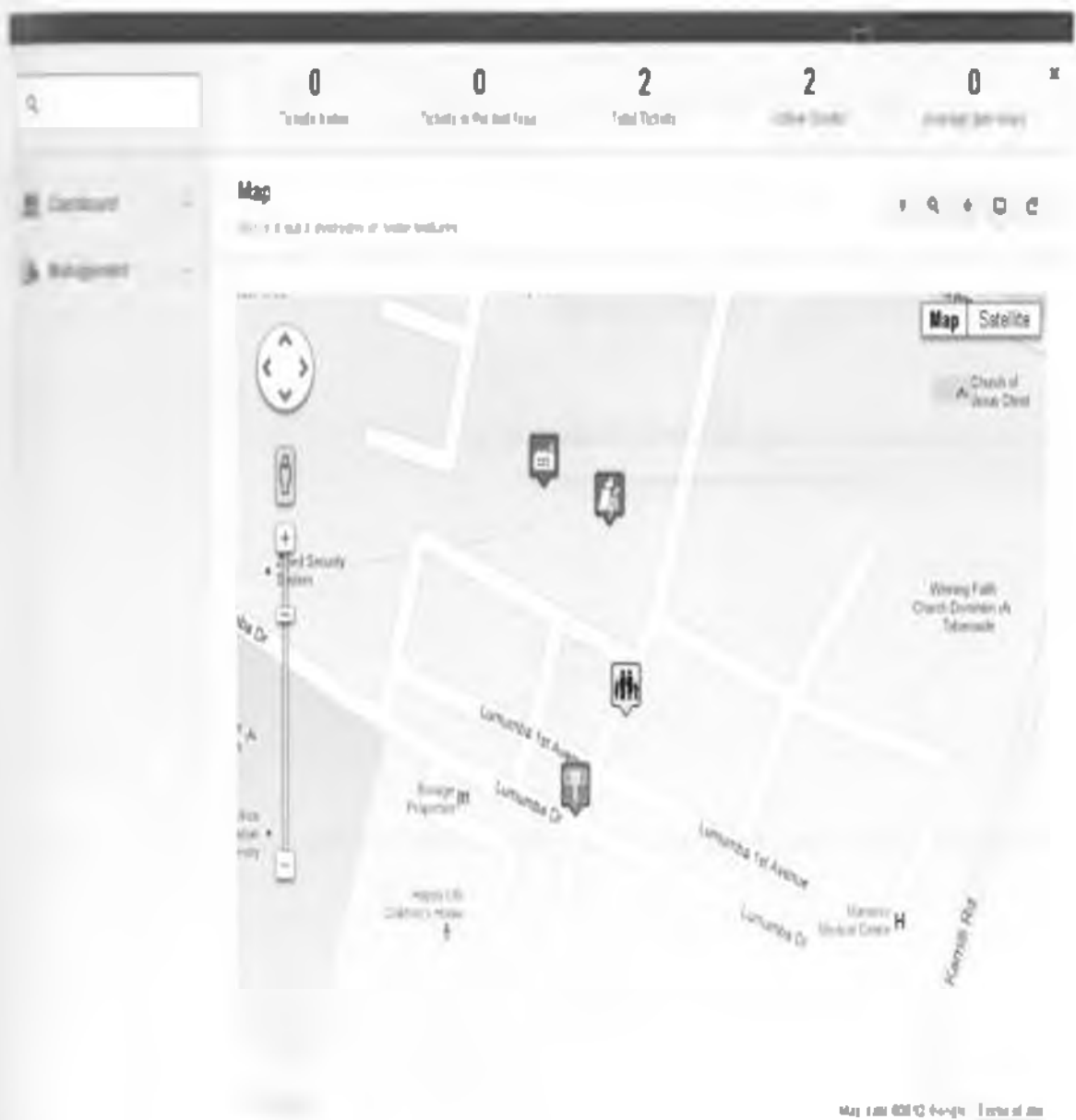


Figure 4.10 showing number of active tickets and total tickets

The figure 4.11 shows number of active and total tickets and also spatial details of a specific transformer in the Utility Mapper System.



Figure 4.11 showing number of tickets and spatial details of a specific transformer

#### a) Managing tickets

The Field team personnel will use the ticket number to locate the exact location of the incidence, status details and time are also displayed as shown in figure 4.12

The figure 4.12 shows an open ticket for a reported power incidence, it displays the Name of power user; David Muna, Status of ticket which is in open status, Ticket Number: 1CB39CDE4EE41EECC, date and time when ticket was created which is 5<sup>th</sup> May 2012 at 4:51:05 AM.

