



University of Nairobi

School of Engineering

**Developing a Complementary Mobile & Web-based Application for
Recording and Sharing Electricity Customer Meter Reading and Power
Incidence Data.**

Case Study: Langata Constituency, Nairobi County, Kenya.

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A Project submitted in partial fulfillment for the Degree of Master of Science in Geographic Information Systems, in the Department of Geospatial and Space Technology.

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Abstract

Energy is an essential factor of the economy, the national security of a nation as well as standard of living. Kenya's Vision 2030 identifies energy as one of the major enablers of infrastructure development under the socio-economic pillar. Kenya is undergoing a rapid development stage in relation to its domestic energy demands. The current government demanded that Kenya Power and Lighting Company (KPLC) accelerate electricity connectivity within the country; this called for a totally new approach in the connectivity, meter reading and billing model within the electricity distribution company.

Manual reading of power meters is indeed a time-consuming exercise, KPLC meter readers face a number of challenges while trying to gain access to customer postpaid meters in the field. These challenges range from unrestrained animals, inclement weather conditions, or meters located behind a locked fence and buildings. On the other hand, the company emergency teams also face a number of challenges while resolving power incidences reported by the customers. One of the main challenge includes locating the incident areas based on the vague description from the customers and hence lack of proper preparation (with the right equipment) to handle the reported incident.

The growth in the telecommunication sector has enabled a positive willingness by power consumers to volunteer information and embrace new innovative approaches being implemented by the company. This study seeks to take advantage of this with the main objective of developing a complementary mobile and web-based application for recording and sharing electricity customer meter reading and power incidence data. The objective was achieved and the study was able to develop an electrical network geodatabase using Open Source software, PostgreSQL /PostGIS as the application database, a mobile application developed in Android studio using Java Programming Language, and a web application developed in the Node.JS environment using JavaScript. The application was published and tested within the case study area of Langata constituency in Nairobi County.

The mobile application meter reading and power incidence reporting platform is aimed at improving customer billing process and timely resolution of incidences, ultimately customer satisfaction on service delivery. It is recommended that this application is replicated through all the other constituencies in Kenya to support meter reading and power outage management in the company. Other utility companies can use this application to efficiently improve service delivery to customers. These can range from water and sewerage companies, telecommunication companies to oil and gas distribution companies among others.

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Dedication

I dedicate this project to my family; my wife, sons, my dad and mum for the moral and material support they gave me during; not only the period of doing this project but also during my entire academic journey. May the Almighty Father bless them abundantly.

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List of Abbreviations

API	Application Programming Interface
APK	Android Application Package
APP	Application
ASP	Active Server Page
AVD	Android Virtual Device
AWS	Amazon Web Services
CAK	Communication Authority of Kenya
CRECO	Constitution & Reform Education Consortium
ERC	Energy Regulatory Commission
ESri	Environmental Systems Research Institute
FDI	Foreign Direct Investment
GDC	Geothermal Development Company
GeoJSON	Geographic JavaScript Object
GIS	Geographic Information Systems
GML	Geography Mark-up Language
GOK	Government of Kenya
GPS	Global Positioning System
GWh	Gigawatt Hour
HTML	HyperText Mark-up Language
HTTP	Hypertext Transfer Protocol
HTTPS	Secured HyperText Transfer Protocol
IDE	Integrated Development Environment
IIS	Internet Information Services
IPP	Independent Power Producers
JPG	Joint Photographic Experts Group
JSP	Java Server Pages
JVM	Java Virtual Machine
KENGEN	Kenya Electricity Generating Company
KETRACO	Kenya Electricity and Transmission Company
KIPPRA	Kenya Institute for Public Policy Research and Analysis
KML	Keyhole Markup Language
KNBS	Kenya National Bureau of Statistics
KPLC	Kenya Power and Lighting Company

LAN	Local Area Network
MoEP	Ministry of Energy and Petroleum
OGC	Open Geospatial Consortium
ORDBMS	Object-Relational Database Management System
OSM	OpenStreetMap
PHP	HyperText Preprocessor
REA	Rural Electrification Authority
REP	Rural Electrification Programme
SDK	Software Development Kit
SLD	Styled Layer Descriptor
SODNET	Social Development Network
SOK	Survey of Kenya
SQL	Structured Query Language
SRID	Spatial Reference System Identifier
UNHCR	United Nations High Commissioner for Refugees
URI	Uniform Resource Identifier
URL	Uniform Resource Locator
UTM	Universal Transverse Mercator
VGI	Volunteered Geographic Information
WAN	Wide Area Network
WFS	Web Feature Service
WMS	Web Mapping Service
XML	Extensible Mark-up Language

CHAPTER 1: INTRODUCTION

1.1 Background

Energy is an essential factor of the economy, the national security of a nation as well as standard of living. The amount of energy use in a country gives an indication of its economic growth and development. Energy is identified in Kenya's Vision 2030 as one of the major enablers of infrastructure development under the socio-economic pillar. Low cost, reliable, sustainable and competitive energy for every citizen is the main ingredient in the achievement of the Vision (MoEP, 2015).

Kenya drives its energy requirements from mainly three major sources: wood fuel, petroleum, and electricity. These sources make up 69%, 22%, and 9% respectively of the net energy consumption in Kenya (Deloitte, 2016). Kenya is undergoing a rapid development stage in relation to its domestic energy demands. A report by the Kenya Institute for Public Policy Research and Analysis (2017), indicated that Kenya needs to reduce the cost of energy and provide stable, quality power supply. This will, in turn, decrease the cost of doing business, therefore, attracting Foreign Direct Investments (FDIs) and also boost efficiency and productivity within the industrial sector.

Kenya's electricity is produced from hydro, thermal, geothermal, solar and wind (Institute of Economic Affairs, 2015). Kenya Economic Report by KIPPRA (2017), indicated that the country's electricity domestic demand increased from 7,826.4 GWh in 2015 to 8,053.2 GWh in 2016. Electricity tariffs in Kenya remain relatively high at a regional level, despite efforts by the Energy Regulatory Commission to decrease the tariffs, this could weaken the nation's industrial competitiveness (KIPPRA, 2017). Over the decade the country has had an uptake in electricity connections both in urban and rural areas. This has been driven by a myriad of various factors, chief amongst them being a new political dispensation in 2002 and the promulgation of the Constitution of Kenya in 2010.

The number of Mobile cellular subscriptions worldwide now exceeds the global population (International Telecommunication Union, 2017). The telecommunications sector in Kenya has witnessed the total number of mobile-cellular subscriptions increase significantly in the past few years. A report by the Communications Authority of Kenya (2017), indicated that the performance relating to mobile telephone sub-sector recorded a substantial growth in the

course of the second quarter of the financial year 2017/18. The report further points out that during this period there was a 4.4 percent growth in the total number of active mobile subscriptions, from 41.0 million recorded in the first quarter to 42.8 million subscriptions. Subsequently, the mobile penetration level increased to 94.3percent from 90.4 percent reported in the preceding quarter (Communications Authority of Kenya, 2017).

The advancement of technology has enabled interaction by non-professionals, known as volunteers to produce, share and consume Geographic Information. The phenomenon of Volunteer Geographic Information (VGI) is as a result of the extensive involvement of a large number of private citizens, many times with little or no formal qualifications, in the creation of Geographic Information. VGI can also be defined as a type crowdsourcing data generated by volunteers that provides important mass data for decision-making. VGI continues to be one of the most essential user-generated geographic contents that can provide a better understanding of planning issues and other challenges (Zhou, 2014).

The current government demanded that Kenya Power and Lighting Company (KPLC) accelerate electricity connectivity within the country; this called for a totally new approach in the *connectivity, meter reading and billing model* within the electricity distribution company. This study seeks to take advantage of technological growth in the telecommunication sector, mobile telephony; the positive willingness by power consumers to volunteer information and embrace this new innovative approaches being implemented by the company. To develop a mobile and web application that complements the company's the meter reading process and also provide a spatial platform for reporting power incidences.

1.2 Problem Statement

Economic activities in Kenya are adversely affected by the high cost of energy. Growth and competition amongst the various industries in the country are hindered by the relatively high cost of production, including high electricity tariffs compared to regional markets and power outages (KIPPRA, 2017). There has been an increase in the number of customers connected to the power grid due to the various initiatives launched by the Government. These initiatives are aimed at ensuring low-cost electricity connections to households and achieving over 70% connectivity by 2017 and universal access by 2020 (Republic of Kenya, 2007).

Manual reading of power meters is indeed a time-consuming exercise, especially across large estates, large portfolios, and apartment buildings. The company's customer service personnel (meter readers) face a number of accessibility challenges while undertaking the exercise of reading postpaid meters. Some of the main challenges include a lot of time spent on locating certain customer premises and meters, some premises and meters are locked and hence inaccessible to the meter readers, in other areas premises are located far apart hence the readers are required to cover long distances in harsh weather conditions. With these challenges the scope of work allocated to the meter readers to cover before the next reading cycle may not be covered and hence a negative impact on the accurate reading of all the postpaid meters every month.

Operation and Maintenance personnel (emergency teams) also face a number of challenges while resolving power incidences reported by the customers. The main challenges include; locating incident areas based on a vague description from the customers, lack of proper preparation (tools and equipment) by the emergency team to handle the reported incidence based on wrong or unclear description of the incident reported by the customer. With the wrong information received from the customers, the emergency teams cannot quickly and efficiently respond to their complaints when the services are disrupted.

The steady rise in the number of power customers in the country, in comparison to the limited number of KPLC personnel, tasked with providing meter reading and emergency response services, compounds the above mentioned challenges. Hence the need for the company to employ deferent technologies and processes to enhance service delivery to its customers. This study seeks to bridge this gap by developing a complimentary mobile and web-based application for recording and sharing electricity customer meter reading and power incidence data.

1.3 Research Objectives

Main Objective

The main objective of this study is to develop a complementary mobile and web-based application for recording and sharing electricity customer meter reading and power incidence data.

Specific Objectives

1. To develop an electrical network geodatabase for recording and sharing electricity customer meter reading and power incidence data.
2. To develop a mobile application through which users can report electricity customer meter reading and power incidence data.
3. To develop a web application through which users can directly record, upload and share electricity customer meter reading and power incidence data.
4. To publish, share and test the application with case study area of Langata Constituency, Nairobi County.

1.4 Research Questions

This study intends to address the following research questions:

1. How can an electrical network geodatabase be developed for recording and sharing electricity customer meter reading and power incidence data?
2. How can a mobile application be developed through which users can report electricity customer meter reading and power incidence data?
3. How can a web application be developed through which users can directly record, upload and share electricity customer meter reading and power incidence data?
4. How can this application be published online, shared and tested with a case study area?

1.5 Justification of the Study

The customers benefit if correct electricity consumption bills are dispatched. This can be improved with customers assisting in meter reading, using a mobile phone application to record and share their meter reading on stipulated dates by KPLC. This process will complement the current meter reading process and ensure that a good number of postpaid meters are accessed for billing purpose. The Web application is a platform to receive and display meter readings sent by the customers through their phones. From the Web application, the meter reading personnel can, verify both spatially and using tagged photos,

the accuracy of the reading, and decide on whether to use the reading for billing or visit and capture the readings.

Customers also seek to benefit from prompt responses to the reported power incidences. The Emergency the personnel can obtain, from the web application information needed to restore service quickly and hence reduce the duration of outages. This has been and continues to be a primary goal for every utility company seeking operational excellence. The web application can help in this effort by displaying the actual location of the incidence on the map to enable the teams to plan, prioritize and navigate to the site.

The application also provides a photo of the incidence taken by the customer, this gives the emergency teams a graphical view of the incidence and hence enable them to study and deduce the probable cause of the outage and therefore carry the right equipment and gear. From the location of the site on the map and the uploaded photo, the emergency teams can carry out proper planning and make informed decisions on how to handle the incident. The objective is to make the planning and response process of incidence more accurate and faster. This process can be designed to complement the call center effort currently being used by KPLC, which if put to use will enhance efficiency and effectiveness in incidence responses.

1.6 Scope and Limitations of the Study

Scope

This project was limited to developing a mobile and web application that enables users to record and share electricity customer meter reading and power incidence data. The target users are all postpaid customers, meter readers and emergency teams from KPLC. The target population of this study is limited to the Nairobi urban population which was easy to reach and who provided evaluation and feedback of the system. The application was developed on Google's Android platform.

Limitations

The mobile app will be available only for Android devices and the targeted users are limited to the Nairobi urban population. VGI can sometimes have a lack of data quality assurance and also introduce issues surrounding liability and security. With regards to the privacy of personal information, the customer data used in the application database contain dummy names and numbers. The developed application was limited to the Android platform only and the target users are assumed to have android devices. High voltages power line data was not used as part of the spatial data in the application database.

1.7 Organization of the Study

The project report is structured and organized in chapters and essentially consists of five chapters each having several sub-topics discussed under it as outlined in the table of content; Chapter one entails the background to the project, the gap under the problem statement that the study seeks to address, justification of undertaking the study, the main and specific objectives guiding the study , and finally the scope, and limitations. Chapter two reviews the literature that is significant to the study. Chapter three generally presents the methods and materials used during the project. Chapter four discusses the results obtained after implementing the methodology, analysis, and discussions of the results obtained. Finally, chapter five consists of conclusions and thereafter recommendations.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

This chapter presents an overview of the literature on Kenya's energy sector, the institutional setup and the electricity subsector power supply value chain. This section also describes the mandate of the electricity distribution company KPLC, a summary of the incidence reporting and meter reading functions in the company. The chapter also gives an overview of the telecommunication industry and mobile phone penetration in Kenya, Android technology, and development. It also reviews the concepts of GIS and web mapping in the context of the development of a complementary Mobile & Web-based Application. Finally, the chapter reviews related case studies.

Kenya Vision 2030 on energy

Kenya Vision 2030 is a long-term development blueprint aimed at creating “a globally competitive and prosperous country with a high quality of life by 2030”. The vision strives to transform Kenya into “*a newly-industrializing, middle-income country providing a high quality of life to all its citizens in a clean and secure environment*” (Republic of Kenya, 2007). Kenya Vision 2030 identifies energy as central to the economic, social and political development of the country. In the face of growing energy demand, the Vision notes that currently, the energy rates in Kenya are above those of her competitors. It consequently gives priority to the expansion of the generation of energy as well as improve efficiency in energy consumption (Institute of Economic Affairs, 2015).

The economic pillar of the Vision 2030 Economic Plan foresees major infrastructural development to expedite economic growth in the country. This will be achieved by ensuring that the energy sector institutional reforms process is continuous, with a framework that defines the regulations in the sector, motivating and creating a conducive environment for private generators of power to operate in, separation of companies involved in the generation and distribution of power, ensuring the new sources of energy are secured and exploited and finally connecting Kenya to countries within the region that export surplus energy (Republic of Kenya, 2007).

Kenyan Government in conjunction with the Energy Regulatory Commission (ERC) has been able to develop an energy policy framework detailing provision of energy services that are cost-effective, affordable and of adequate quality on a sustainable basis over the period 2004-2023.

2.2 Kenya's Energy Sector Institutional Set up

The Ministry of Energy and Petroleum (MoEP) is tasked with facilitating provision of energy in Kenya while the industry regulator is the Energy Regulatory Commission (ERC). The Energy Act which created the ERC as the sole sector regulator integrated all laws pertaining to the energy sector and in turn ensured legal frameworks, policies and institutions have been developed now and again. This provides a platform for reforms within the energy sector. Figure 2.1 illustrates the major institutions in Kenya's Energy sector.

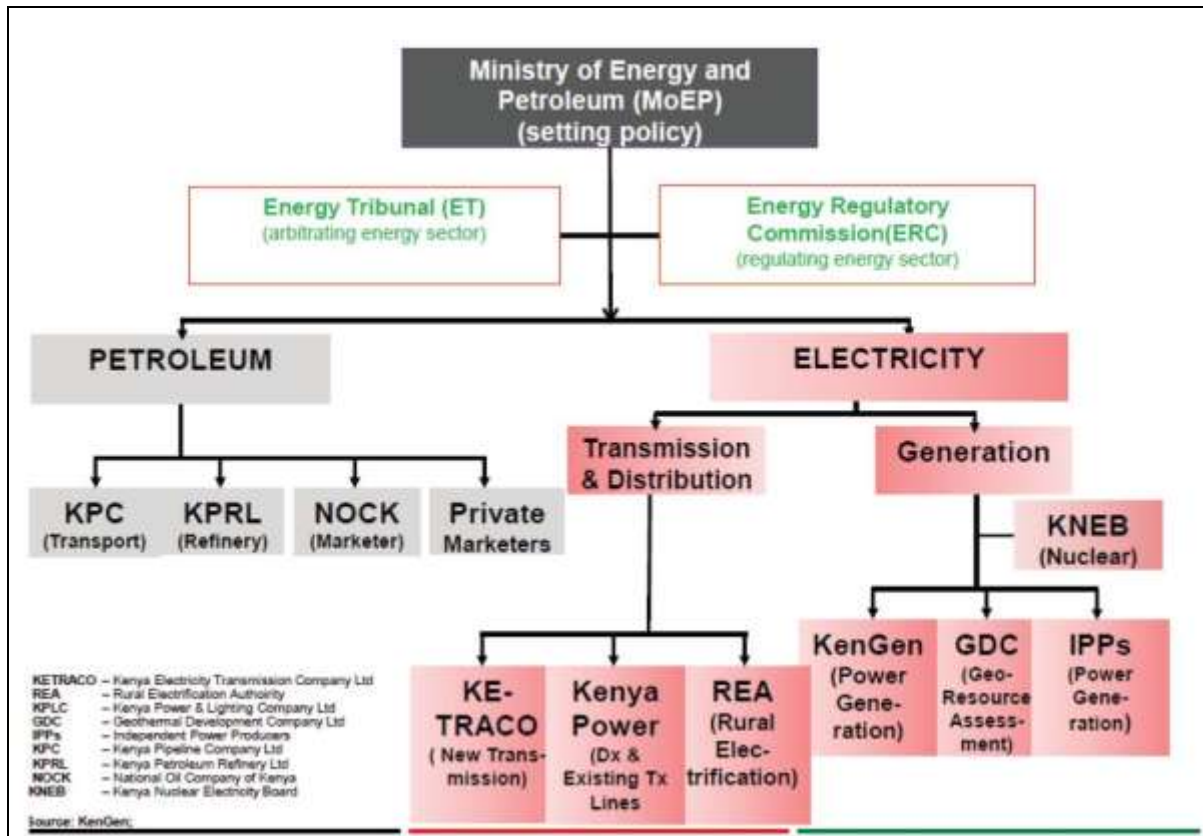


Figure 2.1: The Energy Sector Institutional Framework in Kenya (Source: IEA, 2015)

The country's energy sector is made up of policy making and implementation institutions. The policy making institutions include; the Ministry of Energy and Petroleum (MoEP) that receives advice from the ERC and the Energy Tribunal to provide an enabling environment to all stakeholders by formulating and articulating policies. The ministry has been tasked with providing training of manpower, planning for the national energy and petroleum, and sourcing the financial resources required (Ministry of Energy and Petroleum, 2015). The Energy Tribunal came into operation in July 2007, founded by the Energy Act, 2006 under section 108. The tribunal has authority to hear and determine appeals against decisions made by ERC and all cases relating to the energy sector that have been referred to the tribunal.

Finally the Energy Act, 2006 formed the Energy Regulatory Commission (ERC), to provide technical and economic regulation in the energy sub-sector. Other functions include setting, reviewing, licensing and enforcing energy purchase tariffs, ensuring that disputes emanating from power purchase and network service contracts are settled and approved.

The implementing institutions under the electricity Sub-sector include power generation companies such as Kenya Electricity Generating Company Limited (KenGen), The Geothermal Development Corporation (GDC) and Independent Power Producers (IPPs).

KenGen is the major power producer of the bulk of electricity consumed in the country. It produces about 82.1% of the electricity consumed in Kenya (Owiro et al., 2015). Currently, the company is utilizing the different sources to generate electricity including; hydro, geothermal, and thermal and wind. The Geothermal Development Corporation (GDC) is a government owned organization, established by the Energy Act of 2006 with the following specific roles: to fast-track development of geothermal resources in Kenya, to provide constant supply of steam to power plant developers for electricity generation, and to promote alternative uses of geothermal resources other than electricity generation e.g. drying of grains (Owiro et al., 2015). Finally, Independent Power Producers (IPPs) that are private companies which generate power and sell electricity in bulk to KPLC.

Other implementing institutions under the electricity Sub-sector are transmission and distribution companies. These include Kenya Power and Lighting Company Limited (KPLC), Kenya Electricity Transmission Company Limited (KETRACO), and Rural Electrification Authority (REA).

KETRACO is a state owned Corporation that was formed to develop infrastructure for high voltage electricity transmission. KETRACO is tasked with inspection, planning, designing, constructing and maintenance of transmission lines in the country. These transmission lines form the backbone of the countries National Transmission Grid. The transmission networks linked to other countries enable regional trade power trade that is facilitated by KETRACO.

REA was founded by the Energy Act of 2006 under section 66 tasked to manage rural electrification fund disbursed by the government, to acquire all the resources required for rural electrification, to extend the existing electricity supply to rural areas in the country, and encourage the development and utilization of renewable energy (Owiro et al., 2015).

2.3 Kenya's Electricity Subsector

Kenya's electricity system is still largely public sector owned and driven, despite the past years of private sector participation. Sectoral reforms have included unbundling of generation from transmission and distribution/retail businesses and liberalization of generation to allow entry of IPPs. Figure 2.2 illustrates the various companies in the electricity subsector in Kenya, grouped under distribution, transmission, and generation categories.

Electric Power Distribution, Transmission, and Generation Companies.

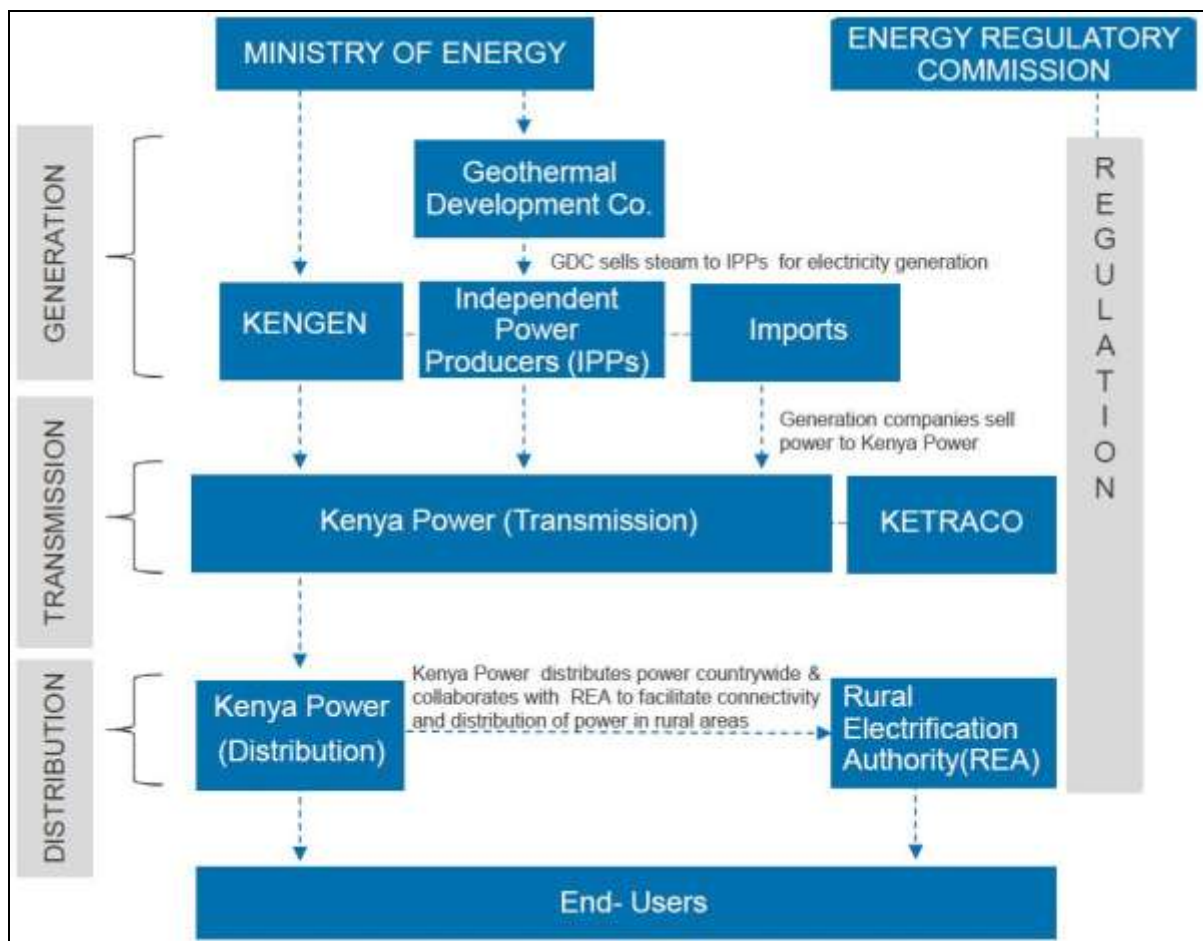


Figure 2.2: Electric Power Supply Value Chain (Source: Business Sweden, 2016)

2.4 Kenya Power and Lighting Company Ltd (KPLC)

2.4.1 KPLC Mandate

The Company's core mandate is selling of electricity to its customers, building and maintaining the power distribution and transmission network, carrying out energy balance by planning for ample electricity generation as well as transmission capacity to meet demand.

KPLC strives to efficiently transmit and distribute high-quality electricity that is safe, adequate and reliable at cost-effective tariffs. This ensures the company delivers high-quality customer service to the power consumers. KPLC is a key player in the electric power supply subsector with the mandate to purchase bulk electricity supply, transmit, distribute and retail electricity to end-use customers in Kenya. Therefore this reason responsible for customer connection, metering, and management of all the transmission and distribution lines. They collect revenue and endeavour to ensure reliable and quality electric power reaches the customer.

2.4.2 KPLC Corporate Objectives

KPLC, (2012) in the companies 5 Year corporate strategic plan outlines the following as the some of the main corporate objectives:

- To accelerate customer connectivity to fulfil the Vision 2030 Medium Term Plan II Flagship project of one million new customers connected in a five year period.
- To carry out distribution system expansion that facilitates achievement of the Government's 5,000+MW generation expansion plan by 2017.
- To improve the delivery of customer services and the transmission and distribution efficiency of electricity in the country.
- To improve electricity supply quality to exceed customer expectations, reduce the cost of doing business and increase sales revenue.
- To expand and maintain robust electricity system infrastructure at the least cost possible and *modernise operations* through automation in order to enhance efficiency
- To *carry out innovation* in all business spheres to enhance efficiency and service quality

Electrical distribution network

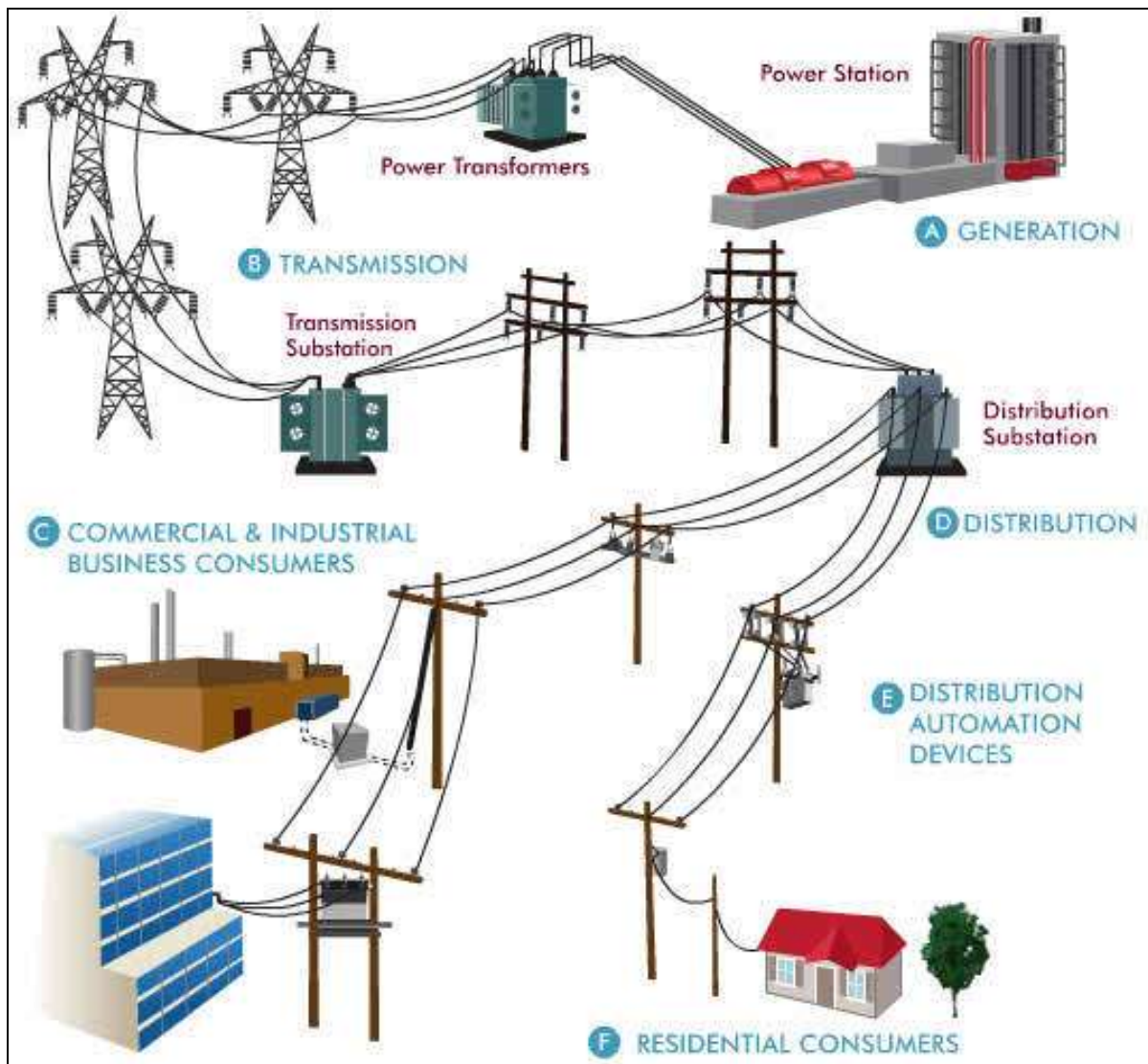


Figure 2.3: An illustration of the electrical distribution network (Source: Author, 2018)

The Figure 2.3 above illustrates a typical electrical network distribution from generation to transmission network and finally to distribution substation that connects various consumers. The consumers range from large and medium commercial consumers, industrial consumers, and domestic and small commercial users.

2.4.3 Customer Service Division

The Customer Service division tasked to handle customer related aspects of the business. These tasks include sales from new and existing customers, analysis of electricity unit sales growth in the plan period, innovations and service reforms to boost sales growth and customer satisfaction. Meter reading function falls under customer service division, tasked with carrying out field reading of postpaid customer meters.

Meter reading procedure

Meter reader uses a mobile handset to carry out the meter reading process. Each meter reader is allocated an itinerary; an itinerary is composed of a number of meters within the same location, which can be optimally read by one meter reader within a day. The number of meters per Itinerary varies from one area to another within the country, depending on the density of population. Extra high-density areas are town flats next to each other while low density is mainly rural areas.

The meter reader turns on the handset and confirms the date, itinerary loaded and the number of meters and proceeds to the field where the first property of the meter is situated. The reader is expected to gain access to the premises of customers for purposes of carrying out meter reading. The reader verifies the meter in the property corresponds to the one in the mobile handset. If the meter corresponds, he/she keys in the reading in the handset by punching the correct keys/numbers to reflect the same, and confirming the reading keyed in is correct. He/she records any property anomaly noted in his/her notebook.

The reader then proceeds to the next property as listed in the mobile handset and repeats the same procedure above, doing so until the whole itinerary is complete. He/she records all unread meters and the reasons for being unread. This information will be relayed back to the office. The meter reading services entail monthly reading of all meters allocated to the reader and uploading them to Kenya Power's billing system via the local reading application. The reading is done based on Kenya Power's meter reading calendar. The company encourages meter readers to maintain 100% meter reading coverage and accuracy in their respective Itineraries. The Government directed KPLC to cease electricity bill estimation for postpaid customers, hence the company is obligated to invest more resources in its meter reading operations

2.4.4 Operation and Maintenance

Kenya power manages its outage incidences using a non-spatial application called Incidence Management System (IMS). The IMS is operated at the company's call center which was recently set up as a specialized central point for incidence management. It is also at the regional Emergency offices which follow up on these incidences until when they are resolved. The call center forwards the recorded incidences to regional offices for actions. The IMS data is received via customer calls for incidences related to power outages. This data in IMS does not have the spatial components for the customer location or for the distribution

networks. It only has the alphanumeric information linking the customer to the transformer serving him and subsequently to its feeder and substation. The customer details are retrieved by keying his or her account number in the Customer Information System.

Incidence reporting procedure

Information pertaining to the nature of outage is first received from the customer and recorded. The operator then assigns the field crew the incidences to resolve. The customer location is traced by phone calls which make the field personnel's work tedious and time-consuming. The actual cause of the outage will be known when the person arrives at the site. They will track the network from consumer end to fault point. They may, therefore, not have the right equipment and materials to restore power.

When an incident is resolved, the field personnel calls the emergency office to enable them to record the cause of the outage, the solution given and time of completion. They are then directed to the next incidence. Some incidences might be repetitive and are solved at one point such as at the transformer or at a broken jumper and therefore the many incidences booked under the same parent needed no more attention.

2.5 Telecommunication Subsector in Kenya

One of the main objectives of the study is to develop a mobile application through which users can report electricity customer meter reading and power incidence data. This section gives an overview of the telecommunication sector, mobile phone penetration and subscription rate in the country in Kenya. The section also reviews background information on Android technology and development. This is vital to justify the use of mobile phone and Android operating system in the study.

Revenue streams from mobile networks, employment opportunities offered by companies, innovations, and services contribute immensely to the economy of developing countries. Internet and data services are gaining popularity in many mobile network services but traditional services like SMS and voice still remain the most popular among users.

Mobile telephone capacity expanded by 14.0 percent from 62.8 million in 2015 to 71.6 million in 2016 mainly on account of strong demand for mobile services. Mobile subscriptions increased from 37.7 million in 2015 to 39.0 million in 2016. The number of mobile money subscribers increased by 19.6 percent to 32.0 million in 2016, according to the Economic Surveys 2015-2017 (KNBS, 2017). Figure 2.4 illustrates how the various devices communicate in a telecommunication system network.

Telecommunication System network devices

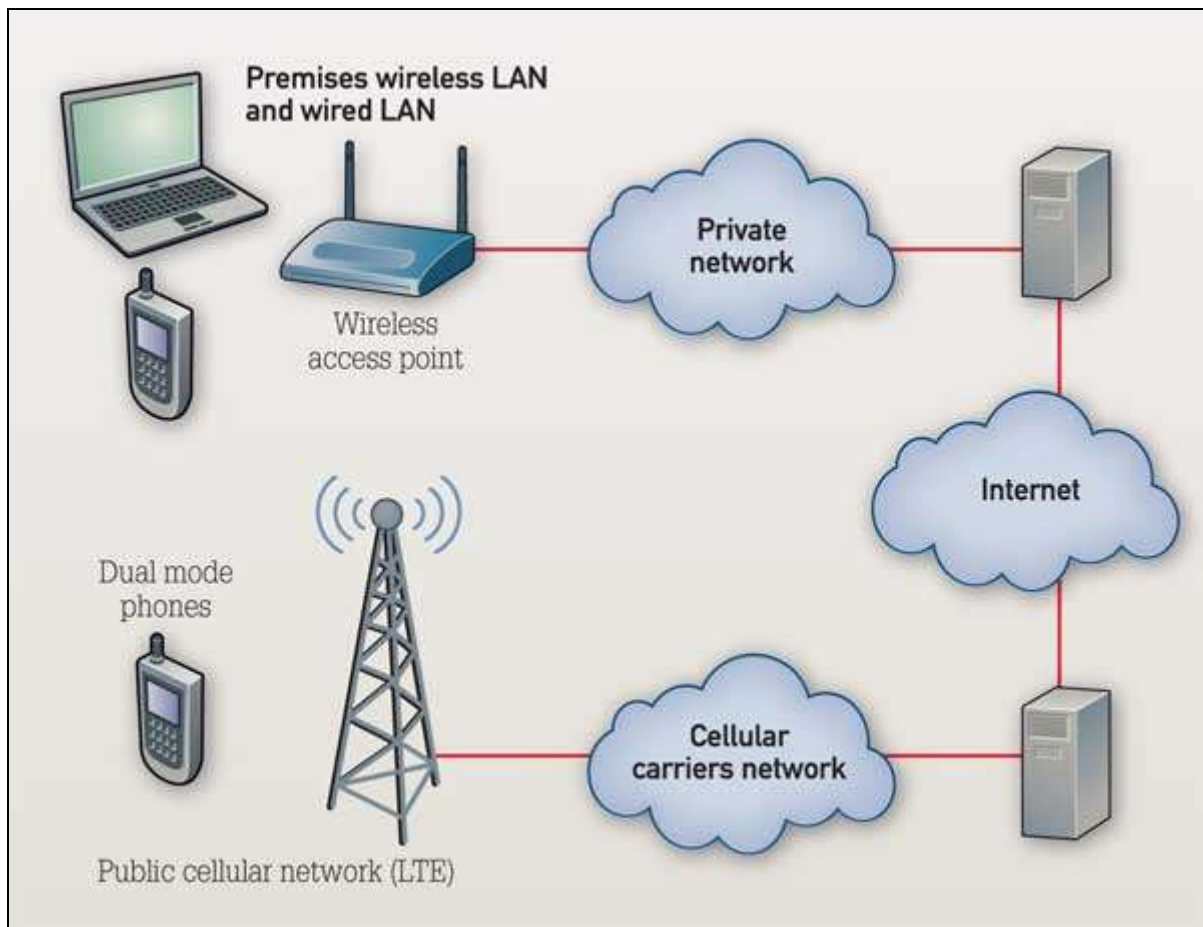


Figure 2.4: An illustration of Telecommunication System (Source: Author, 2018)

2.5.1 Mobile Phone Penetration in Kenya

Mobile phone penetration rate refers to the number of active mobile phone numbers within a specific population represented as a percentage. This value can go beyond 100% due to the fact that one person can have more than one SIM-card.

Kenya is one of the few countries in Africa after Nigeria and South Africa with the highest mobile penetration. Communication Authority of Kenya (2012) quarterly sector statistics report indicated that the mobile penetration in Kenya stands at 75.4% signifying a 17.5 % growth from 25.2 million recorded in the 2010/2011 period. This was largely due to an increase in the number of mobile users to 29.7 million by October 2012

Smartphones have a 15% penetration in the country (CAK, 2012). The smartphones run on different operating systems like *Symbian*, *Windows Mobile*, *iOS*, and *Android* a popular operating system run by most phones. Among these, iOS and Android are considered the smartest in terms of location because they have GPS and Wi-Fi with the latter being cheaper and receiving the biggest uptake in Kenya.

2.5.2 Android Technology

Android Operating System

Android, Inc. was founded in Palo Alto, California, United States in October 2003 by Andy Rubin and later acquired by Google on August 17, 2005. Android is a mobile operating system based on the Linux kernel and mainly designed for mobile devices such as smartphones and tablet computers. Android Source code is released by Google under the *open source licenses* though most Android devices ship with a combination of open source software and proprietary software developed and licensed by Google. The open source nature of Android has enabled many to create and distribute their own modified version of the OS through the Android Open Source Project (ASOP).

2.5.3 Android Development

Figure 2.5: shows the diagram of Android OS Architecture. Android software stack is divided into five layers: Applications, Application Framework, Libraries, Android Runtime, and the Linux Kernel.

Android operating system (OS) architecture

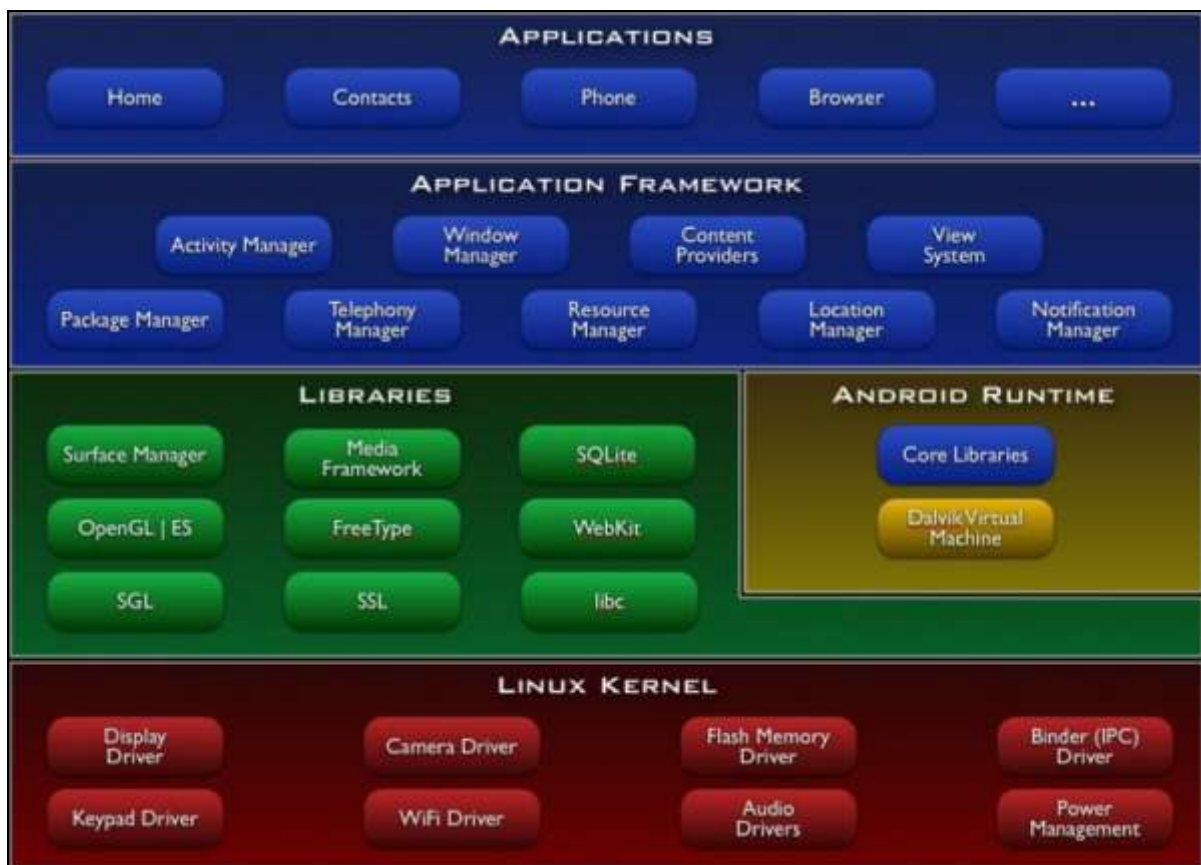


Figure 2.5: Android OS Architecture

Linux Kernel

The kernel is found in the lower layer of the Android operating system and is the core of the operating system. The Linux kernel has all the essential hardware drivers and also acts as an abstraction layer between the device hardware and the upper layers of the Android software stack. The Linux Kernel is what interacts with the hardware and contains all device drivers used by higher levels of the software stack to control and communicate with the hardware. Such drivers are the Display Driver, Camera Driver, Flash Memory Driver, Audio Driver etc.

Libraries

This is the layer that enables the device to handle different types of data. These libraries are written in C or C++ language and are specific to a particular hardware. Some of the core libraries are: *SQLite* used to access data published by content providers and includes SQLite database management classes, *Secure Sockets Layer (SSL)* used to provide internet security and *Skia Graphics Library (SGL)* which is the underlying 2D graphics engine.

Android Runtime

The Android Runtime consists of the *Dalvik Virtual Machine (DVM)* or *Android RunTime (ART)* and *core Java libraries*. Dalvik Virtual Machine a type of Java Virtual Machine (JVM) used in Android devices to run applications and is optimized for low processing power and low memory environments.

Application Framework

The frameworks are blocks in which the applications directly interact with. They are the basic tools used to build applications and provide the basic functions of phones like resource management, voice call management etc. The Android framework includes the following key services: *Content Providers*: Manages data sharing between applications (Allows applications to publish and share data with other applications). *Activity Manager*: Manages all aspects of the application lifecycle and activity stack. *Telephone Manager*: Manages all voice calls providing the telephony services available on the device such as status and subscriber information. *Location Manager*: Uses GPS or cell towers for location management allowing an application to receive updates about location changes.

Applications

In Android architecture, the applications are found at the top layer of the architecture. The user of the Android device would mostly interact with this layer and several standard applications come pre-installed with every device, such as SMS client application, Dialer, Web browser and Contact manager. A developer is able to write applications that replace default system applications and applications that solve a specific problem.

2.6 GIS and Web Mapping

2.6.1 Geographic Information Systems (GIS)

GIS refers to a system of hardware, software and procedures that capture, store, edit, manipulate, manage, analyze, share and visualize georeferenced data (Fu and Sun, 2011). GIS is used to produce a wide range of maps but its capabilities go beyond mapping. It offers a rich set of analytical functions that can reveal hidden relationships, patterns, and trends that are not readily apparent, enabling people to think spatially to solve problems and make smart decisions (Fu and Sun, 2011). By understanding spatially distributed phenomena in many areas GIS can be utilized to assist in decision making and evaluating problems (Sakamoto and Fukui 2004).

2.6.2 Web Mapping

Web mapping is the process by which maps are designed, implemented, generated and delivered on the web (Neumann 2008). Web maps can be viewed from a standard web browser, mobile devices, and desktop map viewers. Web Maps are authored through a variety of means but the traditional method would be through the desktop. A typical workflow would be the standard *author, share* and *use* process. The *authoring* process is carried out by standard desktop GIS software such as ArcGIS for Desktop or free and open source open source such as Quantum GIS. The *sharing* process is done on either enterprise systems or cloud-based platforms that avail the resource into the online platform.

Web mapping is a form of distributed computing based on the client-server architecture. It affords the benefits attributed to a distributed computing system. In principle, in web mapping, any user with internet connectivity can benefit from web mapping services. Notably, it is not required that a user be a GIS expert in order to benefit from web mapping services.

Websites are becoming increasingly popular especially with the distant passage of information: one very effective way of sharing map information to a group of non-technical end users is through a webpage. Mitchell (2005) defines two broad kinds of web map applications as *static* and *dynamic*. Static maps are displayed as an image on a web page while for dynamic maps, a user can interact with the map with functionalities such as querying and zooming of layers on the map. Such maps are much more complex and require programming skills to create and display them.

Advantages of web mapping

The World Wide Web being used as a dissemination medium for maps has empowered GIS and provided new opportunities mapping such as; low cost incurred while sharing the maps, increased frequency updating data and related software at low cost, customizable map contents to suit user needs, variety of distributed data sources and generally the ease of sharing of Geographic Information. Web mapping is the easiest way to improve internal and external communication with users who understand maps (Stachowicz, 2004).

Challenges of web mapping

Technical restrictions such as low display resolution and limited bandwidth pose a major challenge to web mapping. Many mobile computing devices are physically small with slow wireless Internet connections. There also exist the challenges of data privacy, copyright and security issues. Data accuracy, reliability, currency and complexity also pose major challenges in web mapping. Today web maps are interactive and integrate multiple media. This means that both web mapping and web cartography also have to deal with interactivity, usability and multimedia issues (Kraak J. & Allan B. 2001).

2.6.3 Components of Web Mapping

The Three-Tier Architecture

Most Web applications employ the use of a Three-Tier Architecture module as a framework on the Internet. This Architecture helps to separate the Business Logic from the Application, Data Storage, and database. Figure: 2.6 below shows the client-server three-tier architecture for creating web applications. It is composed of client (*presentation*), server (*application*) and data (*database*) tiers.

Developers can develop, maintain, upgrade or replace any of the three tiers and hence a preferred over other architectures. The client sends a request to the server which in turn processes and executes the query and directs it to the database. The database returns the result which is fetched by and processed by the server and delivered to the client.

The Three-Tier Architecture

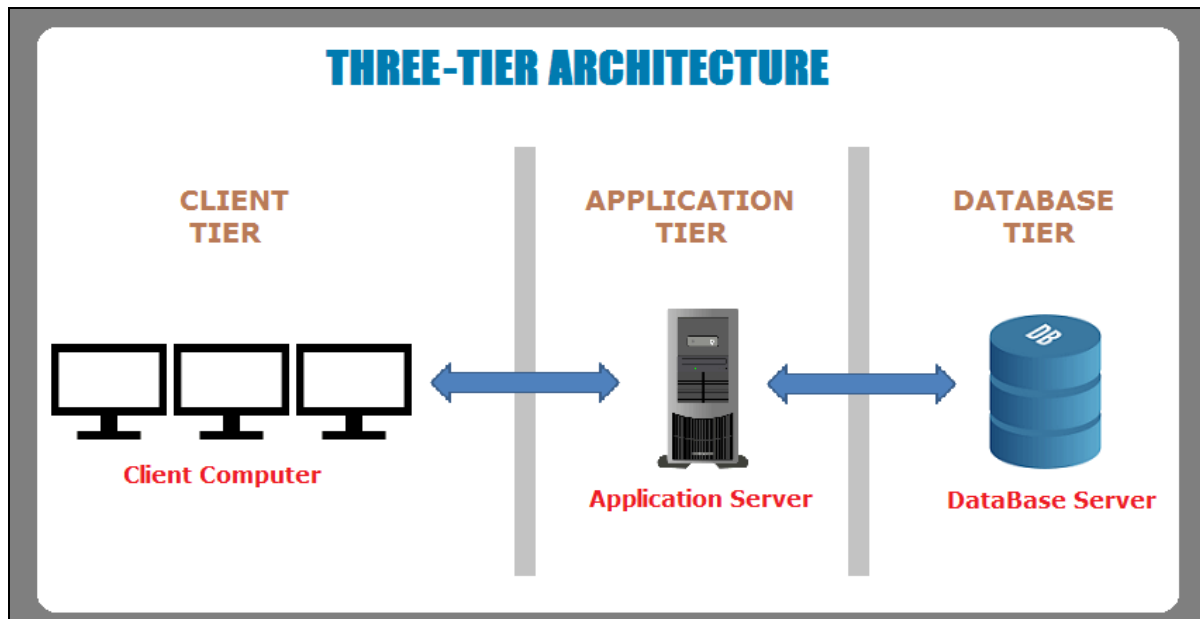


Figure 2.6: System Three-tier architecture (Source: Author, 2018)

(A) Presentation Tier

The presentation tier is responsible for displaying maps computed by the Application tier. This layer also displays the graphical controls that receive the interaction from the user and converts these interactions to requests for the Application Logic layer. In a web mapping architecture the web browser found in the presentation tier is used to retrieve the right web page and then making sense of its content (Dzbor et al., 2003).