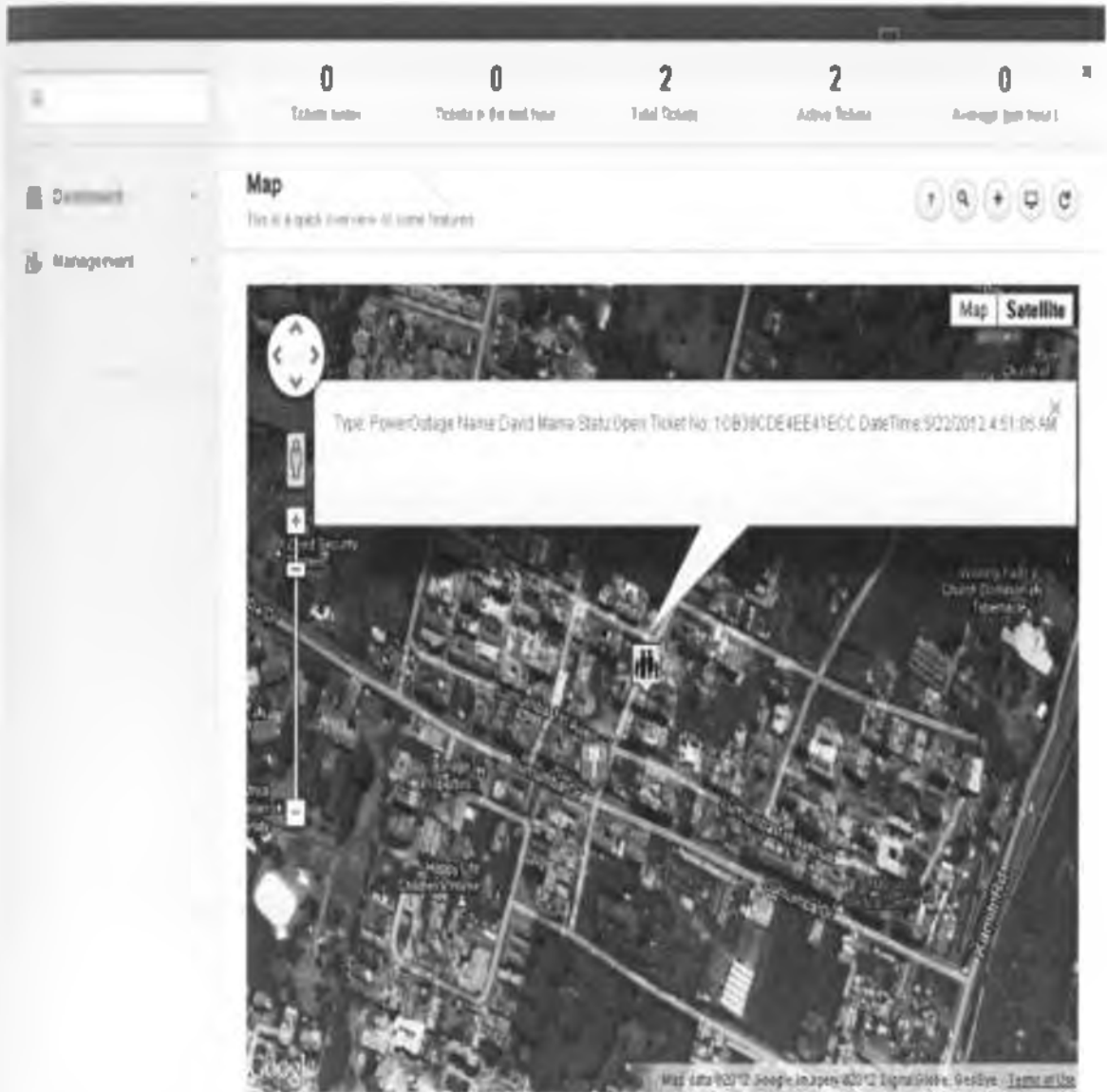
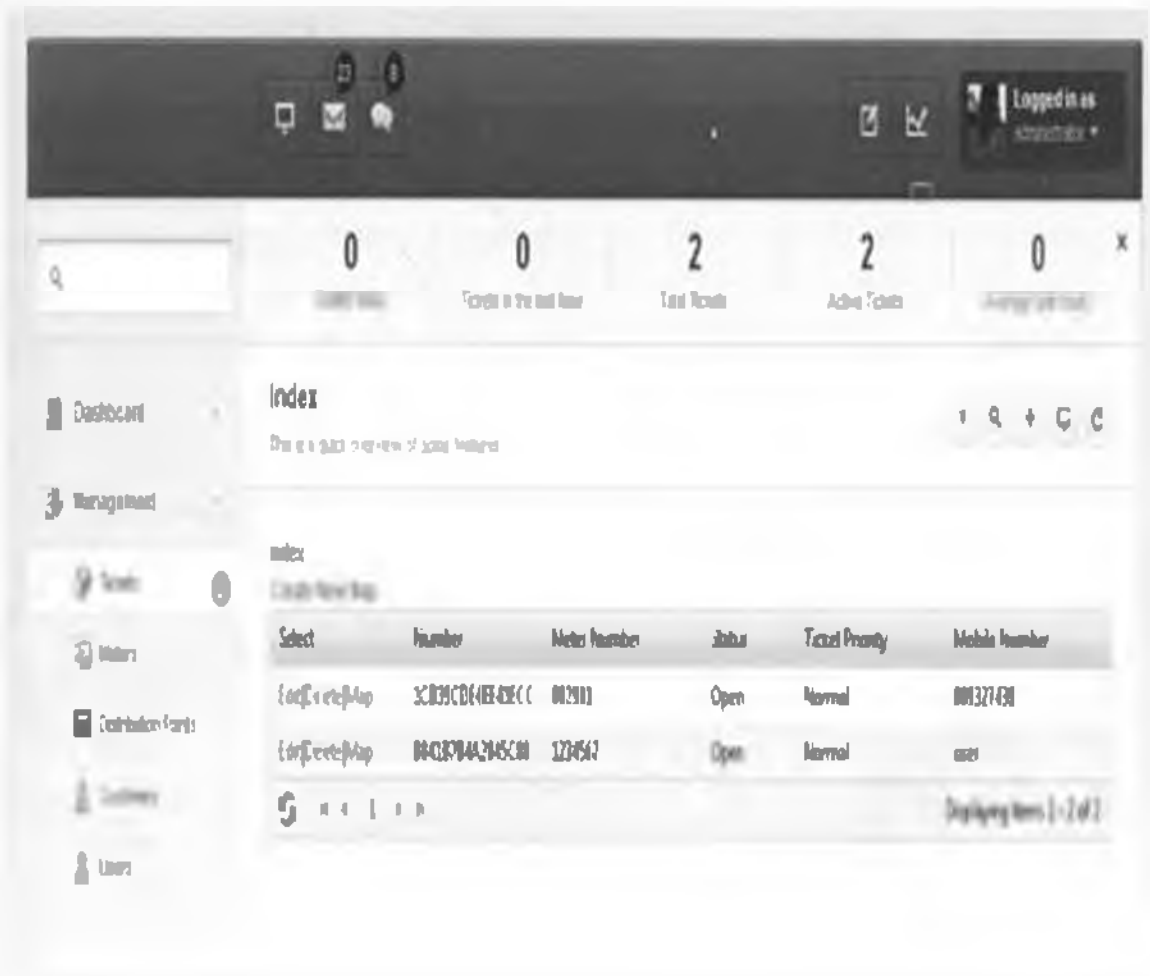


Figure 4.12 showing power outage ticket displaying customer location, ticket number, user name, date and time

## b) Tickets List

Through the system, it's possible for agents and supervisors to view all tickets at a glance. The Figure 4.13 shows a sample of a list of raised tickets.