(B) Logic/Application Tier

Logic tier consists of a web server application code and a map server. The web server receives the user requests and transfers the output map result to the clients. The application code receives the information requested by the user and compiles the request. It detects the user required information and sends the information to the map server. The map server detects which map is requested and sends information to the database. After receiving map data from the database server the map is processed. Editing, map processing and generating an output map are done in this tier.

Output maps are sent to the client web browser through the Internet. Web servers connect different software components with a scripting language. The two main types of web server are Internet Information Service (IIS) and Apache. Internet Information Service is a high-performance Web Server from Microsoft which is proprietary software. Apache is an open source software and can be installed on almost all operating systems including Linux, UNIX, Windows, FreeBSD, Mac OS X and more.

(C) Database Tier

The Database tier manages and organizes the map data. The relational database table is created using the relational database model and used for efficient retrieval of data. It sends and receives instruction and information through maps server and application code compiling center. Map file stores the whole map in a file which is accessed by the map server. This project uses the PostgreSQL database with PostGIS Extension.

2.6.4 Available Web Mapping Technologies

(1) Scripting language and JavaScript

Scripting languages often follow the syntax and semantics of command languages that allow controlling one or more software application. Client-side scripting is executed on the client side by web browsers whereas in the server side scripting runs on the server side or application servers. The popular server-side scripts are PHP, ASP, and JSP. JavaScript and VBScript are client-side object-oriented scripting language and is popular for developing a client-side application. Developed by Netscape, JavaScript is an object-based client-side, e scripting language which can be embedded directly into HTML pages. It allows users to create dynamic, interactive Web-based applications that run completely within a Web browser.

(2) Application Programming Interface

In computer programming, an application programming interface (API) is a set of routines, protocols, and tools used by an application to communicate with other control programs, communication protocol or operating system. In addition to accessing databases or computer hardware, such as hard disk drives or video cards, an API can ease the work of programming GUI components. Almost every application depends on the APIs of the underlying operating system to perform such basic functions as accessing the file system (Orenstein, 2000).

Each API is designed in a specific programming language and has several specifications that define it facilitates communication between two applications to exchange messages or data. A set of functions and procedures that offers a library so other software can use it as an abstraction layer, both using each other's information without compromising their independence. The Android mobile application will use an API to communicate with the portal and upload information sent by the customer

(3) Cloud computing

Cloud computing is the delivery of computing services over the internet, providing a shared a shared pool of resources, including data storage space, networks, computer processing power, and specialized corporate and user applications. Cloud computing architecture allows users to access information and computer resources from anywhere that a network connection is available. The hardware and software resources are provided to users on-demand managed by third parties at remote locations.

Some of the major characteristics of cloud computing include: *On-demand self-service*, where the can request and manage their own computing resources, *broad network access* that allows services to be offered over the Internet or private networks, *resource pooling* where customers draw from a pool of computing resources, usually in remote data centres, *rapid elasticity* where services can be scaled larger or smaller and finally the service is measured and customers are billed accordingly.

(a) Cloud computing Service Models.

Cloud Providers offer services that can be grouped into three categories.

- *Software as a Service (SaaS)* in this model, a complete application is offered to the customer, as a service on demand. A single instance of the service runs on the cloud & multiple end users are serviced. The service provider hosts only a single application on the server and the customer does not need upfront investment in servers or software licenses hence the costs are lowered.
- *Platform as a Service (PaaS)* an operating system, hardware, and network are provided, and the customer installs or develops its own software and applications. The operating systems and network access are not managed by the customer, and there might be constraints as to which applications can be deployed. The customer has the freedom to build his own applications, which run on the provider's infrastructure. Examples include Amazon Web Services (AWS), Rackspace and Microsoft Azure.
- *Infrastructure as a Service (IaaS)* provides just the hardware and network; the customer installs or develops its own operating systems, software and applications. The customer controls and manages the systems in terms of the operating systems, applications, storage, and network connectivity, but do not themselves control the cloud infrastructure.

(b) Deployment of cloud services

Deploying cloud computing can differ depending on requirements. The following are the main deployment models each with specific characteristics that support the needs of the services and users of the clouds in particular ways.

- *Private Cloud:* The cloud infrastructure is operated solely for a specific organization and is managed by the organization or a third party. The cloud infrastructure has been deployed and is maintained and operated for a specific organization. The operation may be in-house or with a third party on the premises.
- *Community Cloud:* The service is shared among a number of organizations with similar interests and requirements and made available only to those groups. The infrastructure may be owned and operated by the organizations or by a cloud service provider.
- *Public Cloud:* The cloud infrastructure is available to the public on a commercial basis by a cloud service provider. This enables a consumer to develop and deploy a service in the cloud with very little financial outlay compared to the capital expenditure requirements normally associated with other deployment options.

(c) Cloud Computing Benefits

The following are some of the possible benefits for those who offer cloud computing-based services and applications:

- *Reduced Cost:* Companies can reduce their capital expenditures and use operational expenditures for increasing their computing capabilities. The billing model is paid as per usage; the infrastructure is not purchased thus lowering maintenance. Initial expense and recurring expenses are much lower than traditional computing.
- *Increased Storage.* With the massive Infrastructure that is offered by Cloud providers today, storage & maintenance of large volumes of data is a reality. Sudden workload spikes are also managed effectively & efficiently since the cloud can scale dynamically.
- *Scalability/Flexibility.* Companies can start with a small deployment and grow to a large deployment fairly rapidly, and then scale back if necessary. Also, the flexibility of cloud computing allows companies to use extra resources at peak times, enabling them to satisfy consumer
- *Maintenance.* Cloud service providers do the system maintenance, and access is through APIs that do not require application installations onto PCs, thus further reducing maintenance requirements.

- *Mobile Accessible.* Mobile workers have increased productivity due to systems accessible in an infrastructure available from anywhere.
- *Reliability* Services using multiple redundant sites can support business continuity and disaster recovery.

2.7 Volunteered Geographic Information (VGI)

VGI based on a usually one-way flow of information is intended to create, collect, validate, analyse, and disseminate geographic data contributed voluntarily by individuals (Elwood, 2008d; Goodchild, 2007b, 2008; Miscione et al., 2011; Tulloch, 2008). VGI employed as a collective effort is usually associated with crowdsourcing or externally decided joint activities (Xu and Nyerges, 2016).

VGI can be defined as "crowdsourced" geographic information provided by a wide range of participants with varying levels of education, knowledge and skills, a valued and useful source of information for governments and organizations in the modern society. In this approach, data sources are provided by communities of volunteers as opposed to government entities, organizations i.e. research institutions. This has been fuelled by the emergence of Web 2.0 technologies, miniaturization of the Global Positioning System (GPS) devices and advancement of broadband communication links (Goodchild. 2007). Mobile computing Services are multiplying rapidly in terms of range, processing speeds, and storage capacities. The growing interest in compiling and editing georeferenced data has manifested itself in the growth of volunteered geographic information systems such as OpenStreetMap and Ushahidi, platform VGI or locational crowdsourcing.

VGI Accuracy and Reliability

Concerning quality, VGI can be said to be the most current data source. However. VGI compared to traditional authoritative data sources can be said to have poor positional accuracy and overall veracity, however, this assertion might not be entirely accurate and can be debated using Linus's law. This law states that the more people involved and watching over a project, the more likely errors can be spotted and fixed early (Howard and Leblanc. 2003). Another argument in support of VGI is the argument that near things are more related than distant things and therefore citizen contributions will be more accurate for places which these people understand. Citizen contributions will be more accurate for places which these people understand.

Example of VGI initiative

Ushahidi is an open source web application for information collection, visualization, and interactive mapping. It helps one to collect info from: SMS, Twitter, RSS feeds and Email. It helps one to process that information, categorize it, geo-locate it and publish it on a map. Ushahidi, which translates to "testimony" in Swahili was developed to map reports of the aftermath of 2007-08 post-election violence in Kenya. It is a non-profit software company that develops free and open-source software for information collection, visualization, and interactive mapping. Since then, thousands have used Ushahidi's crowdsourcing tools to raise their voice.

2.8 Geo-tagging

Geotagging refers to the process of appending geospatial identification metadata to various types of media such as narrative documents, web content, and images (Hunter, 2012). With various social web tools and applications, users can add geospatial information to web content, photographs, audio, and video. Using hardware integrated with Global Positioning System (GPS) receivers, this can be done automatically (Hu & Ge, 2008).

Geo-tagging photos

This allows users to associate a photo with a particular location. This is achieved by adding metadata containing coordinates or other location data like address systems to a picture or any other media type. Essentially any type of media can have a location associated with it but the only thing that will vary is the way a location is expressed and stored.

Geo-tagging can be an automatic process of a camera which is GPS enabled, however, it can also be accomplished manually or by pairing the time a picture was taken with the time a coordinate was taken. For automatic geo-tagging, it is usually the position of the photographer or rather the camera itself which gets recorded. In the resulting pictures, this information is stored in the digital file; predominantly in jpg format. (UNHCR, 2012)

Geo-tagging can help users find a wide variety of location-specific information. Geo-tagging enabled information services can also potentially be used to find location-based news, websites, or other resources. Platforms like Google Maps or Flickr where users upload their geo-tagged pictures can be used to look at sites, find unmapped infrastructure or share geo-tagged pictures with the wider public or a selected user group only. Geo-tagging indicates the location of the content of a given picture or other media, and on some media platforms show media relevant to a given location. (UNHCR, 2012)

2.9 Similar Case studies City of Windhoek-Self-Reading (SMS)

The city of Windhoek is the capital and largest city of the Republic of Namibia. It is located in central Namibia and offers a self-reading using short message service (SMS) that allows the customer to submit their monthly water/electricity meter reading via SMS. This service is offered by the Department of Finance. The City in an effort to improve service delivery and satisfy customer needs introduced a self-reading SMS facility whereby residents of the capital can self-register to submit their water and electricity meter readings via SMS from the comfort of their own homes.

The owner of the premises is required to go to the City of Windhoek townhouse to complete the application form after which they register their cell phone number to an Account by sending an SMS with their account number and statement key. Once registered, clients are required and obliged to provide monthly readings between the 20th and 30th of each month to avoid utility consumption being estimated. The system allows for only one registration per Account and a single mobile phone can register to more than one Account. The Account Number and Statement Key are found on the user monthly statement. Once your cell phone number is registered to an Account, the user is eligible to submit their monthly reading by sending an SMS. The Meter Number is indicated on the customer's statement and only one reading per month is acceptable. Spot checks on readings are conducted frequently by the council personnel. The City Council have the right to take confirmation readings from time to time in order to double check the readings provided by the client.

2.10 Conclusion on the literature review

The literature review discussed in this chapter points out that the growing interest in compiling and editing georeferenced data by citizens has manifested itself in the growth of volunteered geographic information systems such as OpenStreetMap and Ushahidi platforms. Most of this VGI initiatives focus on offering humanitarian and social solutions to the users. Effective service delivery to power consumers calls for utility companies utilizing the available technologies and contributions from the public to support their processes.

Self-Reading (SMS) system by City of Windhoek, Namibia case study is a good demonstration of how the customers can provide information to aid in the billing process. This system implemented by the City of Windhoek lacks a mechanism to confirm the meter reading sent by the user and location of the user at the time of reading. It requires the Council personnel to conduct frequent spot checks from time to time to confirm readings sent.

CHAPTER 3: MATERIALS AND METHODS

3.1 Introduction

Chapter three is concerned with the software development process of the mobile and web applications. This chapter highlights the study area of the project, data identification, and collection and preparation process carried out. The various aspects of developing an electrical network database, a mobile and web application are illustrated in detail in this chapter. The final part of this chapter explains how the application was published and tested.

3.2 The Study Area

The study area is Langata constituency in Nairobi County which is the capital city of Kenya. The county has an estimated population of **3.138 million** (Kenya National Bureau of Statistics, 2010), within a surface area of 696 square kilometers. Nairobi is one of the forty-seven counties in Kenya with seventeen sub-counties and several wards within these sub-counties. Geographically, Nairobi County is located approximately between latitudes 1°10'S and 1°27'S in the north-south direction and longitude 36°40'E to 37°0'E in the east-west direction. *Langata constituency* is located at approximately 1°22'S and 36°44'E, with an area of **196.80 Km²** and has a population of approximately **176,314 people** (Kenya National Bureau of Statistics, 2010). Langata constituency constitutes five county wards, whose names, area and population are illustrated in Table 3.2 below.

Table 3.2: Langata Constituency County wards.

Location/Ward Name	Population (Approx.)	Area (Sq. Km)	Description
1. Karen	24,507	48.00	Comprises Karen, Langata, Hardy and Lenana Sub-Locations of Nairobi County
2. Nairobi West	33,377	6.90	Comprises Nairobi West Sub-Location of Nairobi County
3. Mugumo-ini	47,037	126.40	Comprises Mugumo-ini and Bomas Sub-Locations of Nairobi County
4. South C	47,202	15.10	Comprises South C Sub-Location of Nairobi County
5. Nyayo Highrise	24,191	0.40	Comprises Highrise Sub-Location of Nairobi County

(Source: Kenya National Bureau of Statistics, 2010).

Study area Langata constituency in Nairobi County.

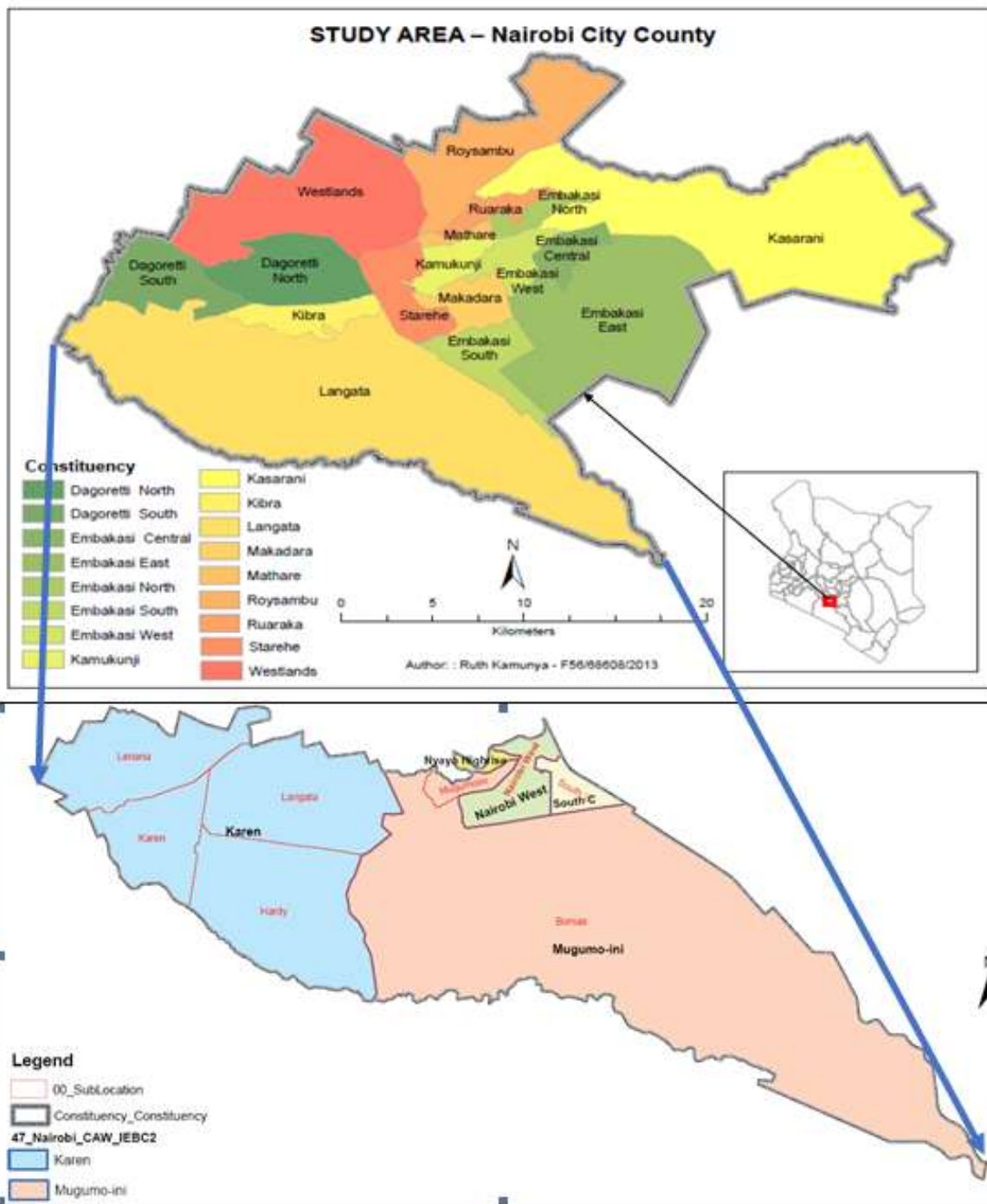


Figure 3.1: Study area Langata constituency in Nairobi County (Source: Author, 2018).

Figure 3.1 illustrates the location of the study area (Langata constituency) within Nairobi County and the various sub-locations within the constituency. The sourced dataset from KPLC on the electrical network was extracted around Langata constituency area hence the constituency was selected as a case study area to maximize on the available electrical network data.

3.3 Summary of Project Objectives, Methods and Results

Table 3.1: Summary of project objectives, research questions, methods, and Results.

	Research Objectives	Research Questions	Methods	Output/Results
1.	To develop an electrical network geodatabase for Recording and sharing electricity customer Meter Reading and power Incidence Data.	How can an electrical network geodatabase be developed for recording and sharing electricity customer meter reading and power incidence data?	1. Database design of customer details using Open Model Sphere software. 2. Database Implementation in PostGIS and GeoServer software.	An <i>Electrical network Geodatabase</i> with both: Spatial electrical data and Customer data information.
2.	To develop a mobile application through which users can report customer meter reading and power incidence data.	How can a mobile application be developed through which users can report customer meter reading and power incidence data?	1. Android Mobile development, testing and compiling on Android Studio software.	A mobile Application that runs on the Android platform. Name of the app. <i>"GSOMEE Mobile App"</i>
3.	To develop a web application through which users can directly upload, record and share customer meter reading and power incidence data.	How can a web application be developed through which users can directly upload, record and share customer meter reading and power incidence data?	1. Web portal application development and testing using JavaScript in Node.js environment	A web Application portal that runs on JavaScript platform. Name of the portal <i>"GSOMEE Web Portal"</i>
4.	To publish, share and test the application with case a study area in Nairobi, Langata Constituency.	How can this application be published online, shared and tested in the case study area?	2. Publishing the web portal on Amazon Web Services (AWS) cloud. 3. Sending sample meter reading and Incidence data to the portal from the app.	Web portal that <i>records readings</i> sent from the mobile app that is can be <i>accessed from the internet</i> on a standard web browser

Table 3.1 above summarizes the project methodology giving the various methods used for each of the research objectives and the output/results obtained.

3.4 Methodology for the Study.

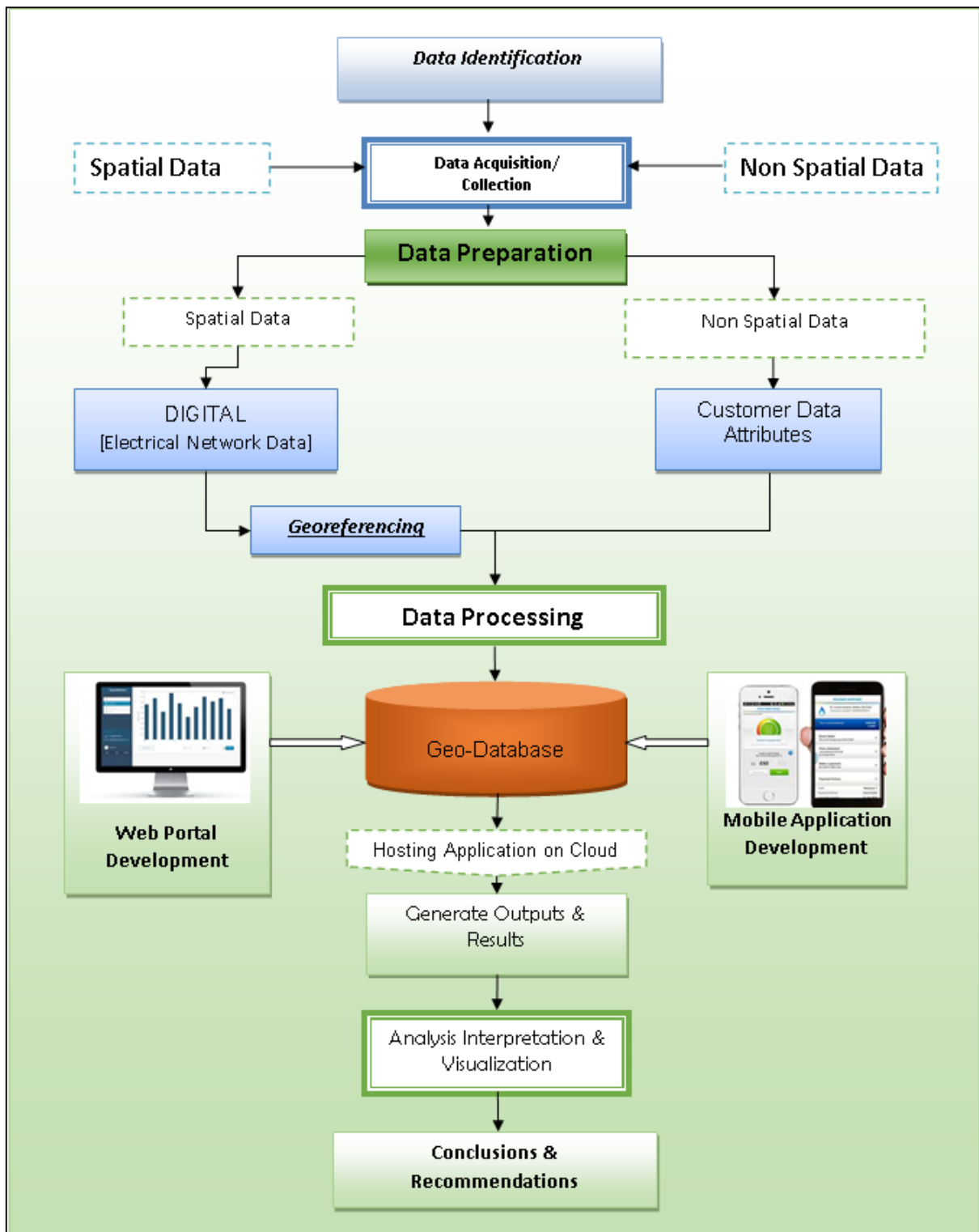


Figure 3.2: Overview of Methodology (Source: Author, 2018).

Figure 3.2 is a summary of the project methodology, illustrating the various stages involved in developing the Geo-Database, mobile, and web application, the generate output and results and finally the conclusions and recommendations.

3.5 Data Identification

In this study, the main objective was to come up with an interactive mobile and web application to support recording and sharing electricity customer power meter readings and incidences. There was a need, therefore, to map the entire electrical network in the study area. This ensured that the customer can have his/her location identified and the associated electrical connectivity shown. There was also need to come up with a dummy customer Meter details to support the same.

In view of the objectives set, it was concluded that the data required was:

- Electrical data on Medium and Low voltage power lines, Secondary substations (Transformers) associated with the lines in the study area, Customer meter box location with dummy details.
- Kenya map showing administrative boundaries
- Dummy customer meter details associated to the above meter boxes.

3.6 Data Collection and Preparation

3.6.1 Data Tools Used (Hardware and Software)

ESRI Arc Map version 10.2.1.

This was used to prepared (clipping and editing) the electrical network data. The software was also used to input the required attributes for the edited electrical network data

Global Mapper version 18.

This was used to transform the coordinates system of the various datasets from one coordinate system to another. It also used to export data into various data formats used in the application.

3.6.2 Data Collection

Data collection involved gathering the requisite data obtained from KPLC. The data were re-projected to the same coordinate system, Arc 1960, UTM 37S and saved as shapefiles data format for ease of manipulation in the PostGIS and GeoServer software. Important attributes for the different datasets were also picked from the field and used to sample the accuracy of the electrical network data obtained.

The administrative boundary data was acquired from the Survey of Kenya. The administrative boundaries had all the counties in Kenya and were used to extract the study area boundaries.

Table 3.3: Project Data sources

	DATA TYPE	CHARACTERISTICS	SOURCE OF DATA
1	Electrical Network Data	Shapefiles Format	KPLC
2	Administrative boundary Data, (Kenya Counties Map)	Shapefiles Format	Survey of Kenya
3	Customer Meter Data	Excel Format	Generated
3	Online Base Map (Open layers)	Digital Format	Online: https://openlayers.org/
4	Mapping Libraries (leaflet)	Digital Format	Online: https://leafletjs.com/

3.6.3 Data Preparation

Clipping Electrical Network Datasets

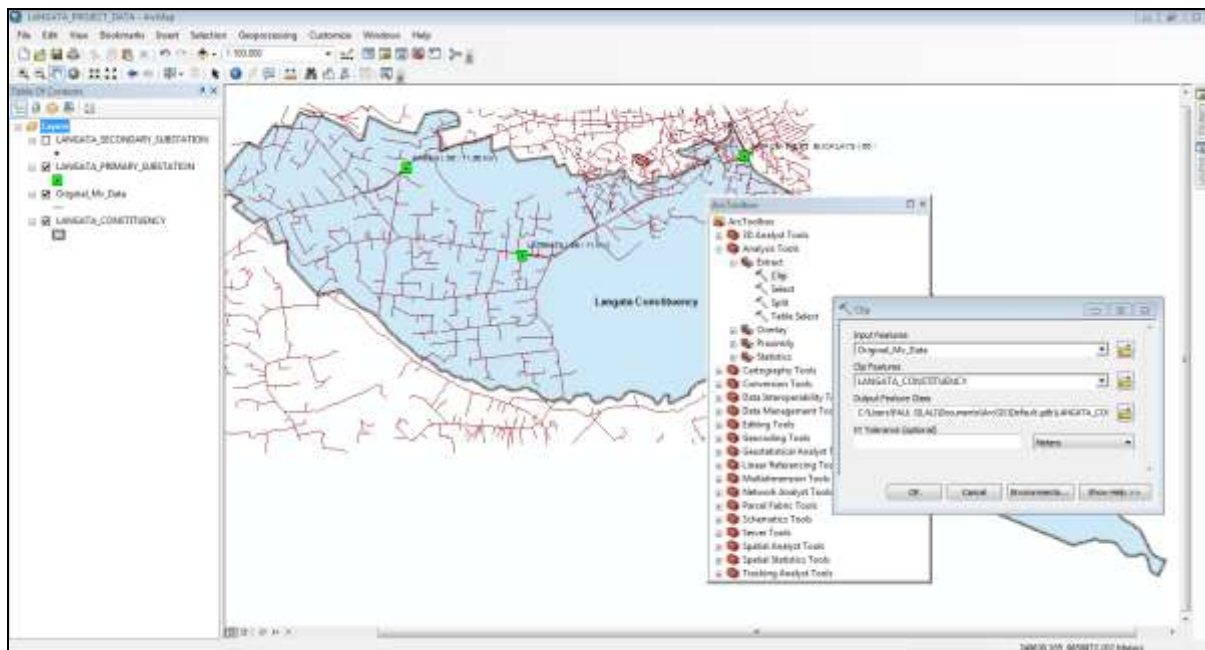


Figure 3.3: Clipping Medium Voltage electrical network data in ArcGIS software

The boundaries that were relevant to the county and constituency of the study area were extracted from the dataset using ArcGIS. All the electrical network datasets were clipped in ArcGIS using the extracted Langata constituency boundary.

Data Editing

Data editing was done to remove errors in electrical network datasets for the study area. The editing task included;

- Cleaning and quality control
- Checking and correcting the integrity of the captured data.
- Checking the coordinate system and carrying out transformations to adjust the projection where necessary.
- Others involved, removal of dangles, overshoot, undershoot and spelling mistakes.

3.7 Developing an Electrical Network Geodatabase

3.7.1 Data Tools Used (Hardware and Software)

- Open ModelSphere Version 3.2

Open ModelSphere is an open source for data processing and UML modeling tool. This application was used for conceptual and logical data modeling as well as the physical design of the database (database modeling).

- PostgreSQL Version 10

PostgreSQL is an open source object-relational database management system used together with the PostGIS to develop the spatial database.

- PostGIS Version 2.0

PostGIS is an open source software that extends the functionalities of PostgreSQL adding support for geographic objects allowing location queries to be run in SQL. PostGIS is compliant with specifications from Open Geospatial Consortium (OGC).

- GeoServer

GeoServer is an open-source server written in Java. Was used to share, process and edit geospatial electrical network data. It has high interoperability and publishes data from any major spatial data source using open standards.

- uDig

This is a User-friendly Desktop Internet GIS (uDig), an open source desktop application framework, whose goal is to provide a complete Java solution for desktop GIS data access, editing, and viewing. In this project, uDig was used in styling the spatial data geometries before publishing.

3.7.2 Database Design.

The process of creating this database design consisted of the following steps **External modeling, Conceptual modeling** and **Logical modeling**.

1.0 External modeling (User Needs assessment)

This is the determination of a finite set of potential users of the database. The External Model is the end user view of the data. The External model required the subdivision of a set of requirements and constraints into functional modules that can be examined within the framework of their external models.

These potential users information needs were determined and the data required to be housed in the database to meet those requirements. External modeling ensured a common understanding between the database developer and those who have a vested interest in the setup of the database;

The identified users of the database were *Meter Reader Supervisor* or *Meter Readers*, *Emergency Teams* and *Postpaid Customers*. The external models for the system are shown in Figure 3.3: below.

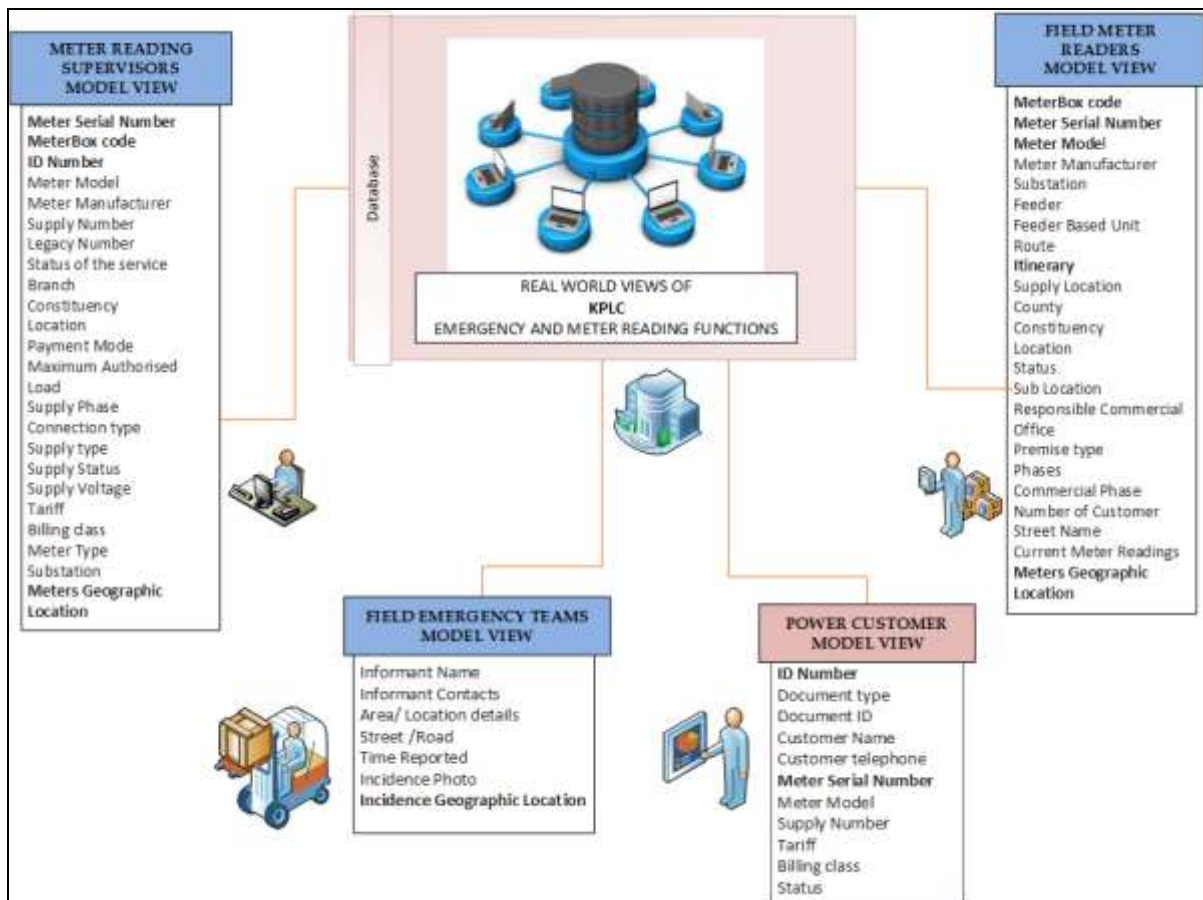


Figure 3.4: External Model Diagram

2.0 Conceptual modeling

'This is the process of constructing a model data used in an enterprise, independent of all physical considerations. The data model is built using the information documented in the user's requirements specifications. Conceptual database design is entirely independent of implementation details such as target DBMS software, application programs Programming languages and Hardware platform '(Connoly & Begg 2015).

Conceptual modeling involves synthesizing the External Models into an Entity-Relationship diagram (as shown in Figure 3.5: below) showing all the entities involved, their attributes and relationships. The external models for the system are

Entity Relationship diagram

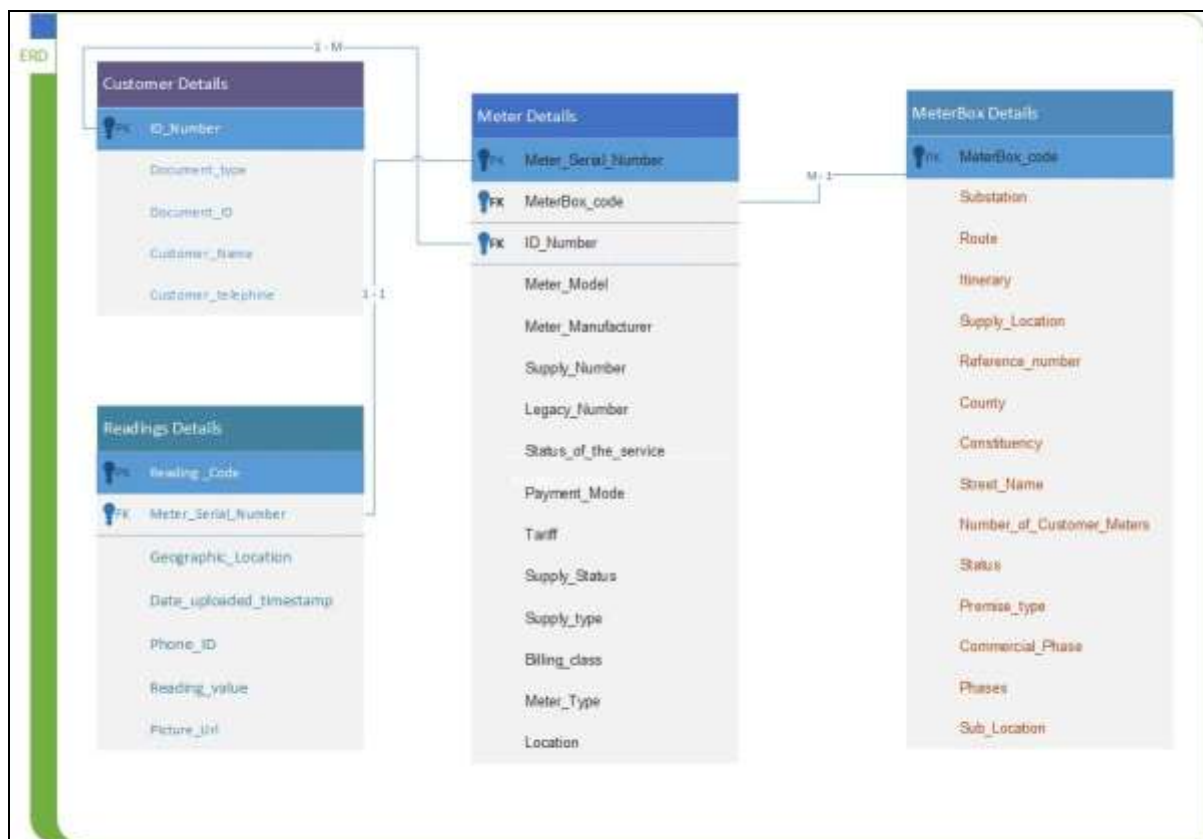


Figure 3.5: Normalized Entity Relationship Diagram

4.0 Logical modeling

'This is the process of constructing a model of data used in an enterprise based on a specific data model, but independent of a particular DBMS and other considerations. The Logical model is derived knowing the underlying data model of the target DBMS, if the DBMS is, for example, relational, network or Hierarchical or Object-oriented.' (Connoly & Begg 2015)

The logical data model conveys the logical functioning and structure of the database and describes how the data is stored (e.g. what tables are used, what constraints are applied but is not specific to any DBMS). The logical database model is a lower-level conceptual model, which must be translated to a physical design. The steps for designing the logical data model was as follows:

- Primary and Foreign keys for all entities were specified
- All the relationships between different entities were identified and specified.
- All the attributes for each entity were identified and specified.
- Any many-to-many relationships were identified and resolved.
- Normalization of database tables was carried on each database table to make sure they complied with the 1 normalization, 2nd normalization, and 3rd normalization.

The properties of each field were defined by specifying the data type, field size, validation rule, requirement constraint, format, and indexes. This design assumed a Relational Data model involved creation schema for this database.

The schema for this database are as follows:

PK – Primary Key FK – Foreign Key

Relation 1: Customer Details (*ID Number (PK), Document type, Document ID, Customer name, Client telephone*)

Table 3.4: Schema for Customer Details table

ID Number (PK)	Document type	Document ID	Customer name	Client telephone

Relation 2: Meter Details (

Meter_Serial_Number (PK), MeterBox_code (FK), ID_Number (FK), Meter_Model, Meter_Manufacturer, Supply_Number, Legacy_Number, Status_of_the_service, Branch, Constituency, Location, Payment_Mode, Maximum_Authorised_Load, Supply_Phase, Connection_type, Supply_type, Supply_Status, Supply_Voltage, Tariff, Billing_class, Meter_Type, Substation)

Table 3.5: Schema for Meter Details table

Meter_Serial_N umber (PK)	MeterBox_ code (FK),	ID_Number (FK),	Meter_Mode I	Meter_Manufacturer	Supply Number

Legacy_Number	Status_of_the_service	Branch	Constituency	Location	Payment_Mode
Maximum_Authorised_Load	Supply_Phase	Connection_type	Supply_type	Supply_Voltage	Tariff, Billing_class
Meter_Type	Substation				

Relation 3: MeterBoxDetails (

MeterBox_code (PK), Substation, Feeder, Feeder_Based_Unit, Route, Itinerary, Supply_Location, Premise_Number, Reference_number, County, Branch, Constituency, Location, Status, Sub_Location, Responsible_Commercial_Office, Premise_type, Phases, Commercial_Phase, Number_of_Customer_Meters, Street Name)

Table 3.6: Schema for Meter box Details table

MeterBox_code (PK),	Substation	Feeder	Feeder_Based_Unit	Route	Itinerary
Supply_Location	Premise_Number	Reference_number	County	Branch	Constituency,
Location	Status	Sub_Location	Responsible_Commercial_Office	Premise_type	Phases
Commercial_Phase	Number_of_Customer_Meters	Street Name			

Relation 4: ReadingDetails (*Reading_code (PK), Meter_Serial_Number (FK), geo_location, Date_uploaded timestamp default, PhoneId, Value, PictureURL*)

Table 3.7: Schema for Reading Details table

Reading code (PK)	Meter_Serial_Number (FK)	geo_location	Date_uploaded timestamp default	PhoneId	Value	Picture URL

This logical model is now ready for use as the basis of a Physical Model of the proposed database.

4.0 Physical modeling

The physical data model was the fourth and final step in database design and it represented how the model will be built into the database. The physical database model showed all table structures, including column name, column data type, column constraints, primary key, foreign key, and relationships between tables. The steps for the physical data model design were as follows:

- Entities were converted into tables.
- Relationships were converted into foreign keys.
- Attributes were converted into columns.
- The physical data model based on physical constraints or requirements were modified.

Table 3.8 is a sample extract of SQL statements were executed to create the tables in PostgreSQL

Table 3.8: SQL statements for creating tables in PostgreSQL

CREATE TABLE Customer Details
(
ID_Number varchar(70) NOT NULL,
Document_type varchar(70),
Document_ID varchar(70),
CUSTOMER_NAME varchar(70),
Client_telephone varchar(70),
PRIMARY KEY (ID_Number)
)
CREATE TABLE ReadingDetails
(
reading_code varchar(70) NOT NULL,
Meter_Serial_Number varchar(70),
geo_location varchar(70),
date_uploaded timestamp default NULL,
phoneld varchar(70),
value varchar(70),
pictureURL varchar(70),
PRIMARY KEY (reading_code),
FOREIGN KEY (Meter_Serial_Number)
REFERENCES
MeterDetails(Meter_Serial_Number)
)

3.7.3 Creating a Spatial Geodatabase in PostgreSQL with PostGIS Extension

A PostgreSQL database with spatial capabilities was created in PostGIS and named 'GSOME_DATABASE' as illustrated in figure 3.6. This is the geodatabase in which all datasets were manipulated before they were imported into the GeoServer.

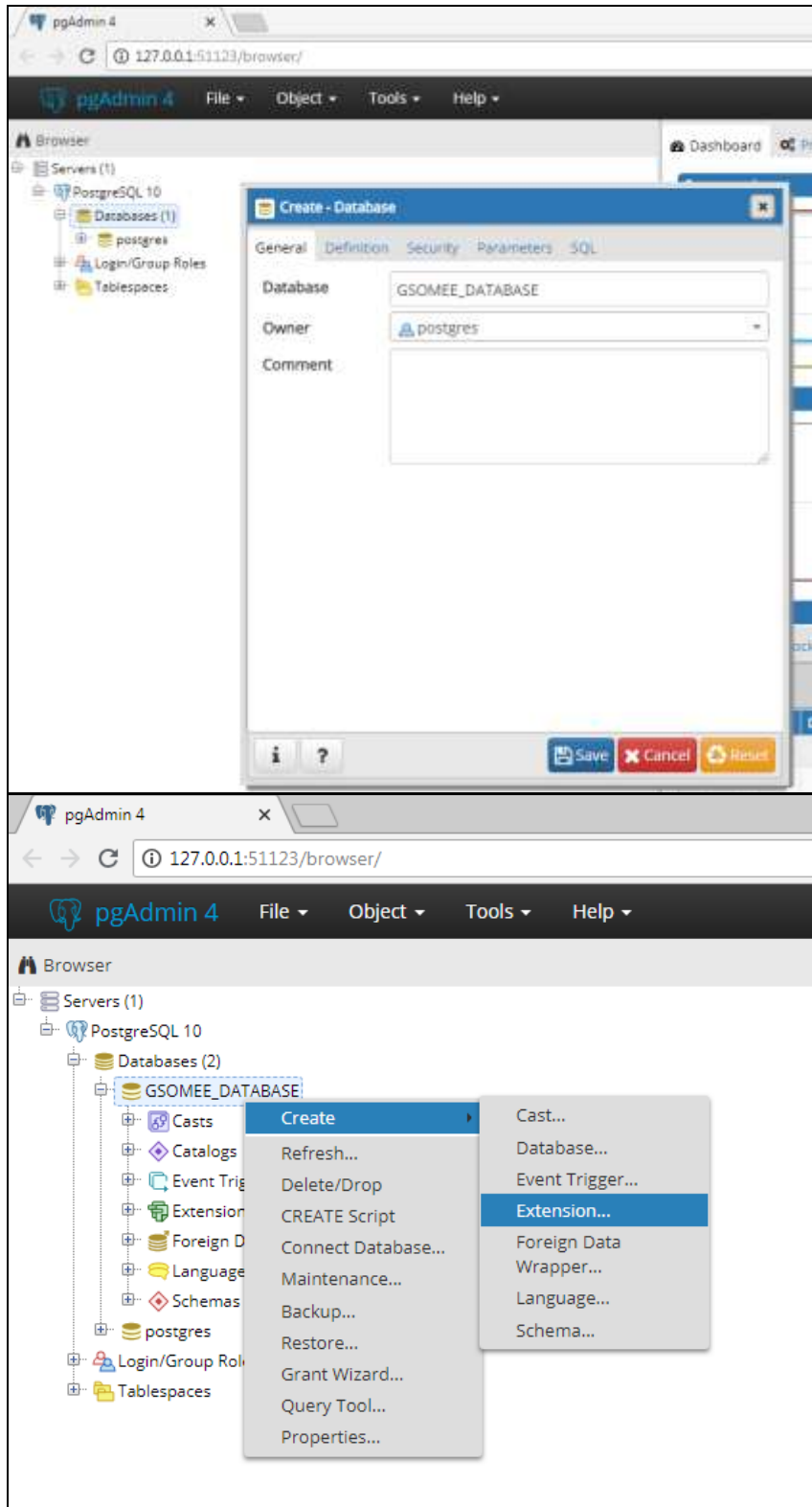


Figure 3.6: Creating a Geodatabase in PostgreSQL with PostGIS Extension

3.7.4 Importing Electrical Network Datasets into PostGIS

The datasets in the shapefile format were then imported to PostGIS by use of the PostGIS Shapefile Import/ Export Manager after a connection was established with the PostgreSQL server. Since all the shapefile were reprojected into the same Projected Coordinate System of Arc1960, UTM 37S, The SRID was set as 21037. Upon this definition, all the datasets were imported into a PostGIS table for editing and other manipulation as illustrated in figure 3.7.

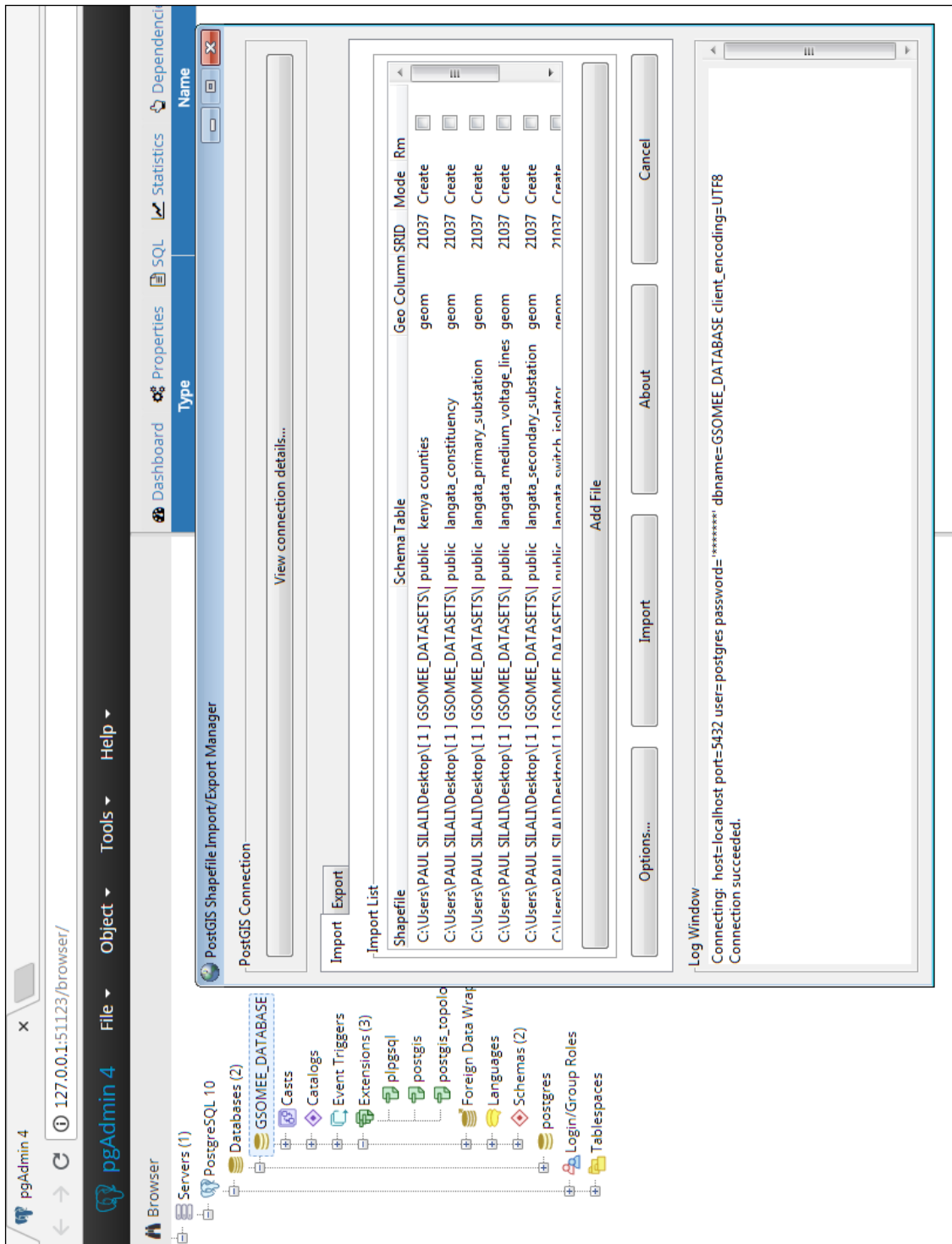


Figure 3.7: Importing shapefiles into PostgreSQL database.

3.7.5 Installing GeoServer and Setting up a GeoServer - PostGIS Connection

Creating a workspace in GeoServer

A workspace with the name 'GSOMEE_WORKSPACE' was created in the GeoServer. This is where all the work associated with the project was done as indicated in figure 3.8

Creating a store in GeoServer

A store was created that was used to import the datasets from the PostGIS server. A connection was therefore established between the GeoServer and PostGIS server to enable importation of the required layers as shown in figure 3.9.