The ticket list will display the meter number, ticket status, ticket number, ticket priority, user contacts, etc.



The screenshot displays a dashboard interface for ticket management. At the top, there is a navigation bar with a search input, notification icons, and a user profile dropdown showing 'Logged in as Administrator'. Below the navigation bar, a summary row shows five metrics: 'Total Tickets' (0), 'Tickets in the last hour' (0), 'Total Tickets' (2), 'Active Tickets' (2), and 'Average wait time' (0). The main content area is titled 'Index' and includes a 'Create New Map' button. A table lists two tickets with columns for 'Select', 'Number', 'Meter Number', 'Status', 'Ticket Priority', and 'Mobile Number'. The table shows two rows of data, both with 'Open' status and 'Normal' priority. A pagination bar at the bottom indicates 'Displaying items 1 - 2 of 2'.

Select	Number	Meter Number	Status	Ticket Priority	Mobile Number
{def:etc}Map	3C039CD64E842ECC	002911	Open	Normal	001327438
{def:etc}Map	0642870442345C00	1234567	Open	Normal	user

Figure 4.13 sample of a list of tickets



### 4.1.3 Customers

From the Utility Mapper System it's possible at glance to get the list of all customers.

The list of customers will include details such as Customer Name, title, Email address, Mobile number, physical address, etc.

The figure 4.14 shows a sample of a list of power customers.

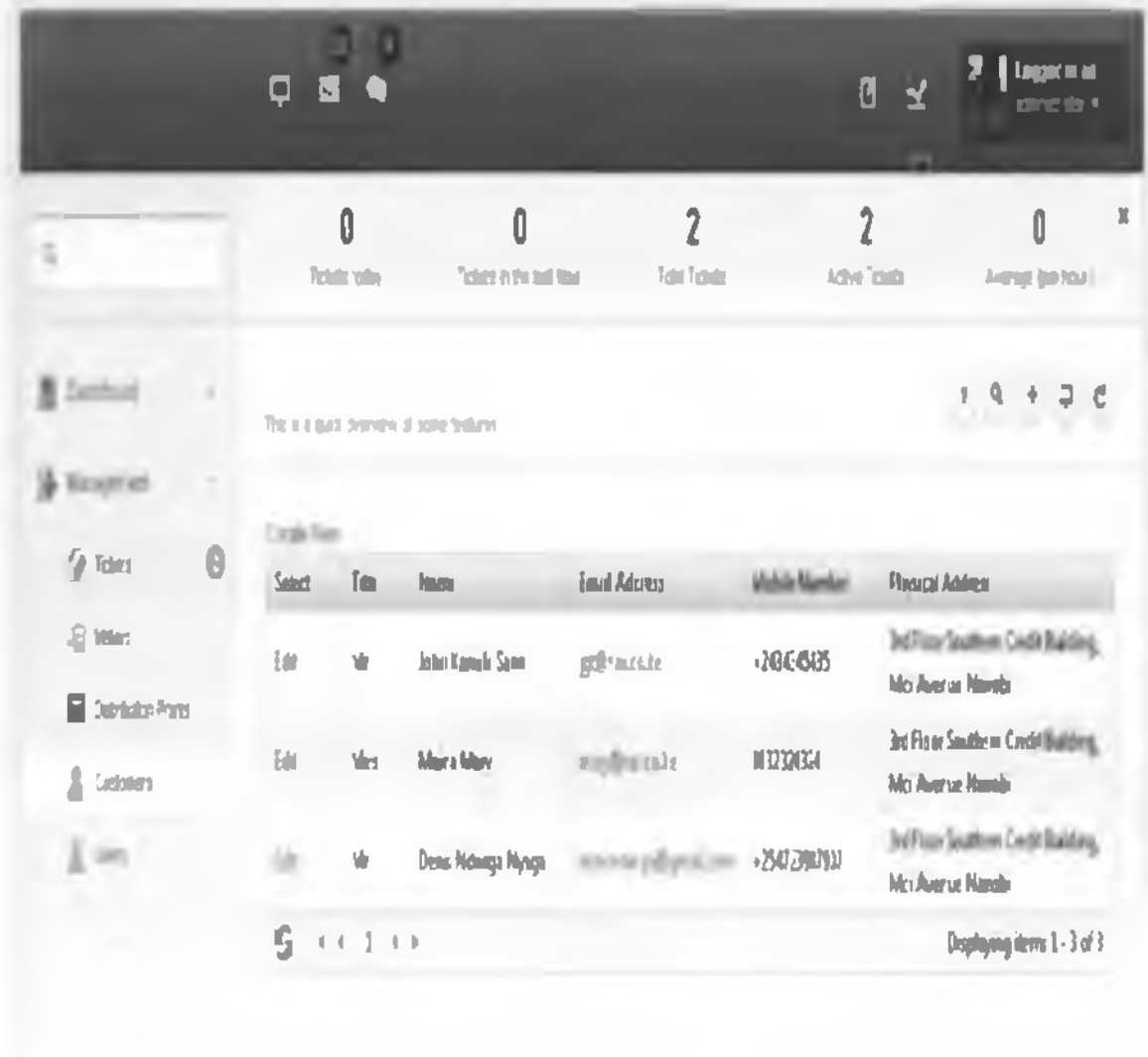


Figure 4.14 sample of a list of power customers

#### 4.1.4 Distribution points

The Utility Mapper System can generate a list of power distribution points including the transformers and power station.

These are points where electricity will be transmitted and distributed from.

The details included are distribution point name, Location, distribution point type, etc.

The Figure 4.15 shows a sample of a list of distribution points.

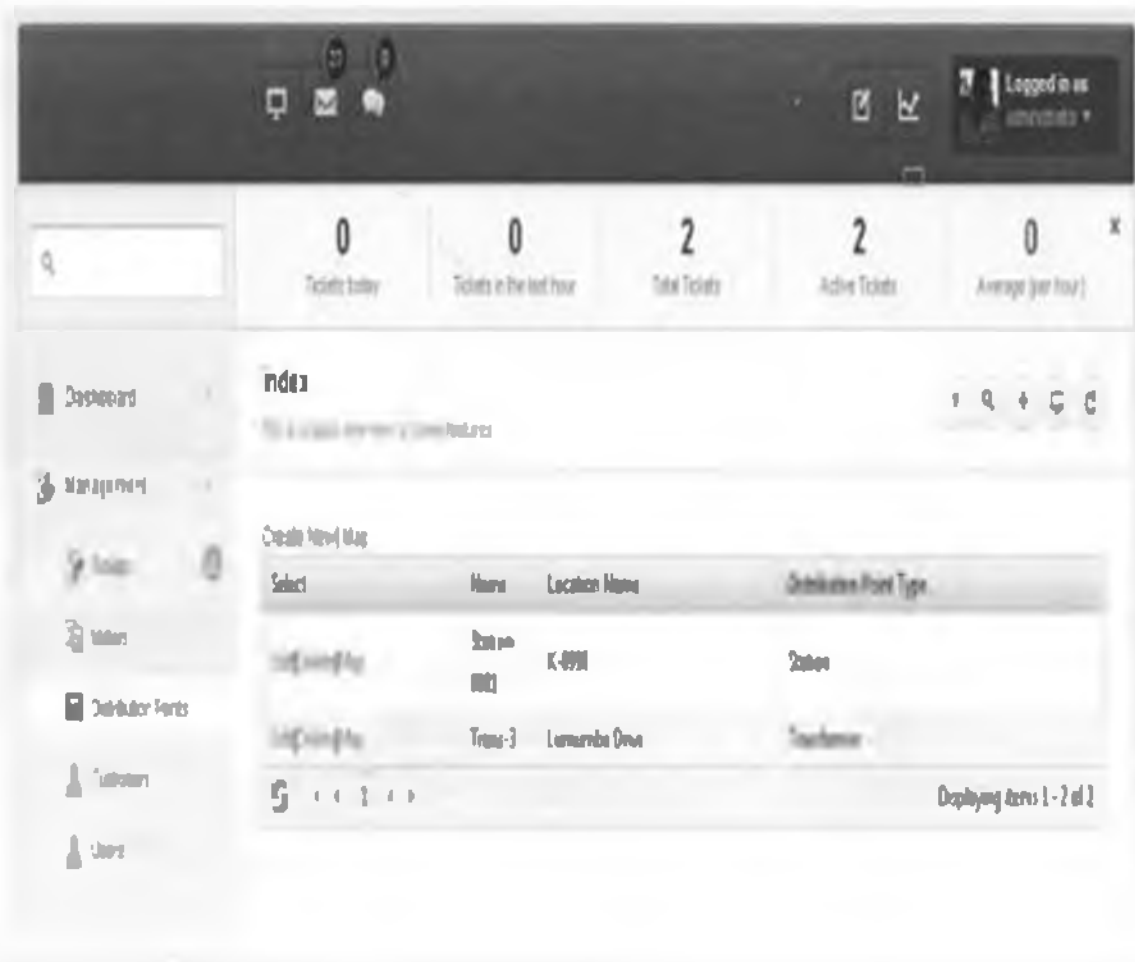


Figure 4.15 sample of a list of distribution points

### 4.1.5 Users list

The Utility Mapper System can generate a list of users.

This is a list of users who use the power or those who report any incidence.

All users must be approved by the Kenya Power System administrator.

The users list includes details such as username, users Email, date created, Status etc.

The figure 4.16 shows a sample of a list of users in the Utility Mapper System.