Creating a workspace in GeoServer

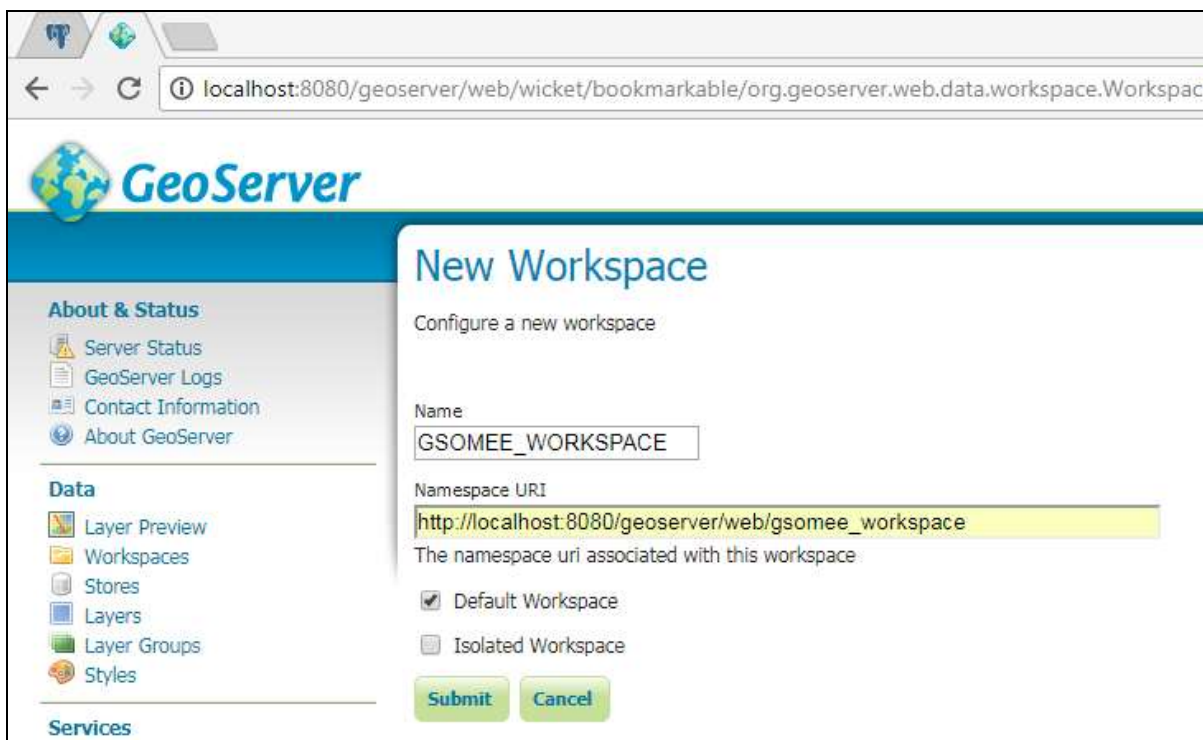


Figure 3.8: Screenshot of workspace created in GeoServer.

While creating a connection to PostGIS the following parameters were defined, the host was set as localhost, and the port 5432 was used to connect to the database

GSOMEEDATABASE in PostGIS. The password of the database was seta and a connection created. The Layers to be imported were selected and imported into GeoServer as indicated in figure 3:10 below.

Creating a connection to PostGIS server and Importing Layers in GeoServer



Figure 3.9: GeoServer - PostGIS Connection Setup

Electrical network layer imported into GeoServer

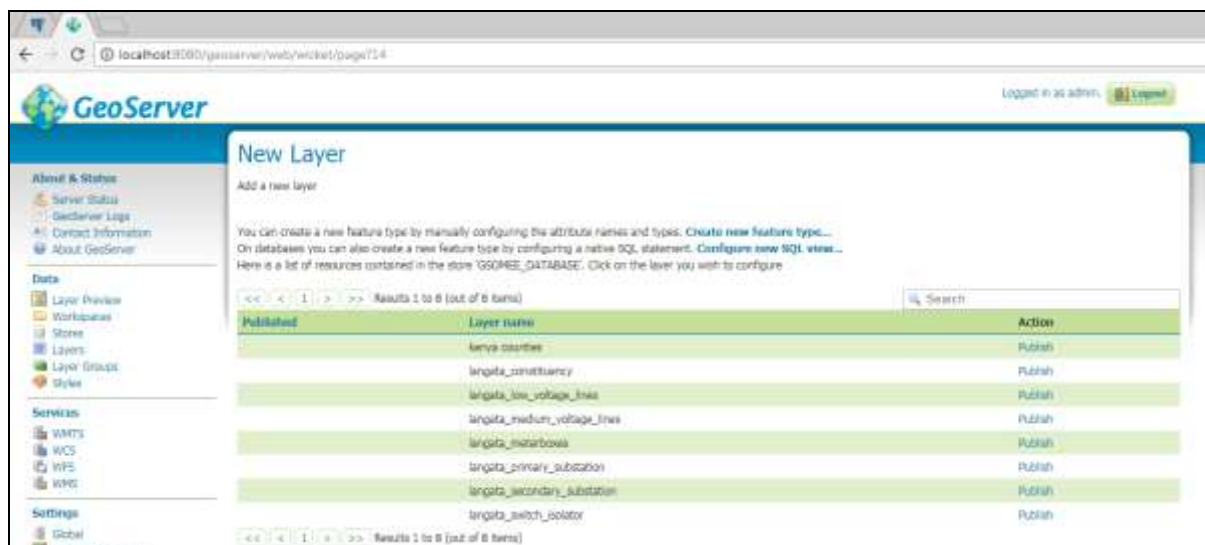


Figure 3.10: Electrical network layer imported into GeoServer

3.7.6 Styling and Publishing Electrical Dataset Layers

The styling of the datasets in uDig

Once a geodatabase for the datasets had been imported into GeoServer, the layers were loaded into uDig software and given the right symbols and colors to enhance cartographic visualization of the layers as indicated in Figure 3.11. Later an SLD (Styled Layer Descriptor) file was saved for each layer and later imported into GeoServer as a new style as illustrated by and Figure 3.12. The styles for each dataset was stored in the GeoServer styles window for application to individual layer before publishing them.

The styling of the datasets in uDig

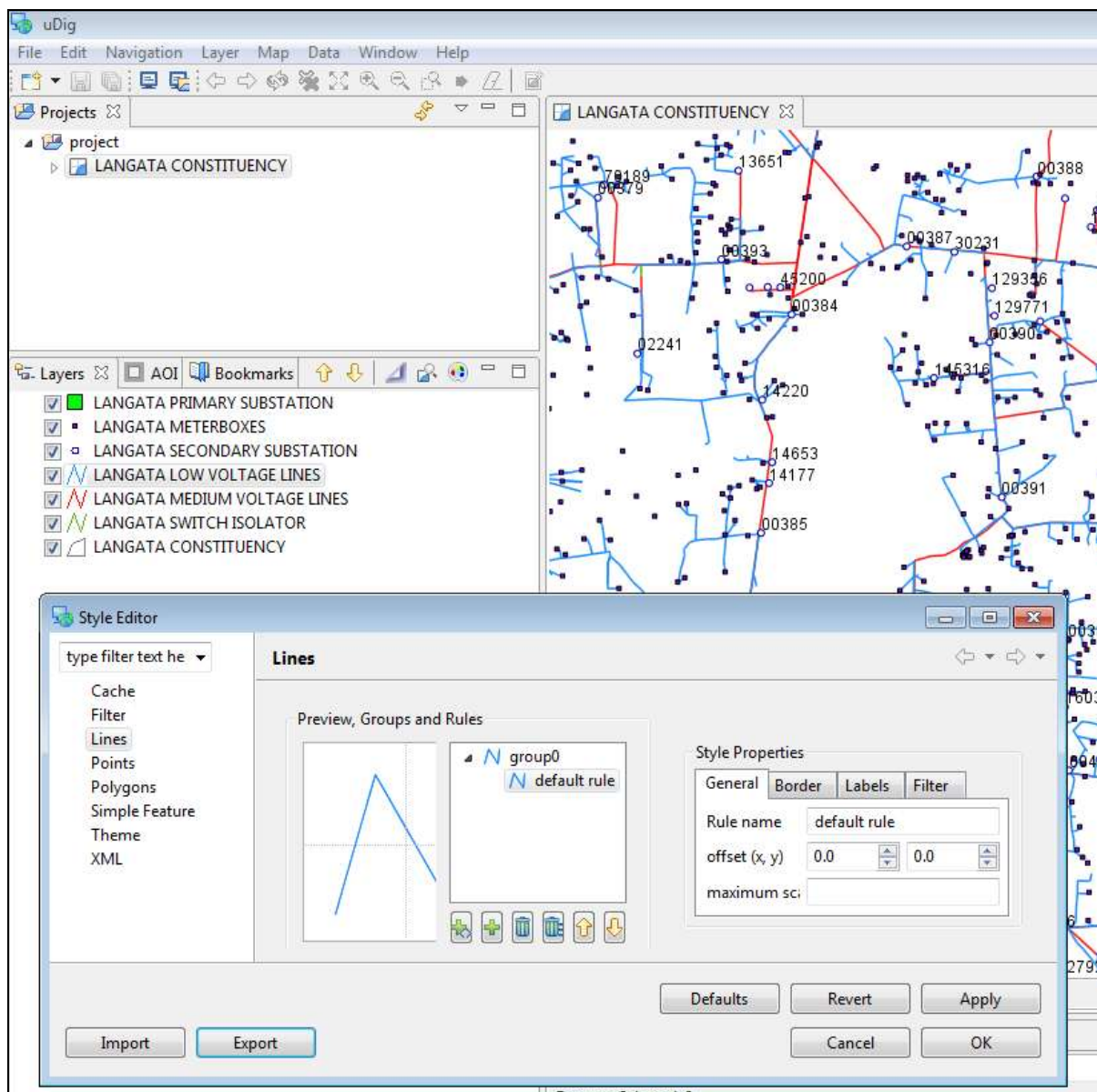


Figure 3.11: The styling of the datasets in uDig

Exporting dataset SDL Files in Udig



Figure 3.12: Exporting dataset SLD files in uDig

Importing styles to GeoServer

All the layers had predefined styles as saved from uDig as SLD files were imported into GeoServer and stored as indicated in figure 3:13 below. The Layers in Geoserver were styled accordingly with their respective styles as illustrated in figure 3:14.



Figure 3.13: Electrical network dataset styles imported into GeoServer

Applying the styles to the Electrical network Datasets in GeoServer

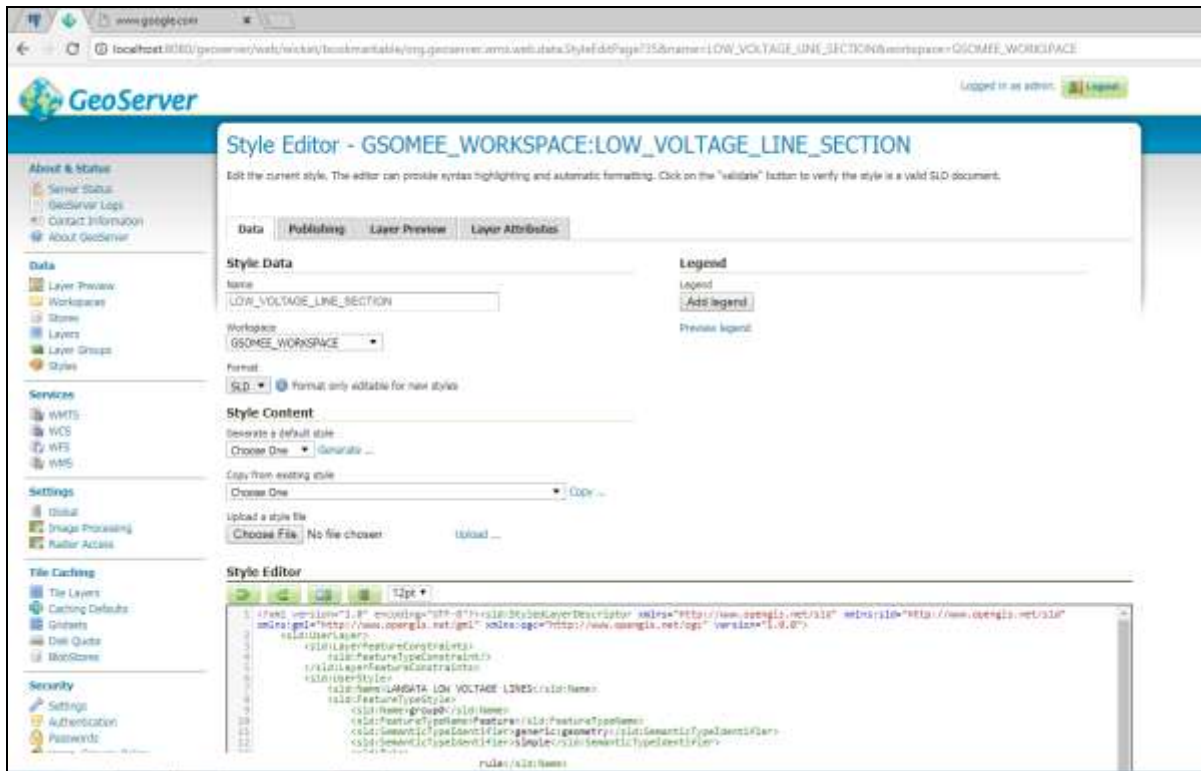


Figure 3.14: Applying the Styling of in GeoServer

3.8 Developing a Mobile Application

3.8.1 Data Tools Used (Hardware and Software)

- Android Studio:

This is an integrated development environment (IDE) for Google's Android operating system, used to provide the interface for the creation of the mobile application and handle file-management behind the scenes. It uses the programming language Java that is installed separately in the computer being used. The studio was used to write, edit and save the projects and the files that comprise said projects. Android Studio also provided access to the Android SDK or 'Software Development Kit', an extension to the Java code that allows it to run smoothly on Android devices and take advantage of the native hardware

- Android Phone (Emulator):

Android emulator is an Android Virtual Device (AVD) that represents a specific Android device (*Phone, Tablet, and Watch*). The Emulator was used as a target platform to run and test the android applications on the computer before installing it on an Android phone.

- A Huawei IDEOS phone running on version Android 2.2 was used for testing and debugging the application.

- Android SDK (Software Development Kit) - Android SDK provided the API libraries and developer tools necessary to build, test, and debug applications for Android. It also.

3.8.2 Installation Android Studio and Creating a Project

The Android studio installation file was downloaded from the android developer site and installed onto the computer. A Project was created and named 'Gsomee_Mobile_app'. It was also paramount to declare the lowest versions of operating systems that the application can be installed in. In this case, the lowest version declared is version 2.2 as illustrated in figure 3.15 and figure 3.16. The application can install on any other version above this. A target version (the latest) was also declared; Version 4.2.

Installation Android studio, creating a project

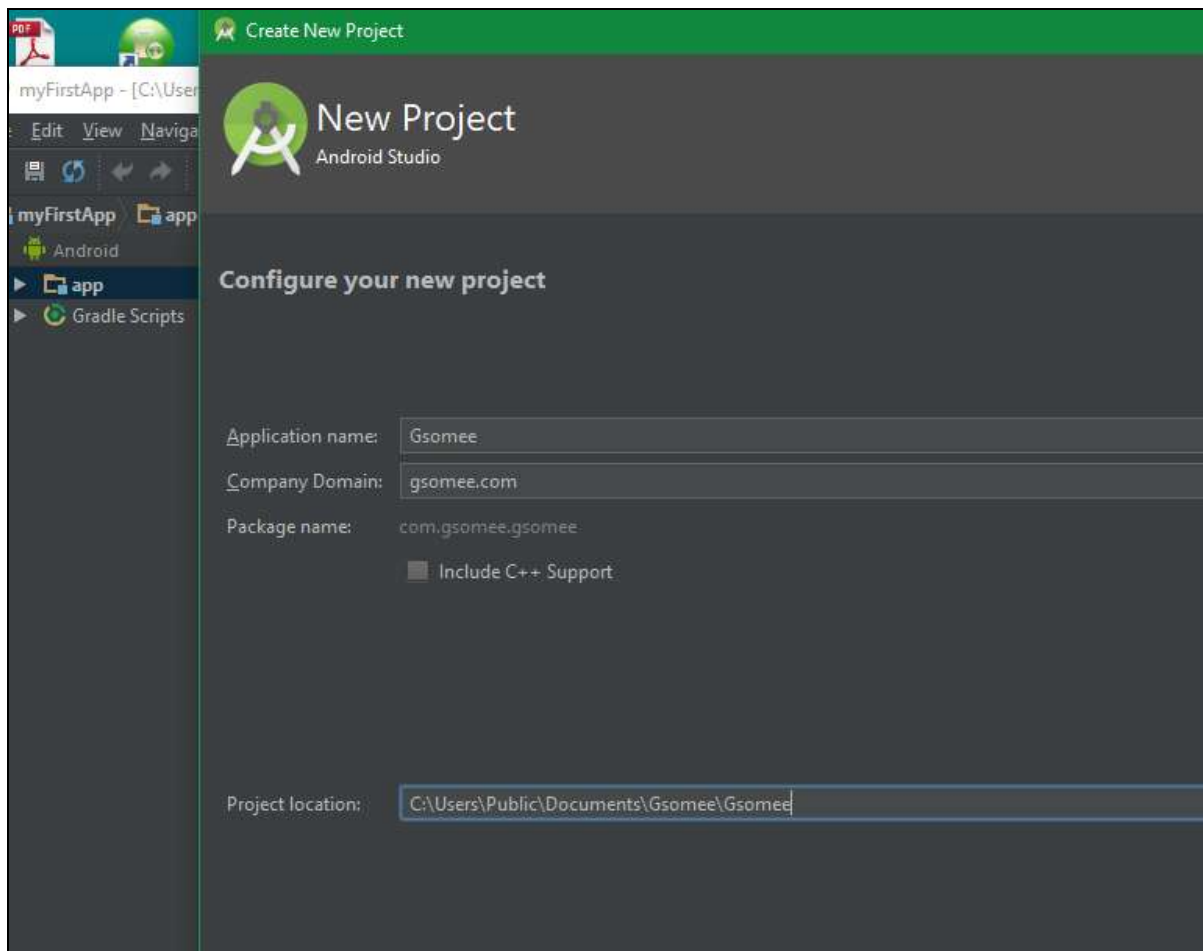


Figure 3.15: Installation Android studio and configuring a new project.

Configuring the target devices for the application

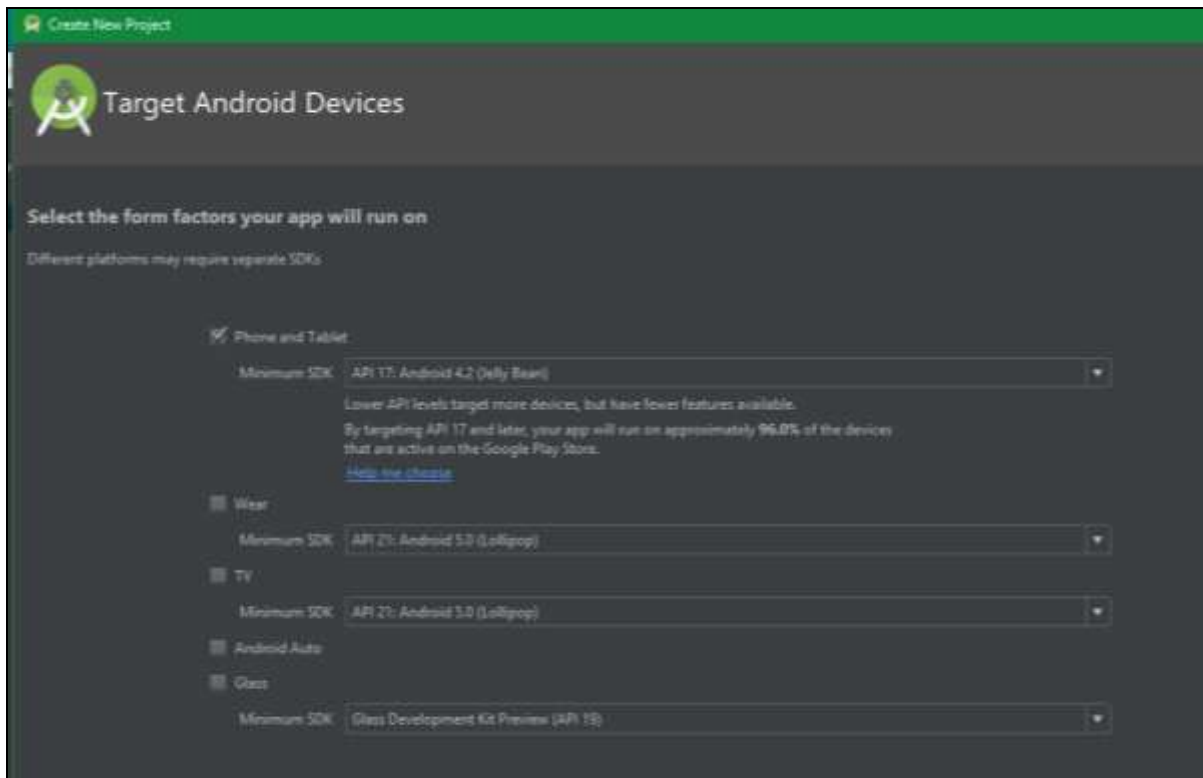


Figure 3.16: Setting the Target Android device

3.8.3 Developing an Android Mobile Application

Using java programming language and XML, the application was developed with the connection to the web application in the AWS server. The application has three different main activities (screens): Account Number Check, Reading details forms and Incidence Form Details.

Figure 3.18 and 3.18 are screenshots illustrating features on the main form of the application are designed and a sample Java programming language and XML code for the incidence form details.

Sample Screenshots on developing android mobile application forms.

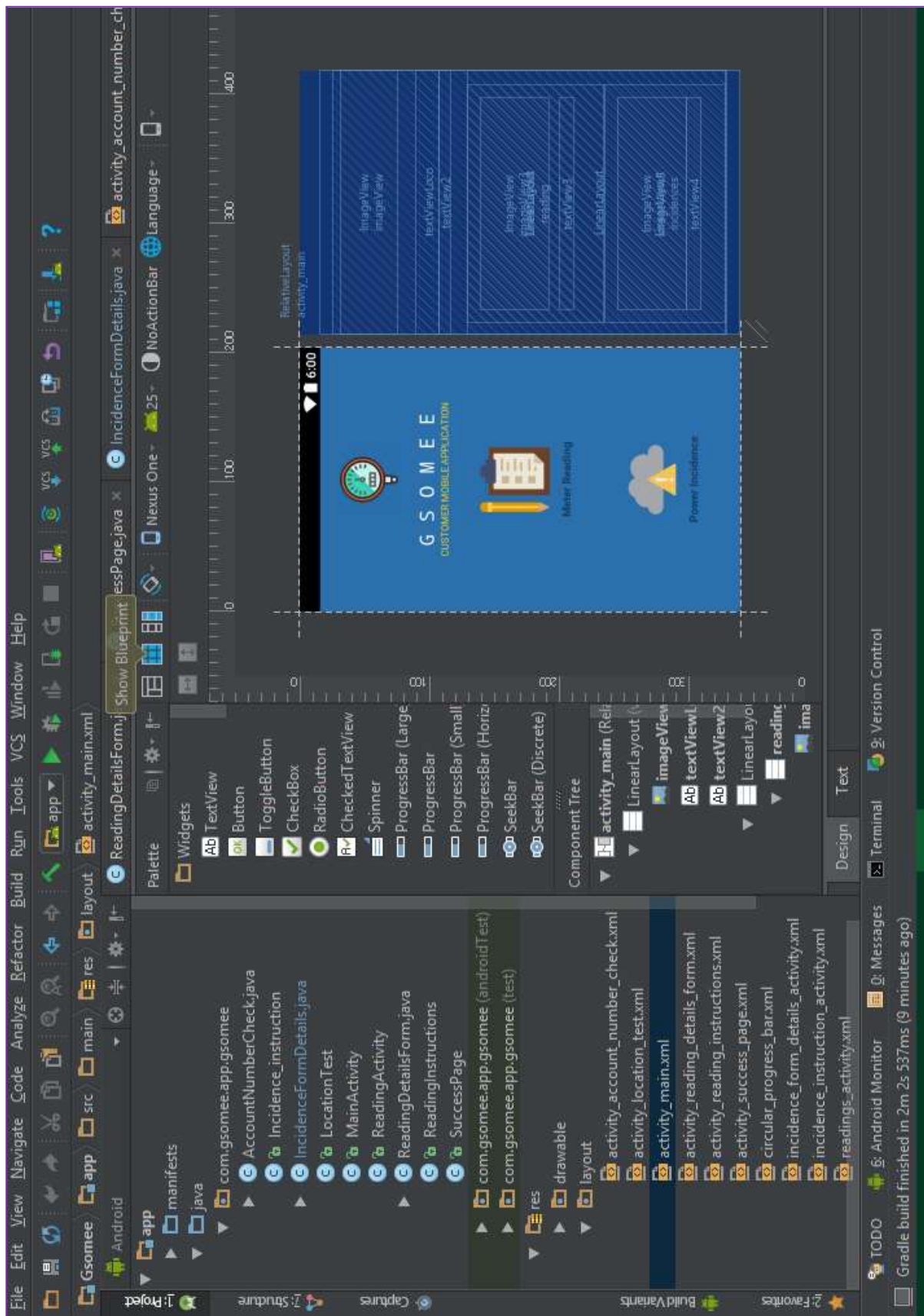


Figure 3.17: Developing the android application main forms

Sample Screenshots on mobile application (Java programming language and XM) code.

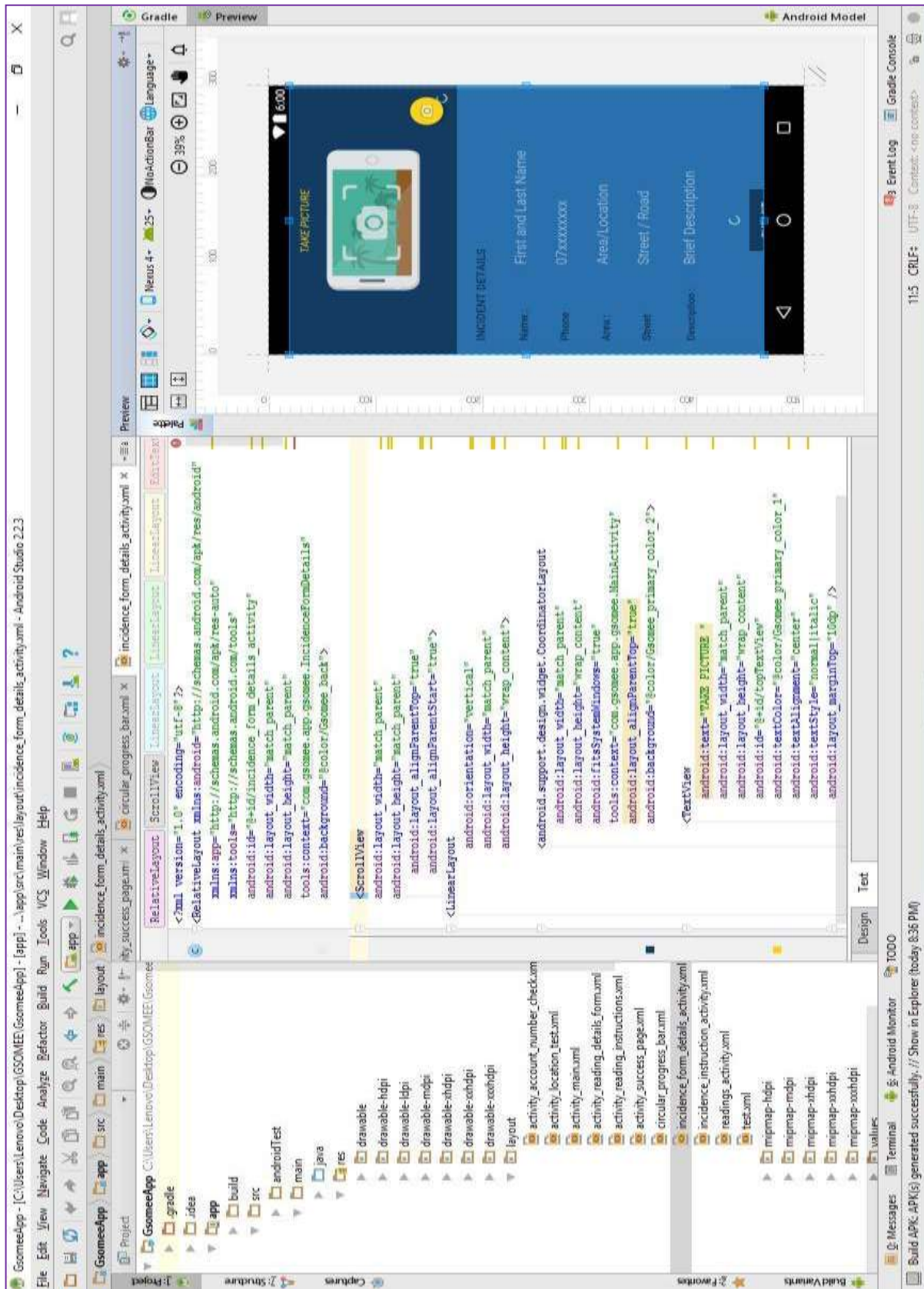


Figure 3.18: Developing the android application (Java programming language and XML)

3.8.4 Testing and Debugging the Mobile Application

The code was tested on an Android device acting as an emulator. From the android studio, the application was executed and results are shown on an android phone connected to the computer via a data cable. Any identified bugs were fixed and process reaped till all bugs were cleared.

3.8.5 Compiling an Executable File and Testing on a Mobile Phone

Once the application was tested, the results were certified, and the application was compiled into an installable file (.apk). This file was loaded and installed on an android phone and tested on the phone to verify that all the related actives were working properly.

3.9 Developing a Web Application Locally

3.9.1 Data Tools Used (Hardware and Software)

- *Code editor (visual studio code)*: This is a source code that was used to edit and write the application code
- *Command prompt*: This was used to run the code and install the required packages.
- *Chrome browser*: This was used to display web application when running.
- *Web development framework environment (node.js)*: This is a JavaScript environment that facilitated the creation and operation of a web application through setting up of a local server and operating the application within the server.
- *Web development libraries*: This provided additional features for the web application e.g. Express library, PostgreSQL library etc.
- *PostgreSQL Database*: This provided the storage of spatial and customer data for the web application.

3.9.2 Installation Node.js Framework Environment and Libraries

Node.js is an open-source, JavaScript run-time environment that allowed the development of a web application and runs the application on the server-side. Node environment was downloaded and installed from the main node website: <https://nodejs.org/en/>. Once the node environment is installed in the pc, special commands were used to initialize the node application from the command prompt, which forms the foundation of this web application.

3.9.3 Creation and Population of PostgreSQL Tables

PostgreSQL was used to hold all the application customer and electrical network data. Customer databases tables were create using SQL statements and the data from generated dummy customer information was used to populate the tables. These datasets were used to be to run and query the web application.

3.9.4 Coding of the Web Application

The application was developed using the following scripting and programming languages libraries and tools: *HTML, JavaScript, OpenLayers, PostgreSQL, and PostGIS*. Figure 3.19: shows the **web-service architecture** that was adopted to facilitate the client and server-side scripting.

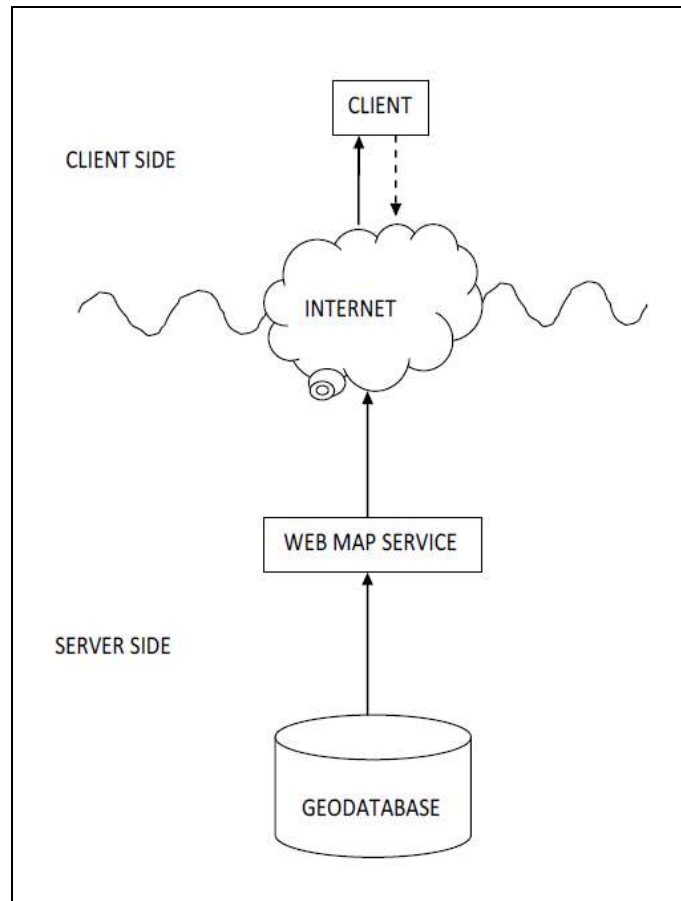


Figure 3.19: Web Service schema

Programming of the web application required *back-end (server-side)* features which included connecting to PostgreSQL database using the installed libraries and development of the applications *Business Logic*. For the *Front-end (client-side)*, the user interface was designed and coded based on HTML and JavaScript. Specific pages in the client-side which had map were connected to the GeoServer to display certain layers onto the maps. All the coding was done with visual studio code editor and uploaded to an online code storage application called repositories.

Visual Studio code editor was used to edit the application code in both HTML and JavaScript. Figure 3:20 is a screenshot of part of the code used to develop the application.

Web Portal programming on visual studio code editor

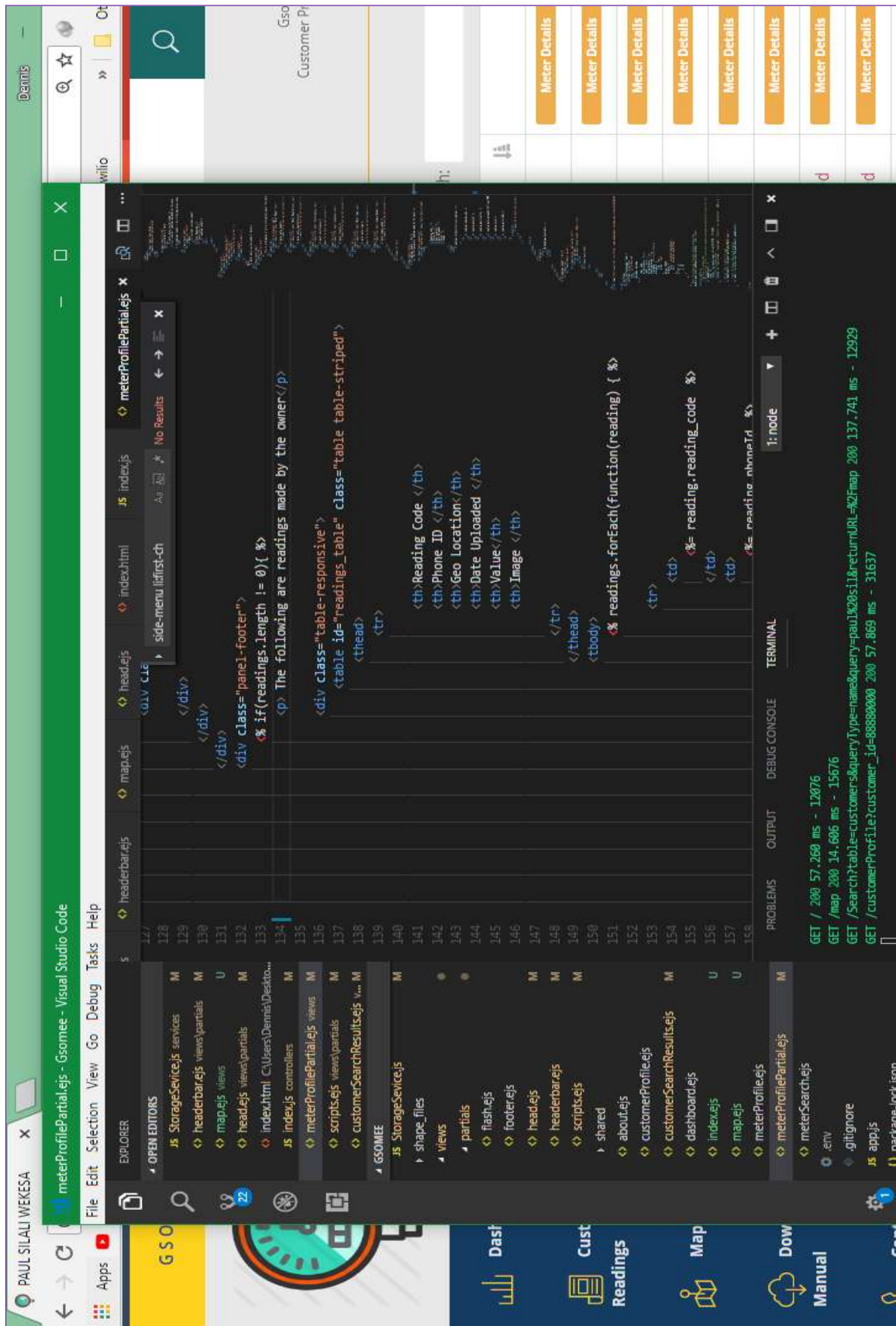


Figure 3.20: Web Portal programming on visual studio code editor

3.9.5 Testing and Debugging the Web Application

The application was frequently tested after every major change and debugged using the command prompt. Using specific node commands of the command prompt the application was set to run and be accessed via the localhost on a predetermined port in a browser. At this stage, the errors encountered while testing was displayed on the command prompt which allowed for easy debugging of the error.

3.10 Publishing, Sharing and Testing the Application

3.10.1 Data Tools Used (Hardware and Software)

- **Amazon Web service (AWS):** Provided the server to host the application (h/w)
- **Putty:** This is a windows software that allowed remote connection to AWS computer on the server using an IP address provided.
- **GPS enabled Android smartphone:** This was used to record and share sample incidence and meter reading data and upload the same on the web portal.

Web linkage Implementation

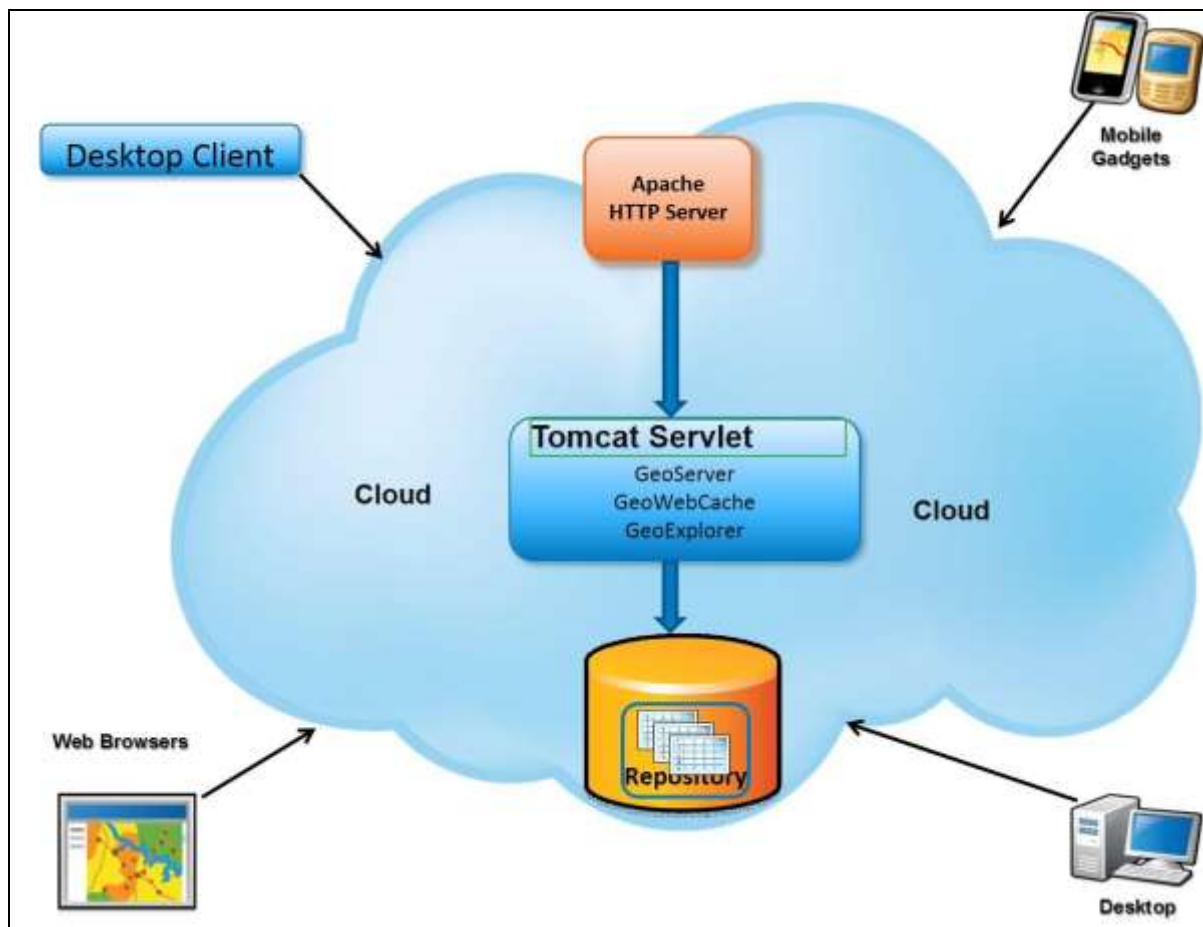


Figure 3.21: Applications interaction on the cloud (Source: Author, 2018)

3.10.2 AWS Account Registration and Creation Server Instance

Amazon Web Services

To enable the application to be accessed remotely, Amazon Web Services were used for hosting the application in the cloud. Figure 3.23: shows the Amazon Web Services interface after registering for an account.

Amazon Web Services interface

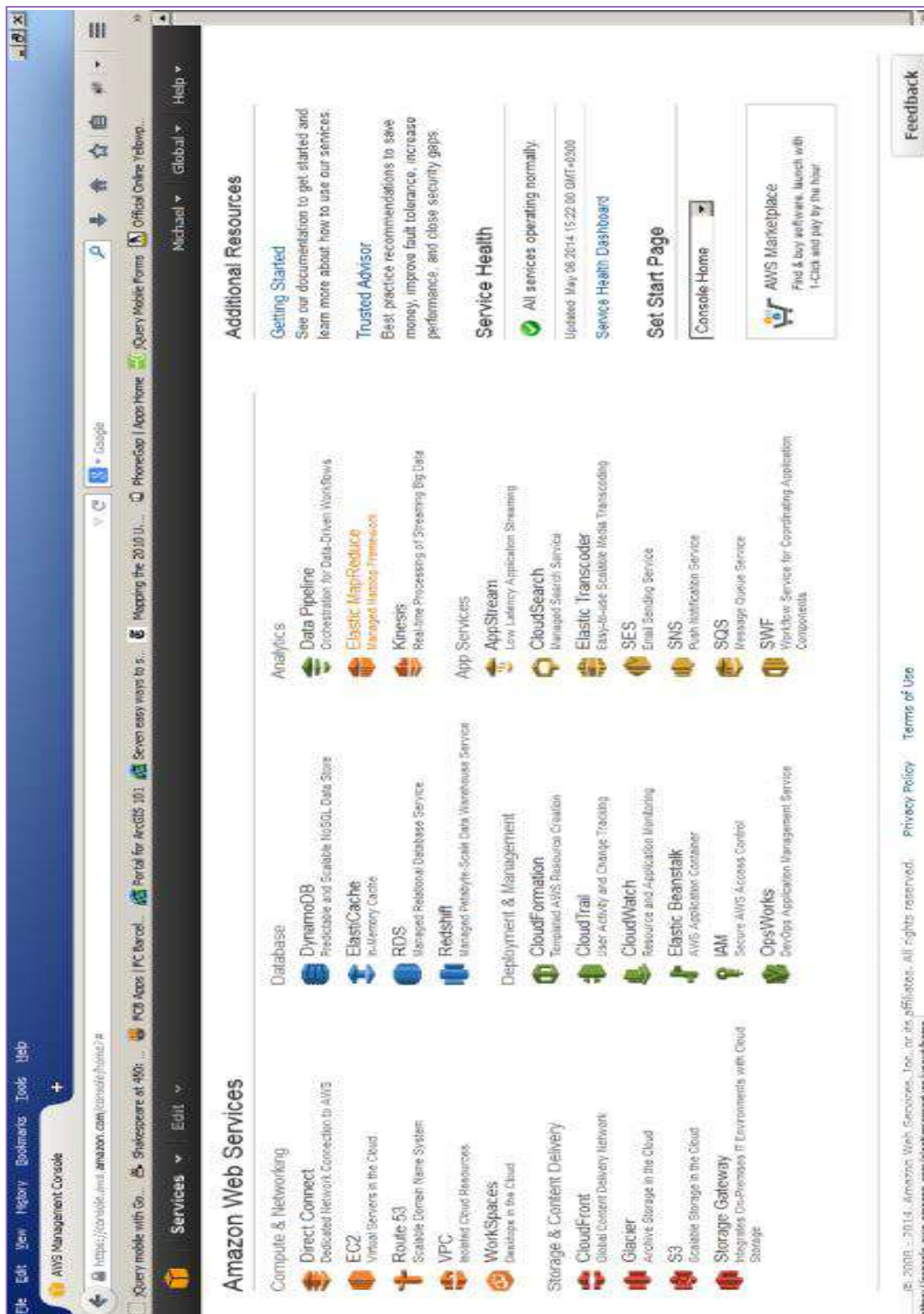


Figure 3.22: Account Registration for Amazon Web Services

The Amazon Elastic Compute Cloud (Amazon EC2) service was set up on the server. The Amazon EC2 feature provides resizable compute capacity in the Amazon Web Services (AWS) cloud. Figure 3.24 shows an EC2 instance being set-up.

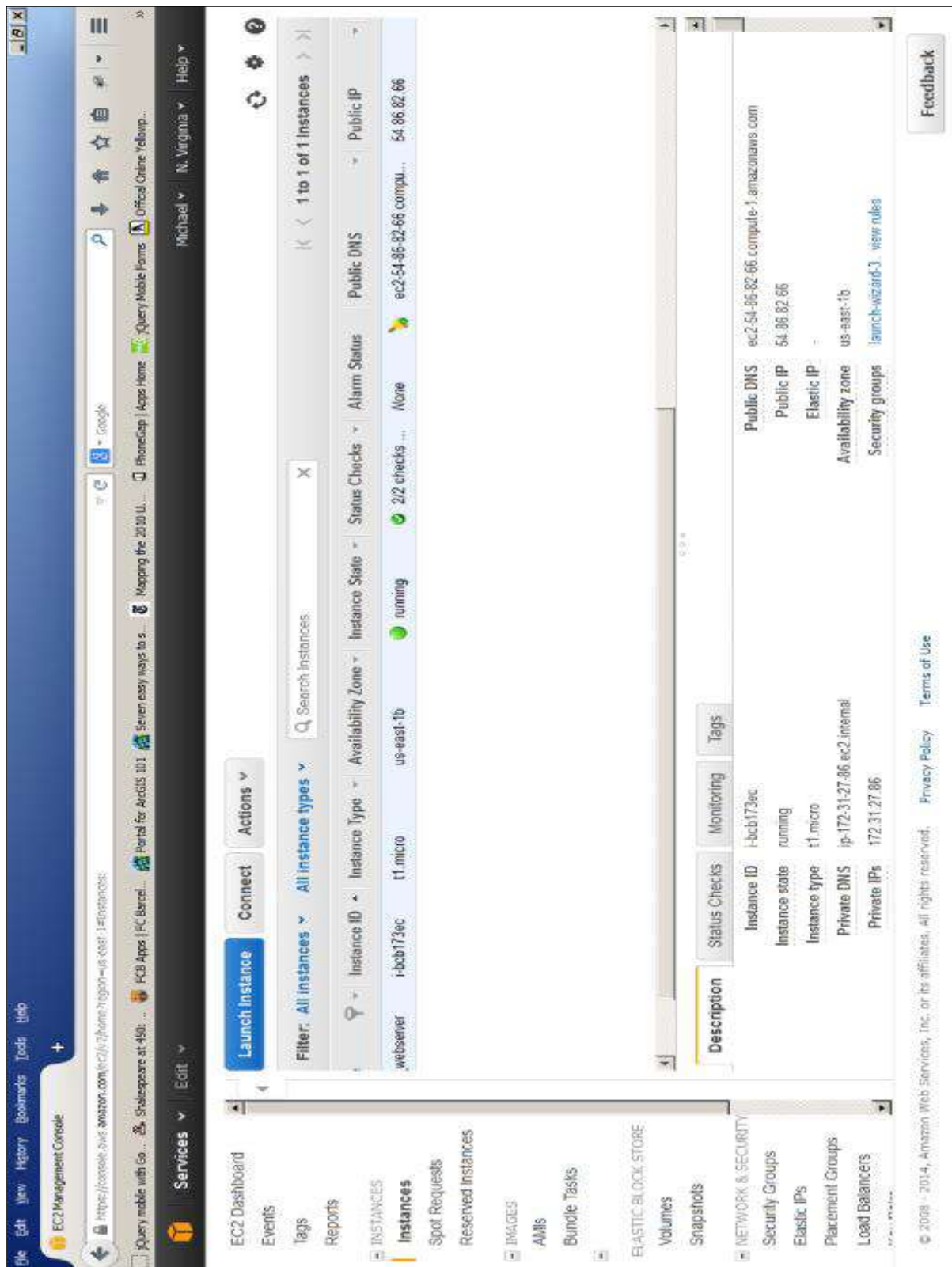


Figure 3.23: Setting up Amazon Elastic Compute Cloud instance

As the instance was set up, the system allocated the user a public Internet Protocol (IP) address that allows one to use the resource remotely; in this case, the IP was **http://13.59.168.60:5437**.

3.10.3 Configuring the Server and Installing the Required Software

Using putty the server was remotely logged into the server from the local computer, a password and firewall were set up. The following software was installed on the server nodes environment, PostgreSQL database, GeoServer. Using the PostgreSQL on the local machine the PostgreSQL on the server was connected to and a database created with tables which were later populated with the relevant data.

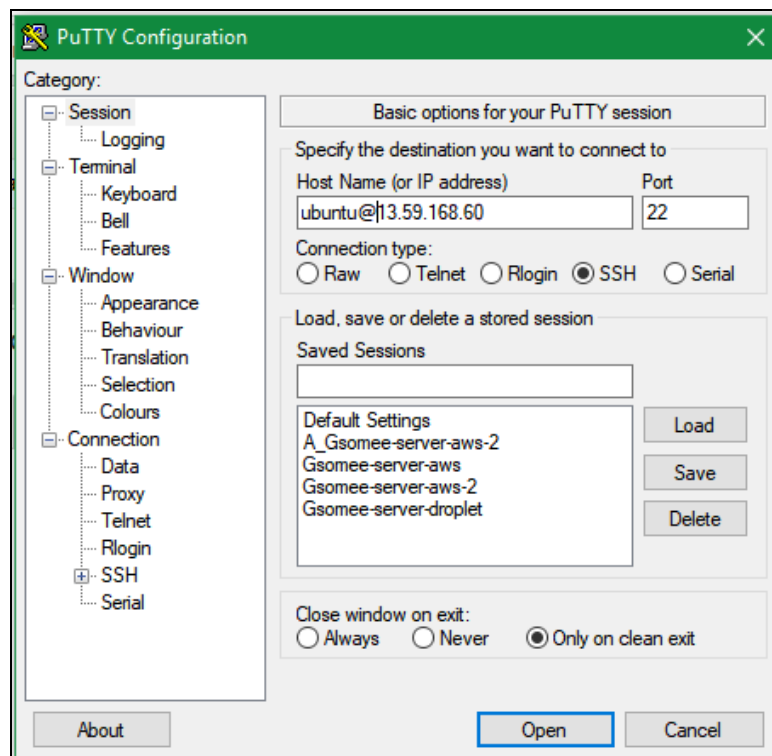


Figure 3.24: Putty configuration to connect to the database

3.10.4 Uploading of Web Application Code to the Server

From the online backup repository, the application code was downloaded onto the server using **git** commands. The installed GeoServer could be accessed via the browser locally using the servers IP address and port 8080. In GeoServer, layers were created from shapefiles stored in PostgreSQL database in the AWS server.