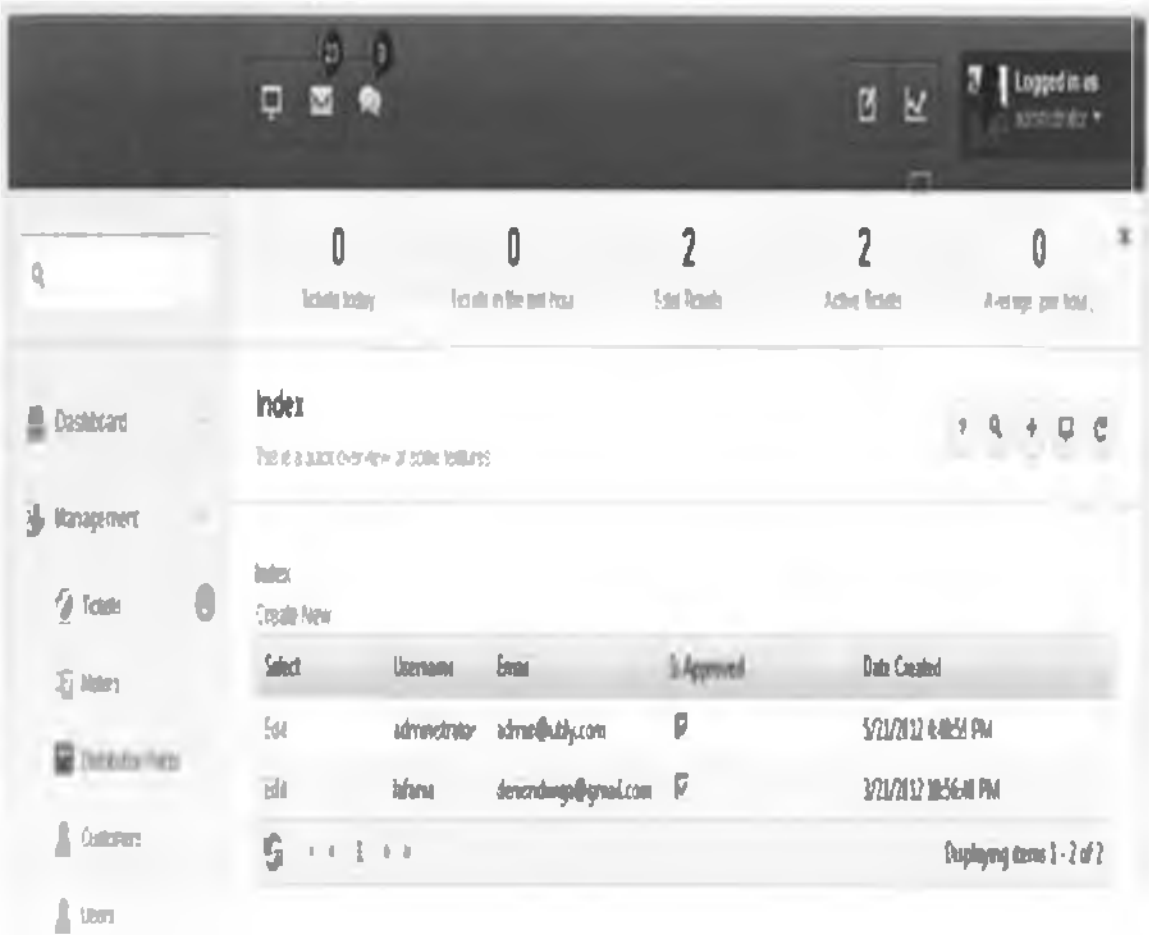


Figure 4.16 sample of a list of users

#### 4.1.6 Ticket status

One can be able to know the reported incidence status by querying the ticket number on the Utility Mapper System.

To get the ticket status, one has to search the ticket number on the search section of the Utility Mapper system; this is available on the system display page.

Figure 4.17 shows how to query the status of a specific ticket number 1CB39CDE4FF41ECC.



Figure 4.17 showing how to query ticket number to get the reported incidence status

#### 4.1.7 Ticket Escalation

This service will be available to Field team, their supervisors and customer care agents only, the field team will be able to update the ticket number by first querying the specific ticket number similar case as in figure 4.17.

The system will have a portion to input the remarks, which can be ticket closure or ticket escalation.

The remarks can be for ticket closure or for ticket escalation for more attention to the incidence. This ensures that there is prompt update of the incidence status and necessary measures taken.

## 4.2 Spatial Database

The project task was to develop a web based solution that included a spatial database to address spatial consideration for addressing power outage incidences. The spatial database was accessed through the Utility Mapper System.

The database will be hosted and managed at Kenya Power company premises. Best practise methods will be applied to ensure there is training done, backups are done, system redundancy, business continuity and disaster recovery techniques are put in place by the company, though these are not preserve of this project.

The spatial database was developed using RavenDB Database which is a document based database management system. RavenDB is an open source 2<sup>nd</sup> generation document database. Document databases are known for their ability to scale well and the quick and robust mapping of the business logic.

RavenDB is a transactional, open-source Document Database written in .NET, offering a flexible data model designed to address requirements coming from real-world systems. RavenDB allows you to build high-performance, low-latency applications quickly and efficiently.

Data in RavenDB is stored schema-less as JSON documents, and can be queried efficiently using Linq queries from .NET code or using RESTful API using other tools. Internally, RavenDB make use of indexes which are automatically created based on your usage, or were created explicitly by the consumer.

RavenDB is built for web-scale, and is offering replication and sharding support out-of-the-box.

The RavenDB database will be used to store both the spatial and attributes details.

The database created includes database for users, customers, meters, distribution points, tickets, roles, sys documents among others, as shown in figure 4.18



Figure 4.18 showing spatial database documents

## 4.2.1 Collections

A Collection in RavenDB is a group of documents sharing the same entity name. It is not a "database table", but rather a logical way of thinking of document groups. In this screen we show a list of all available collections in the database, and documents associated with them. As shown in figure 4.19



Figure 4.19 showing spatial database Collections

## 4.2.2 Documents

The documents are loaded from the database, newest first, and displayed with their ID and Collection name - documents from different collections are striped with different colours. The figures 4.20 and 4.21 shows the spatial database documents data and metadata



Figure 4.20 showing spatial database - Meters data details



Figure 4.21 showing spatial database - Customers data details



### **4.3 Incidence reports**

The system database captures all reported incidences, time taken to solve the incidence, recurring incidences, how they were solved, etc.

As this information is stored in a reliable system, it can be harnessed to generate incidence reports. These reports can include:

- Recurring incidences per locations
- Time taken to solve an incidence by locations
- Most problematic areas per location
- Time and month of year when there are many incidences, etc

These will help in making of informed decision on best way to manage cases of power outage incidences.

### **4.4 System Comparison**

Kenya Power Company currently has an Incidence Management System (IMS) in place for handling power outage issues, through the system they receive all power related issue/complaints, keyed in by agents and generate a work order.

The IMS system operation is similar to the proposed utility mapping system with the only difference in that the IMS system do not take into consideration spatial elements when handling customer complaints and it's not web based while the proposed system is a web based system and takes into consideration spatial factors when addressing customer's incidences.

IMS is used for the all Kenya Power Regions and for all complaints while the proposed system covers only a small area and dealing only with power outage incidences.

The figures 4.22 and 4.23 show comparison between current Kenya Power system and the proposed Utility Mapper System.