3.10.5 Running and Testing the Web Application Remotely

Once the code is uploaded and setup onto the server, it was the executed to run locally onto the server and accessed remotely onto and browser using the servers **IP address 13.59.168.60 Port: 5437**.

CHAPTER 4: RESULTS AND DISCUSSIONS.

4.1 Introduction

Chapter Four describes the findings of the study. The results on the various databases designed and implemented, the Mobile application developed, and the web portal launched on the cloud server and sample readings and incidences recorded to the web portal application. In this chapter, the obtained results were discussed and in the end, the challenges of implementing both applications pointed out.

4.2 Data Collection and Preparation Results

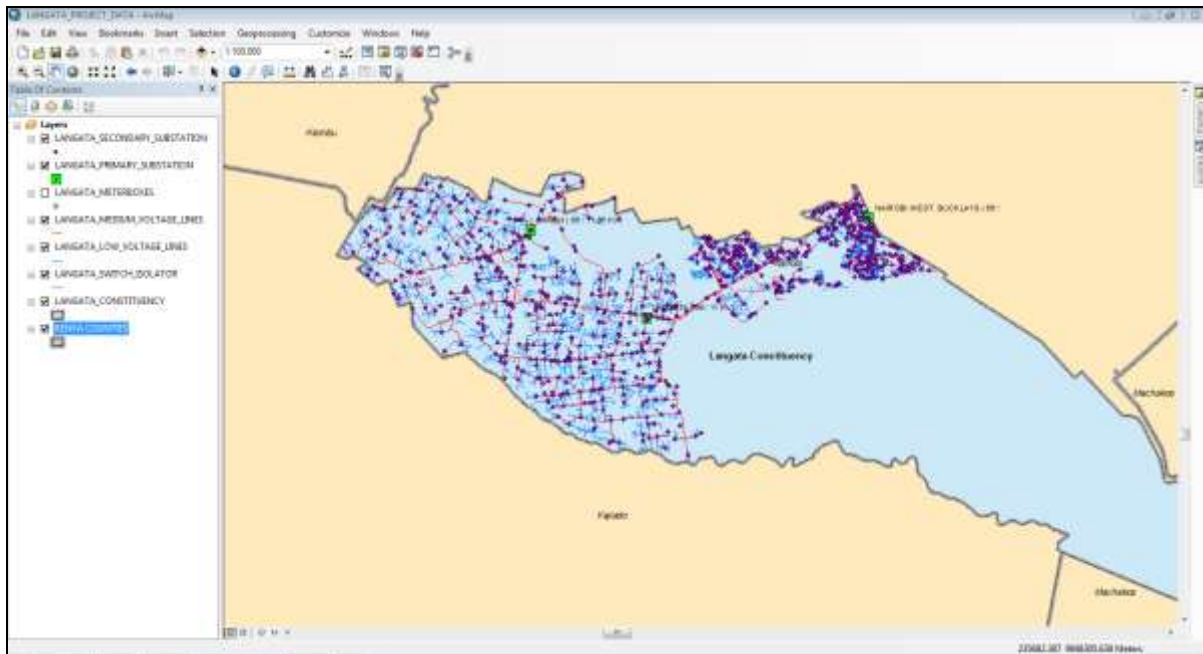


Figure 4.1: Electrical network data prepared in ArcGIS

All the relevant datasets were collected from the identified sources. Figure 4.1: indicates the final output of all the electrical network dataset clipped in ArcGIS using the Langata constituency boundary. The electrical network shape files prepared on ArcGIS were exported in shapefile format to be uploaded to PostGIS. The attribute data was edited to remove unwanted columns and the final output saved as a shapefile.

4.3 Developing an Electrical Network Geodatabase

4.3.1 Output on Design of customer Details Tables.

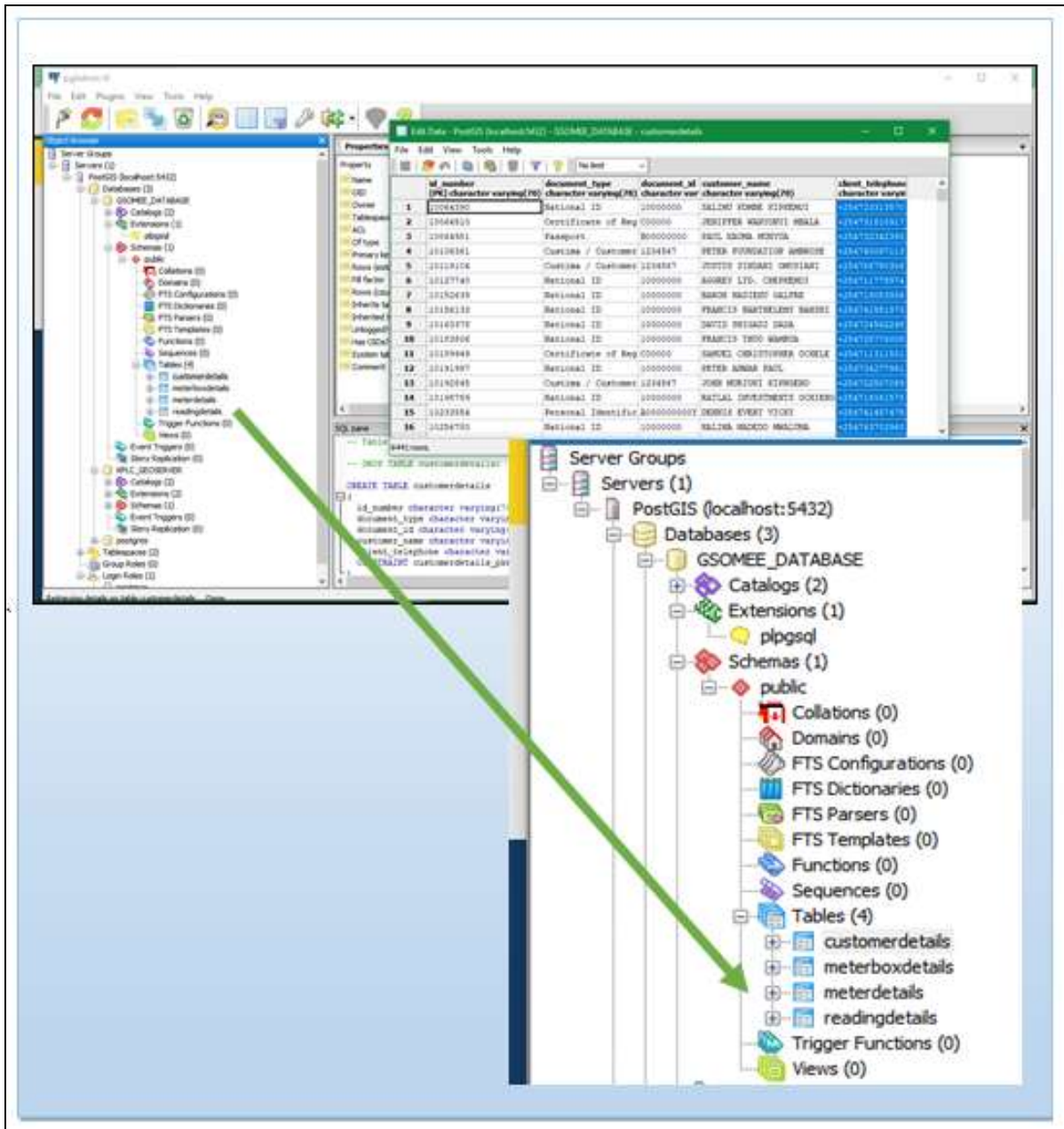


Figure 4.2: Designed customer details data imported in PostGIS

Figure 4.2: illustrated above indicates the final output after the customer data details tables have been designed and imported into PostGIS and relationships created using the relevant primary and foreign keys.

4.3.2 Output on Spatial Geodatabase in PostGIS and GeoServer Output.

[1a.] Results on the imported spatial electrical network data into PostGIS

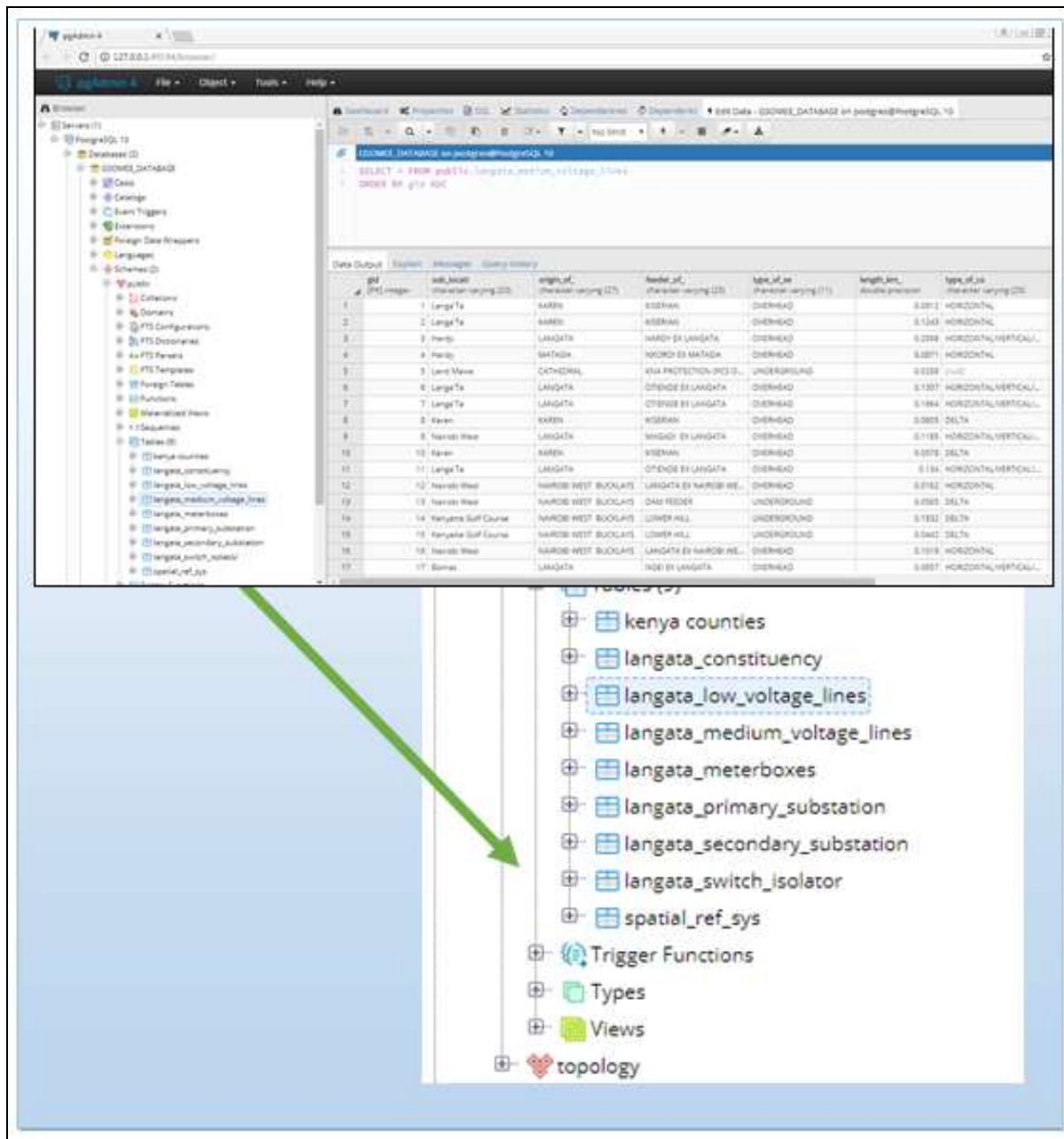


Figure 4.3: Spatial Geodatabase in PostGIS and GeoServer output.

The Figure 4.3: illustrated above indicates the final output after the spatial electrical network data imported into PostGIS. The data was stored on Gsome geodatabase on PostGIS and later used to create the layers in GeoServer.

[1b] Results on the final layers, workspace, and projection in GeoServer

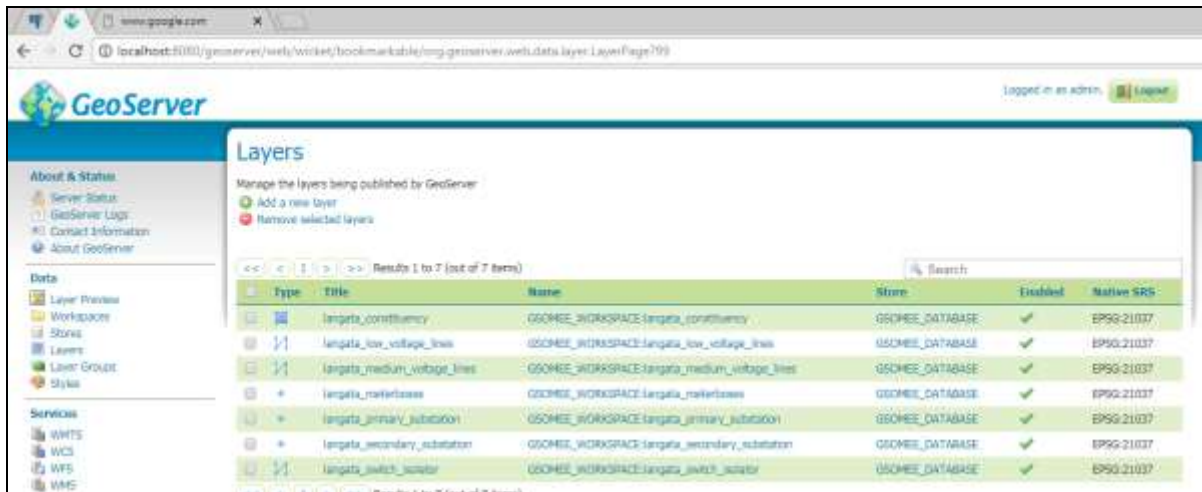


Figure 4.4: Final electrical network data layers workspace and projection in GeoServer

The layers were stored in the workspace “*GSDOMEE WORKSPACE*” as indicated in Figure 4.4: above. The workspace name and layer name were used to request for the layer from GeoServer to the Web portal application.

[1c] Results on the published data layers in GeoServer

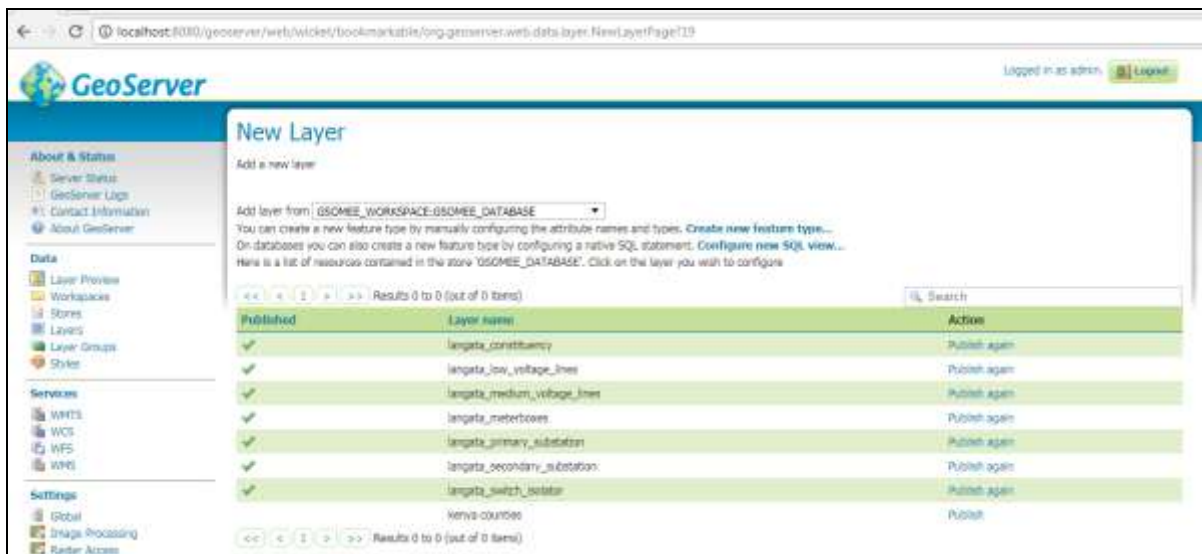


Figure 4.5: Published spatial electrical network data in GeoServer

The Figure 4.5: illustrated above indicates the imported, styled and published in GeoServer that was requested and rendered in the web portal maps rendered on the web portal map using JavaScript code map and leaflet Library.

4.4 Developing a Mobile Application.

The Figure 4.6 below illustrates the application permissions that the user is instructed to allow during installation of the application on the phone. These permissions are required in order for the application to operate. These permissions include *permission for the application to use the phone location, camera, and storage*.

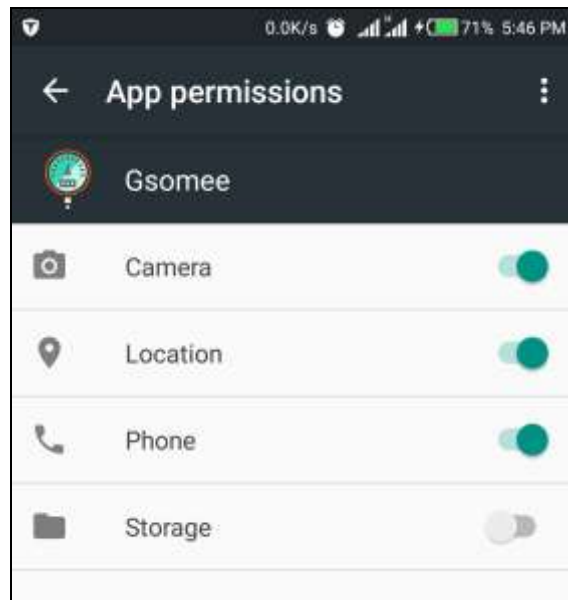


Figure 4.6: A Screenshot illustrating the requested application permissions.

The application can be accessed through the Icon “Gsomee” that appears on the desktop of the phone after installation and when the icon is clicked the application is launched. Figure 4.7 is a screenshot illustrating the application icon on the desktop.

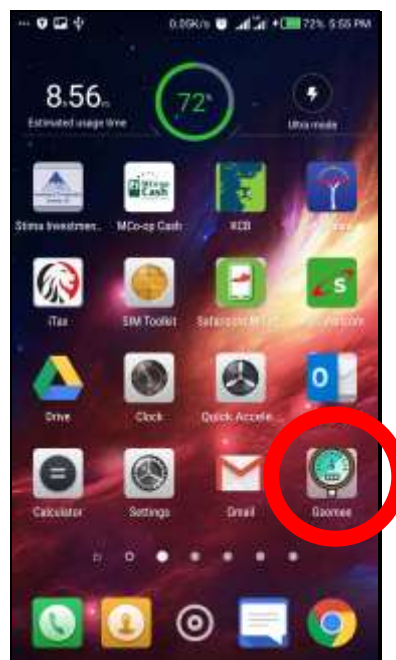


Figure 4.7: A Screenshot illustrating application icon on the android phone desktop

Android Mobile Application Results

Home Page

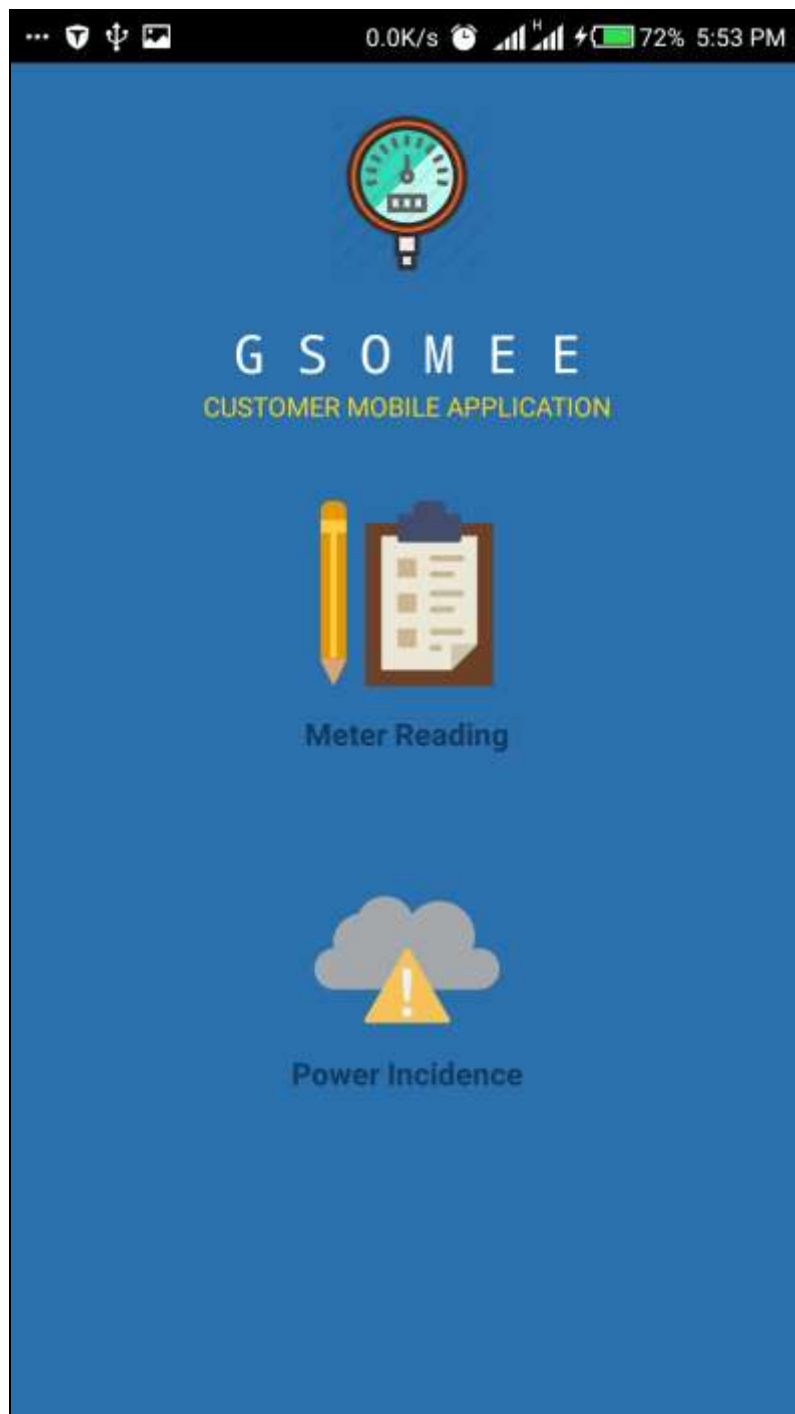


Figure 4.8: The mobile application main page

Figure 4.8 illustrates the final design of the mobile application main page. The page is made up of a simple user-friendly interface with the application title, a link ('Meter Linking') to execute the meter reading process and an icon ('Power Incidences') to execute the incidence reporting process.

Meter Reading Instructions and Reading page

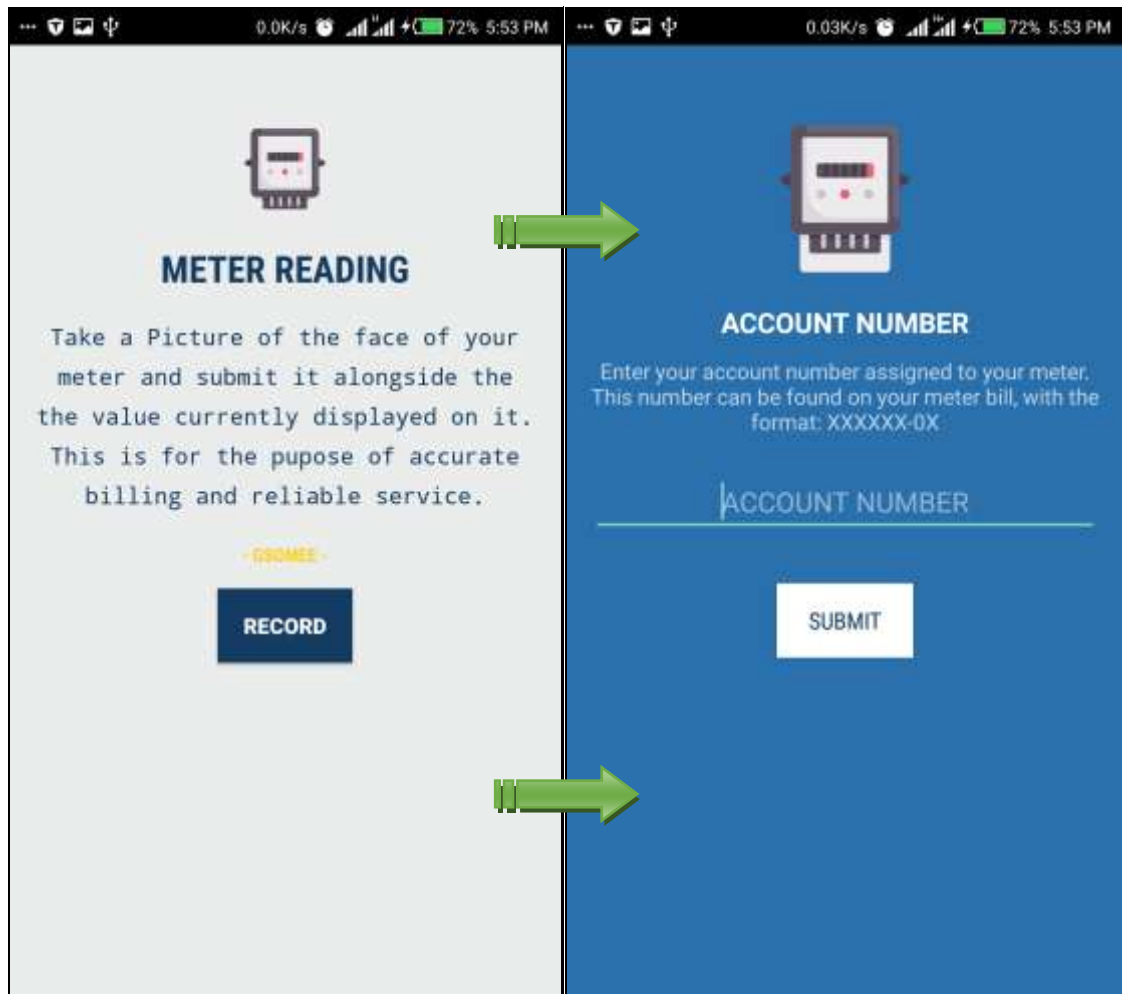


Figure 4.9: The mobile application Meter Reading and Instructions page

The figure 4.9 above illustrate the mobile application instructions page used to inform the user of what the meter reading process entails. After which the user will be requested to input his/her account number in the next page.