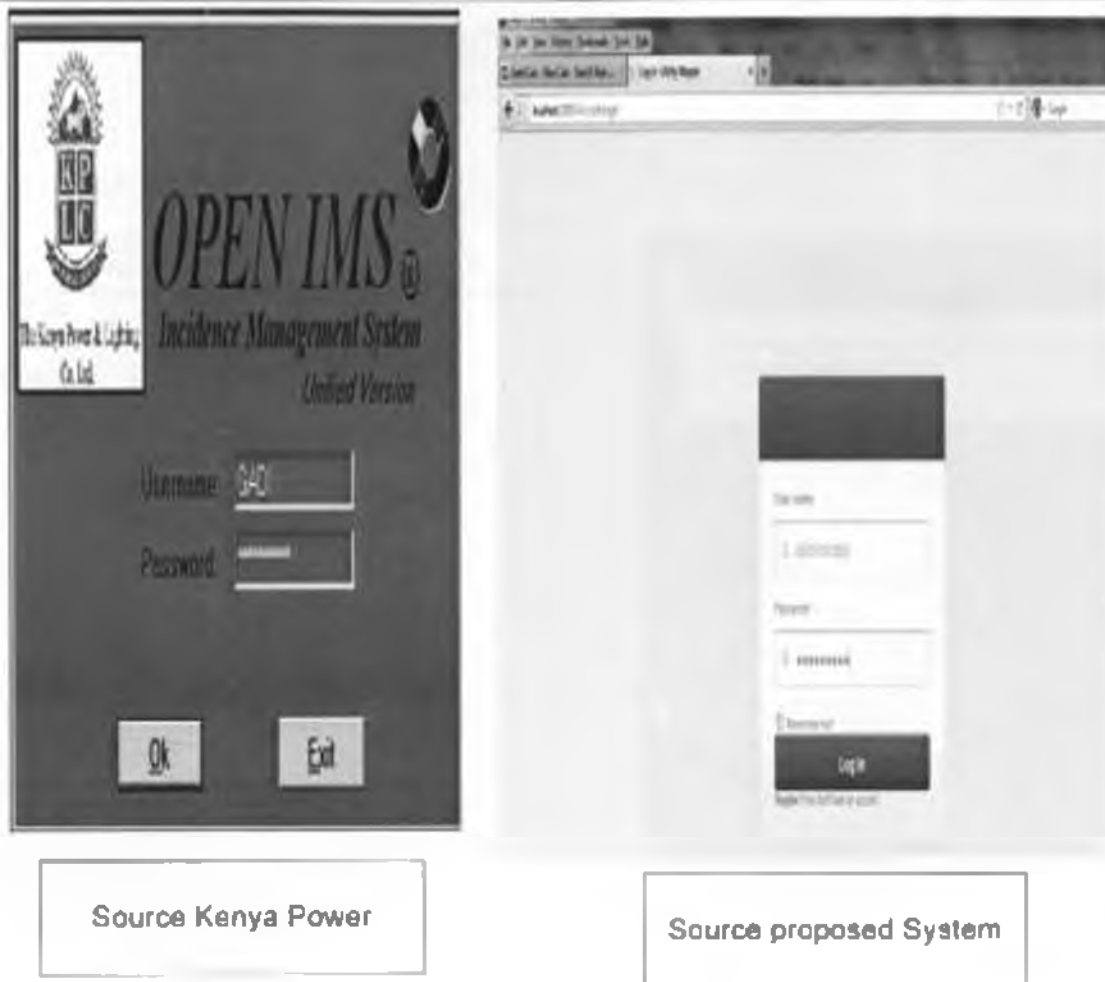
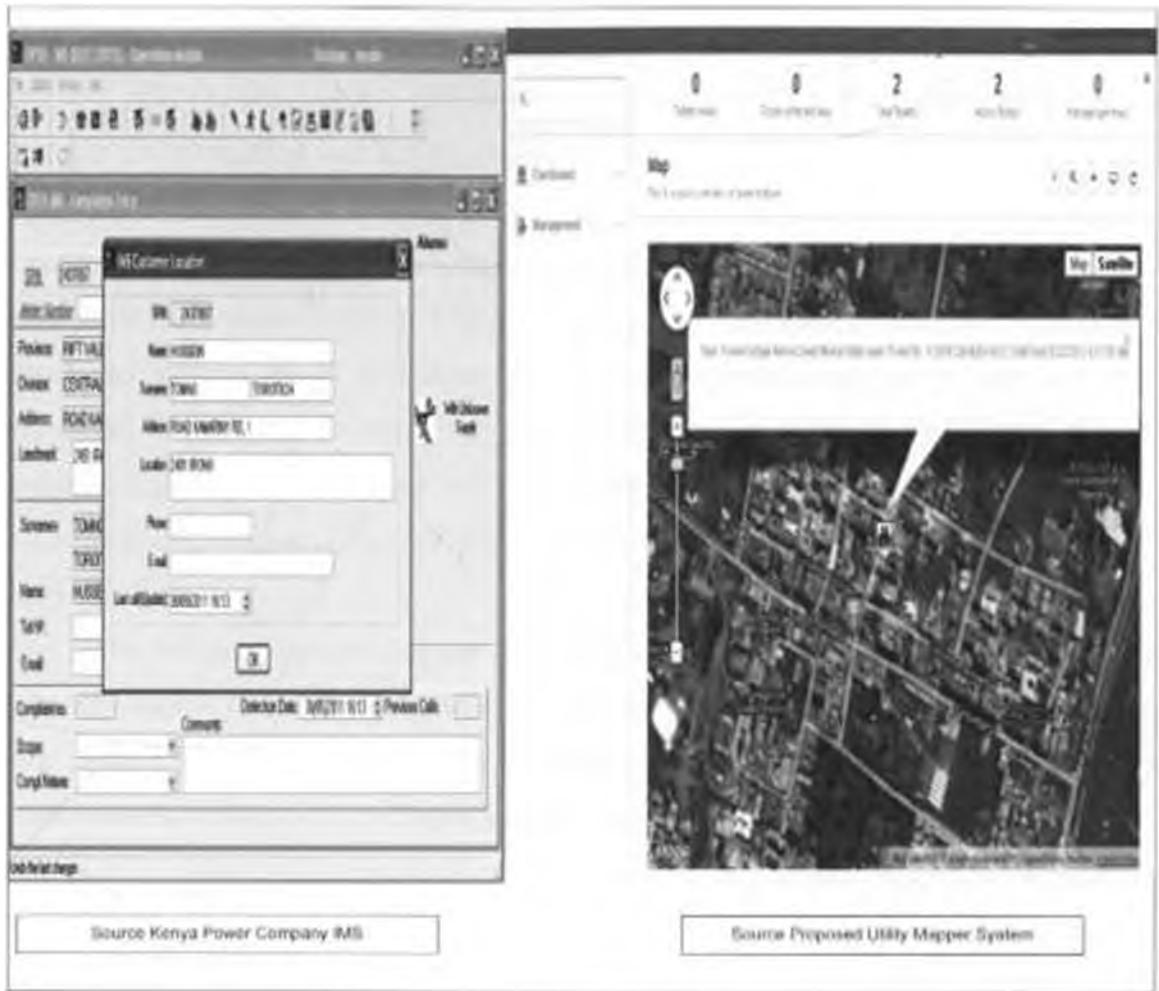


Figure 4.22 showing comparison of the systems type between the Current Kenya Power systems which is local based system and proposed Utility Mapper System which is web based system.

This depicts that the Utility Mapper System is web based, i.e. one will be able to access the system through web browsers like internet explorer, Mozilla firefox, etc. This will make it possible to be accessed by all officers within Kenya Power network and also externally without the need to install the system on each workstation provided one has the required credentials while for the current IMS, the system has to be installed in each and every machine that one requires to access the IMS



**Figure 4.23 showing comparison of Customer location mapping between the Current Kenya Power system which is attribute based, gives only recorded details and proposed Utility Mapper System which display the spatial location on a map.**

This depicts that by using the Utility Mapper System, one will not only be able to precisely locate the incidence location, but will also display the location and the way to navigate to the incidence location i.e. road, street, etc. While the current IMS, its not possible to display the Spatial details.

#### **4.5 Discussions of the results**

The System developed has high potential in improving the Kenya Power company to manage the power incidences in a prompt, efficient and effective manner. The system was not only able to store spatial database of customer's locations and web based solution but also can be intergrated with smart phones and short message services for efficient service provision.

The system will potentially save time and resources.

A web based solution, Utility Mapper System and the spatial database constitutes the developed system, which will store the customer attributes and spatial data and will be accessible through any browser. The accessibility through a browser will bring efficiency and high throughput in that there will be no need to do installation for every machine in the office network, this saves on time and ensures an officer can use any machine in the office network.

The Utility Mapper System displays a map using Google maps, the map will display and present location of the Kenya Power Customers, when a customer report an incidence it will be able to get the spatial details of where the customer is located and the means and route to use to navigate to the customer location.

The system is able to generate various reports such as problematic regions, what time of the year most incidents are reported and time taken to resolve an incidence and so on. These reports will greatly help in prudent and effective decision making in management of power incidences.

The spatial database developed can also be intergarted with other Kenya power databases which can be utilized for report generation for efficient and informed decision making.

The developed Utility Mapper System can be utilized for other company business function in addition to managing the power incidences, such as when company wants to connect new customers in an existing power connection area, they can use the spatial database and the web based system to locate the customer location and the route to navigate to the customer location

## **Chapter 5: CONCLUSIONS AND RECOMMENDATIONS**

### **5.1 Conclusions**

The objective of the study was achieved in that a spatial web based system was developed and tested to address customer's location consideration and web based solution when managing power outage incidences at Roysambu, Nairobi, Kenya.

As depicted in this project the Kenya Power Company already has a working incident management system, which should be positively enhanced by applying GIS and web mapping technology to bridge the spatial consideration and web based solution gap.

The data used in this project was secondary in that it was collected by other organization. This can serve as a launching pad in harnessing of GIS to address location consideration in utility industries.

During execution of this project there were various limitations encountered. The major problem was acquisition of data required for system development.

It was not possible to host the system online, and thus impossible to demonstrate use of smart phones used by field personnel's for incidences resolutions.

The GIS technology is more informative and efficient in managing power outage incidences as depicted in this project.

## 5.2 Recommendations

This study has shown use of GIS technology will have positive impact, cost effective and long lasting solutions in management of power outage incidences which will be both beneficial to Kenya Power Company , its customers and Kenyan Government.

The researcher recommends the following to be done to upscale the system:

- i. The project should be adopted by Kenya Power Company to enhance incidence service management.
- ii. The web based system should be hosted online to enable usage of smart phones.
- iii. The web based system should be integrated with telephone providers to enable short messaging services.
- iv. Further study should be done to incorporate road network analysis to calculate and display the shortest route to the incidence area.
- v. Further system development can be done to enable the system to generate an automatic response ticket if the power goes off.
- vi. The system can be enhanced further by extending it to address all customer complaints for the entire country.
- vii. The System should be extended to map and be incorporated with all other business functions which will greatly aid in effective and informed decision making.

The method used in developing the Utility Mapper System is potentially applicable in other utility industries as well as other investments not necessarily on utility line of business.

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## APPENDIX

The section describes the step by step of using Management section of the system to create tickets, users, meters, distribution points and customers

### Management System actions

To get to system Management section, one has to open the Utility Mapper System, log in and click management on the left hand side of the system as in figure a

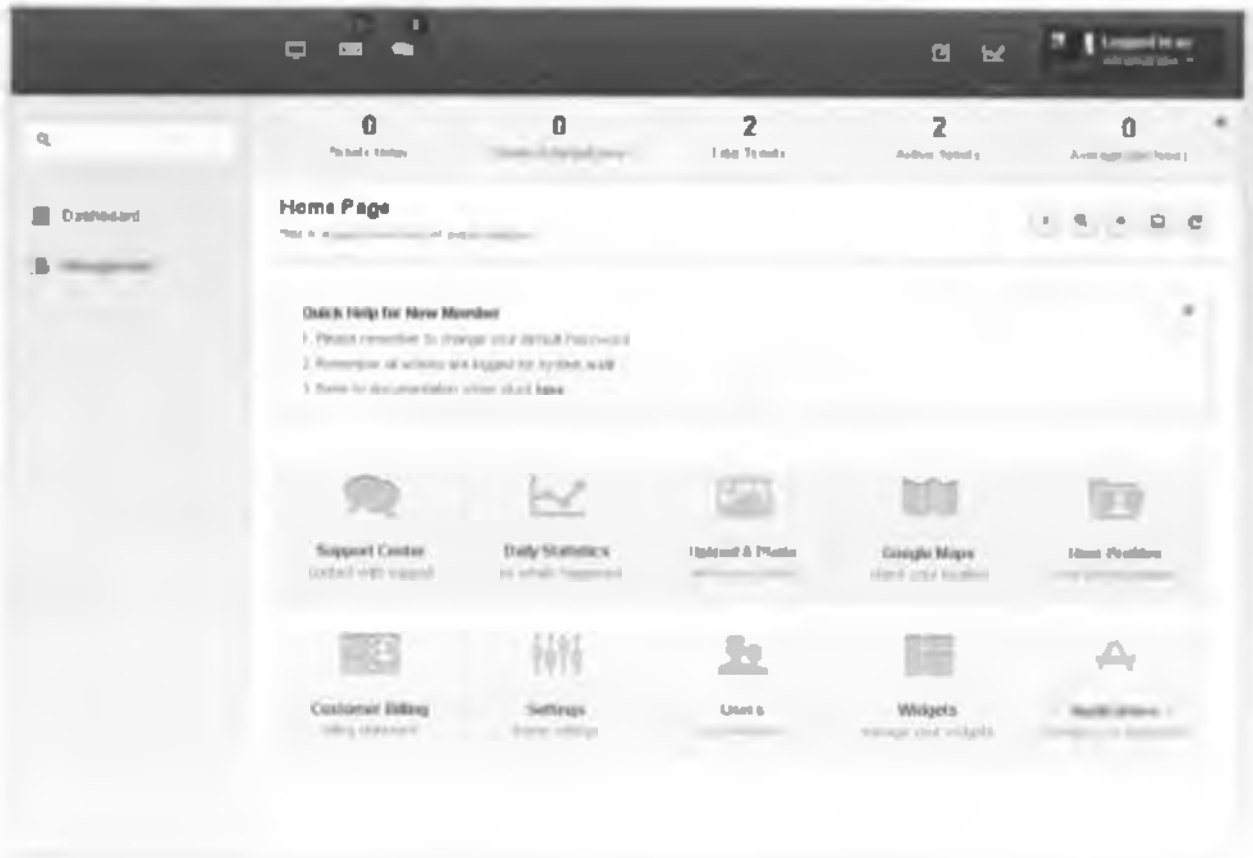


Figure a showing System display page with dashboard and management section

Click on the login menu icon on the left hand side of the system and provide your username and password to access the system as in figure b.



Figure b System login in

1. **Adding and editing new system users**

- a. Click on the users submenu item in the left hand side menu under Management as in figure c



Figure c System users

- b. Click on create or edit and provide the required field values as in figure d

The screenshot shows a web application interface for user registration. On the left is a sidebar menu with categories like 'Dashboard', 'Management', 'Tools', 'Users', 'Customer Data', 'Customer', and 'Admin'. The 'Management' section is active. The main area is titled 'Register' and contains a form with the following fields: 'Username', 'Email', 'Password', 'Confirm Password', and 'Role'. A 'Register' button is located at the bottom right of the form.

Figure d how to add a new user

## 2. Adding and Editing customer information

- a. Click on the customers submenu item in the left hand side menu under Management as in figure e

The screenshot shows a web application interface for viewing customer information. The sidebar menu has 'Management' selected, and the 'Customers' submenu item is active. The main content area displays a table of customer records. The table has the following columns: S/N, Title, Name, Email Address, Mobile Number, and Physical Address. There are three rows of data.

S/N	Title	Name	Email Address	Mobile Number	Physical Address
100	Mr	John Joseph Dede	john@joseph.com	+234904040	3rd Floor Southern Credit Building, Maitama, Abuja, Nigeria
101	Miss	Maria May	maria@maria.com	8022424	3rd Floor Southern Credit Building, Maitama, Abuja, Nigeria
102	Mr	David Akwaga Nwagwu	akwaga@nwagwu.com	+23472881981	3rd Floor Southern Credit Building, Maitama, Abuja, Nigeria

Figure e showing customers

- b. Click on create or edit as in figure e and provide the required field values

### 3. Adding and editing a distribution point

- a. Click on the distribution point's submenu item in the left hand side menu under Management as in figure f.



Figure f Distribution points

- b. Click on create or edit and provide the required field values. Each point can have the source point (station or substation for transformers ) as in figure g



Figure g adding distribution points

- c. Remember to use the map below the form to locate the meter on the map using Google maps location API (Latitude and Longitude coordinates )

#### 4. Adding and Editing a meter

- a. Click on the meters submenu item in the left hand side menu under Management. Each meter has to be tied to a given customer, it has to be of a specific type and has to have a source (Transformer) as in figure h



Figure h adding meter

- b. Remember to use the map below the form to locate the meter on the map using Google maps location API (Latitude and Longitude coordinates )

## 5. Adding a ticket

- a. A ticket can be created by both authenticated and anonymous user (customers), as in figure i



Figure i showing Tickets

For authenticated users click on the tickets submenu on the Management menu tab

- b. Provide the required ticket details as in figure j



Figure j adding tickets

- c. After the ticket has been created one can view it on the tickets menu. Select the identified ticket and click on the map link

- d. To search or view the ticket on the map click on the map link or use the ticket number to search as in figure k



Figure k searching/viewing a ticket