The application confirms the meter number from the server and allows the user to take a picture of the reading. The next window after the account is confirmed requests for a picture of the meter to be taken and the value indicated on the meter as the reading be input by the user in the form provided below the photo taken.

The user clicks on the submit button to send the information to the portal. This step requires an internet connection on the user's phone and location option turned on. A notification appears to inform the user the data has been sent.

Incidence Reporting Instruction and Reporting page

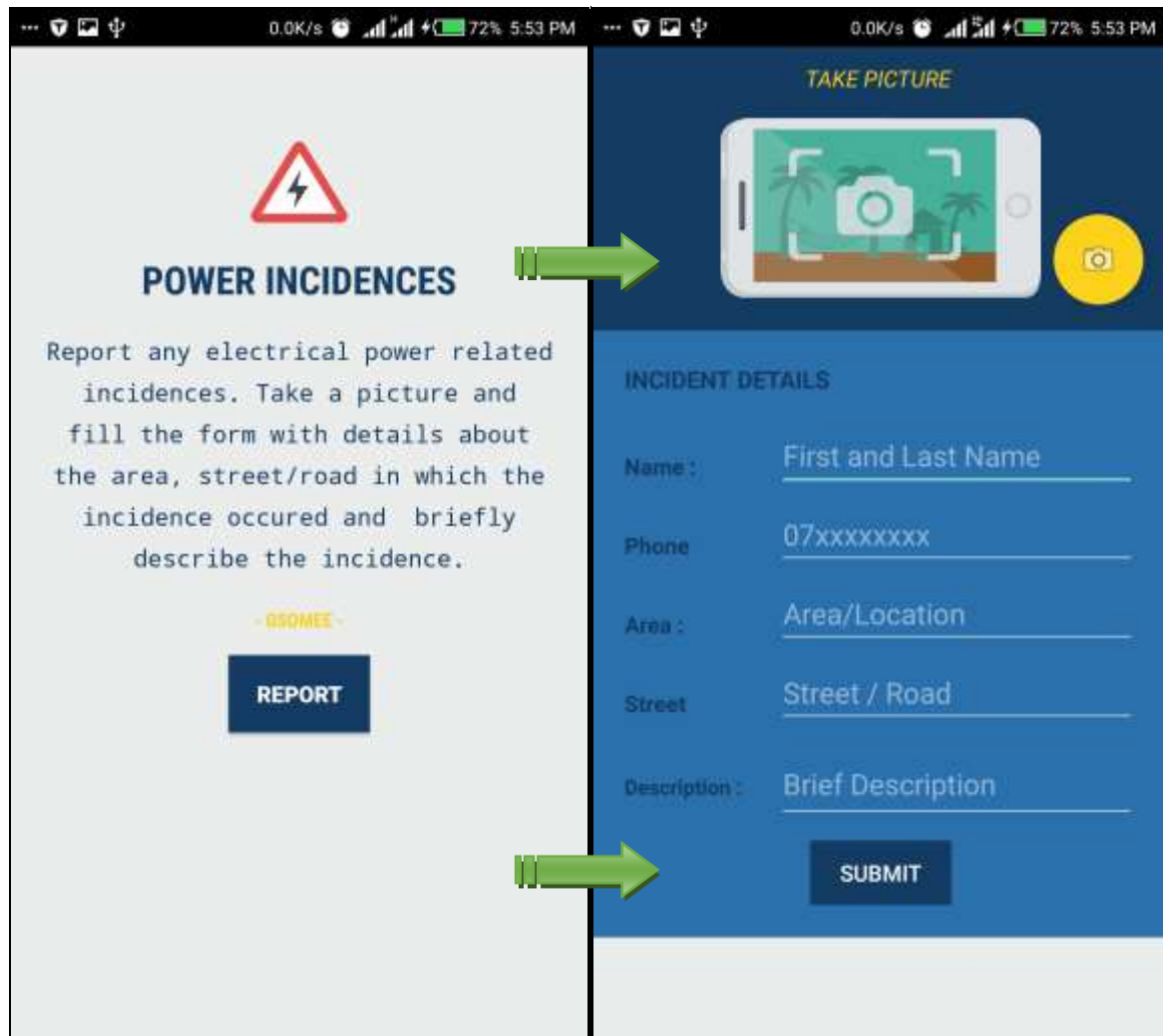


Figure 4.10: The mobile application Incidence Reporting and Instruction page

The figure 4.10 illustrates the mobile application instructions page used to inform the user on what the power incidence reporting process, which the user will be requested to take the picture of the incidence, fill details a form indicating the *informant name*, *phone number*, *area the incidence happened*, *the street* and *a description of the incident*.

The user clicks on the submit button to send the information to the portal. This step requires an internet connection on the user's phone and location option turned on. A notification appears to inform the user the data has been sent.

Data upload Acknowledgement page

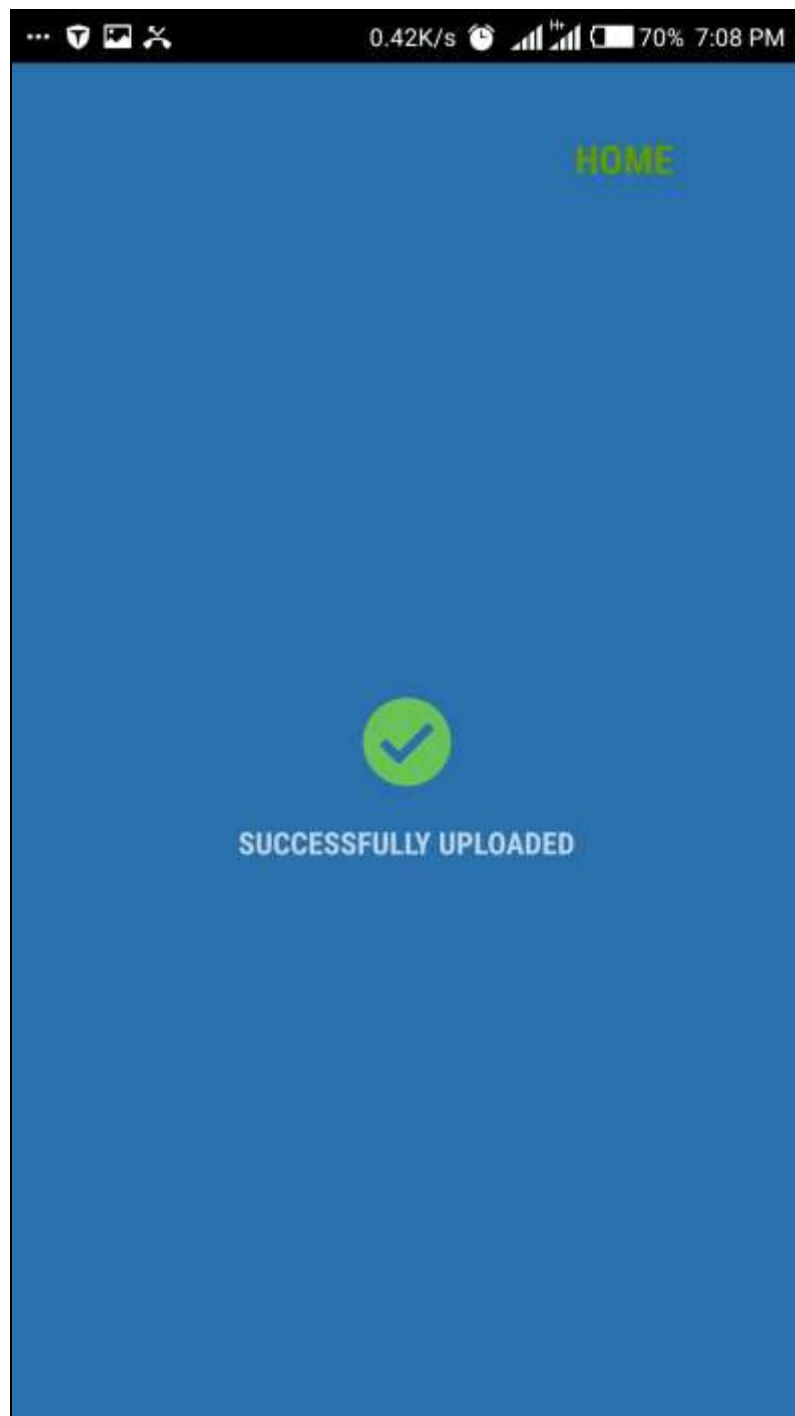


Figure 4.11: The mobile application data upload acknowledgment page.

The figure 4.11 above illustrate the mobile application data upload acknowledgment page used to inform the user that the upload process successful and provides an option for the user to return to the main page through the “Home” icon.

4.5 Developing a Web Application Locally.

Web Application Portal Results

The final output result of the developed system was a dynamic Web application that can be used as a platform to record and share meters reading and incident data sent from the mobile application. Users can also query the portal and retrieve various information. The portal is made up of the following main Pages

[1] Home Page Output

The Home page is the initial page that the user interacts with when they load the portal through the IP address (**http://13.59.168.60:5437**). It displays a brief description of the system and its purpose. From this page, a user can download the manual on how to use the portal and the mobile application **.apk** file to be installed on the user's phone. Figure 4.12: illustrates the home page when the user inputs in the IP address to the portal.

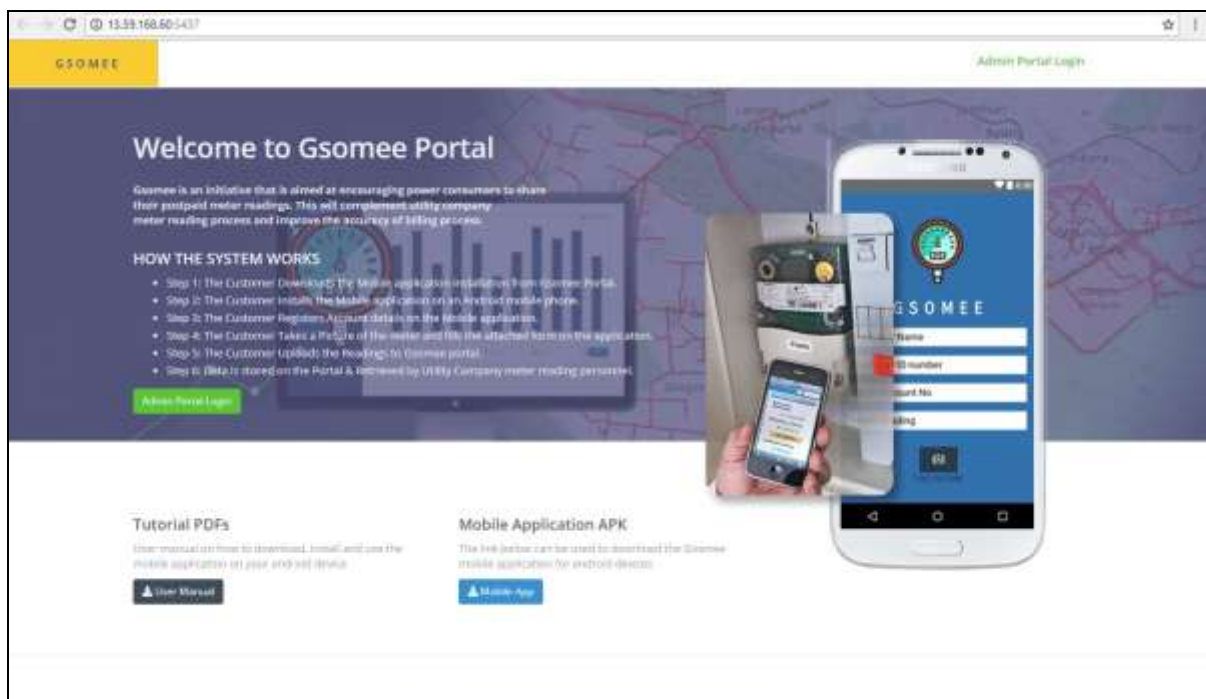


Figure 4.12: Web portal home page

[2] Dashboard Page



Figure 4.13: Web portal Dash board page

Figure 4.13 illustrates the dashboard menu that provides a platform for the user to obtain summary statistics of the data recorded in the portal. The user can get information such as:

- Total Number of Readings Received Vs Total Number of Postpaid Meters
- Number of Power Incidences Reported Per Sub-Location
- Total Number of Readings Accepted Vs Readings Rejected Per month
- Total Number of Readings Accepted Vs Readings Rejected Per month
- Number of Power Incidences Reported Per Month
- Number of Power Incidences Reported Per Month

The figure 4.14 illustrates the Reading Page main window with the details of the readings sent to the portal by the customer. The user can further click on the details link on each customer details on the table to open customer meter readings and location on map section as illustrated in figure 4.15 below.

This section indicates the reading sent by the customer details and its location on the map against the actual location of the meter as captured by KPLC database. This enables verification of the customer's location at the time of reading the meter.

[3a] Readings Page (Part 1) - Main Window

Search:

Show 10 entries

Customer Name	Account Number	Meter Number	Itinerary	Date Uploaded	Value
PAUL SILALI WEKESA	3242267-02	60612527	2153-208001428-502526	Sep 1st 2011	0638 Details
PAUL SILALI WEKESA	3242267-02	60612527	2153-208001428-502526	Aug 8th 2011	395130 Details
PAUL SILALI WEKESA	8221920-02	60739471	2153-208002351-502924	Jan 3rd 2011	53384 Details
PAUL SILALI WEKESA	8221920-02	60739471	2153-208002351-502924	Jan 2nd 2011	662387 Details
PAUL SILALI WEKESA	8221920-02	60739471	2153-208002351-502924	Jan 1st 2011	217793 Details

Showing 1 to 5 of 5 entries

Previous 1 Next

Gsomete Readings

This is a table of all meters readings submitted to Gsomete. This data is acquired from the database. The detail button is a link to the reading details.

Total Readings
5

GSOMETE: PORTAL 2018

© PAUL SILALI WEKESA

Figure 4.14: Web portal Readings Page - Main Window

[3b] Readings Page (Part 2) - Details Link

The screenshot displays a web portal interface for meter readings. At the top, there is a navigation bar with 'GSO MEE' and a search icon. Below this, a 'Total Readings' section shows a count of 7. A table lists customer details:

Customer Name	Account Number	Start Date	End Date
PAUL SKALU WIKESKA	40739477	2153-208001428-502526	Jan 1st 2011
PAUL SKALU WIKESKA	66812327	2153-208001428-502526	Aug 8th 2011

Below the table, a map shows the 'Actual Meter Location' with a red pin. A sidebar on the left contains a navigation menu with icons for Dashboard, Readings, Maps, Incidents, Contact, and Generator. A central panel displays the following information:

- Itinerary: 2153-208001428-502526
- Meter Number: 60612527
- Account Number: 3242267-02
- Phone ID: 58245
- Date (to reader): Sep 1st 2011
- Generator: -1.36199,36.76010
- View: 638

On the right, a 'Photo Captured' section shows a photograph of a meter with the following details:

- Meter Number: 60612527
- View: 638
- Supervisor: Paul Wikeska
- Date: Sep 1st 2011, 12:30:00 pm

The bottom of the page features a footer with 'GSO MEE - PORTAL 2018' and '© PAUL SKALU WIKESKA'.

Figure 4.15: Web portal Readings Page - Details Link

[4] Maps page (With Open Street Map and World Imagery)

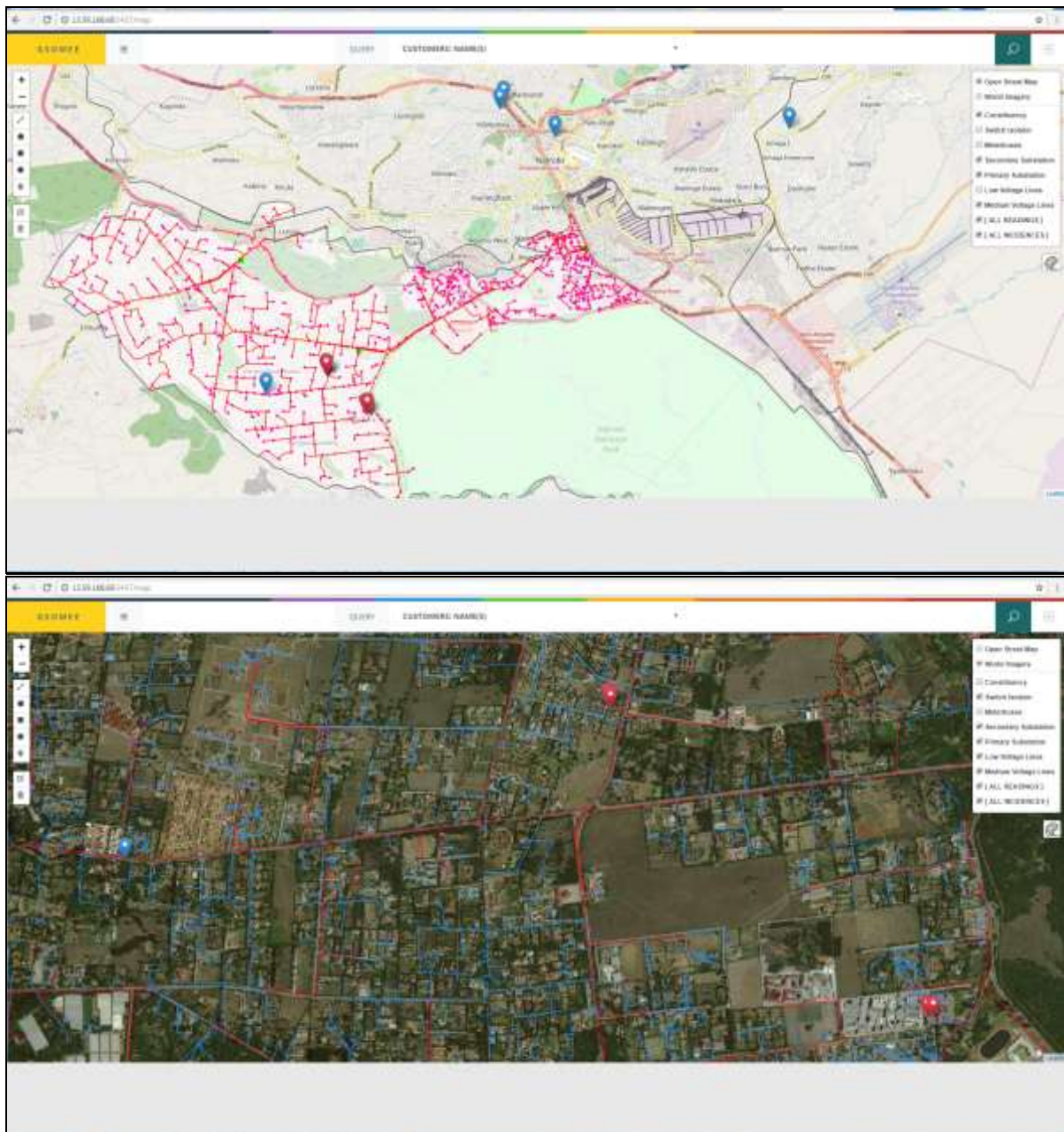


Figure 4.16: Web portal Map page (With Open Street Map and World Imagery base maps)

The figure 4.16 illustrates the Map page, main window with the details of *the electrical network, open street map background layer, reading and all the incidences* sent to the portal. The layer can be switched on and off to display them on the map from the legend menu box.

[5] Power Incidences Page

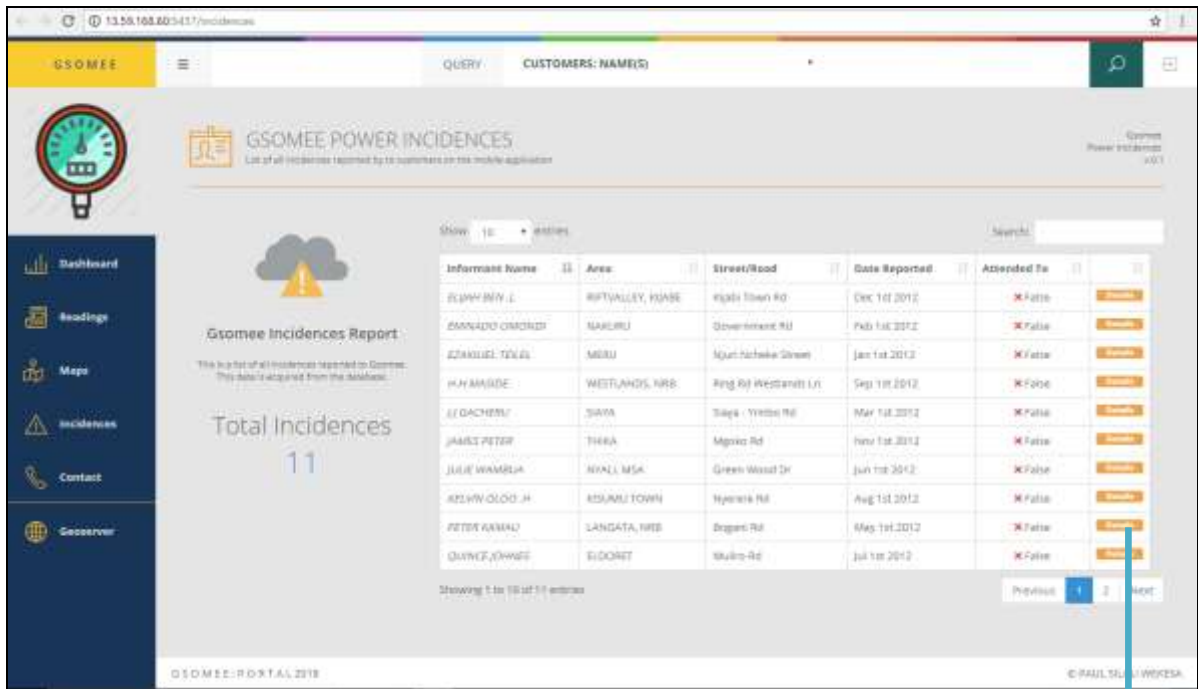


Figure 4.17: Web portal Power Incidences Page

[5] Power Incidences Page - Details Link (1a) on Open street map Base map

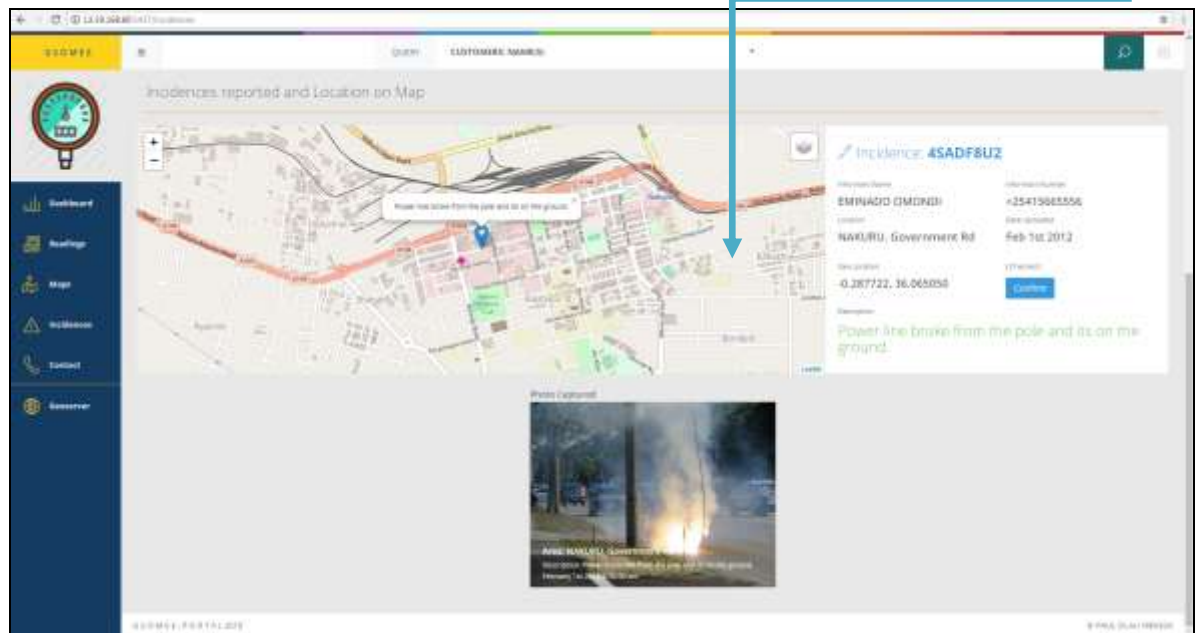


Figure 4.18: Web portal Power Incidences Page Details Link 1

[5] Power Incidences Page - Details Link (1b) on World Imagery map Base map

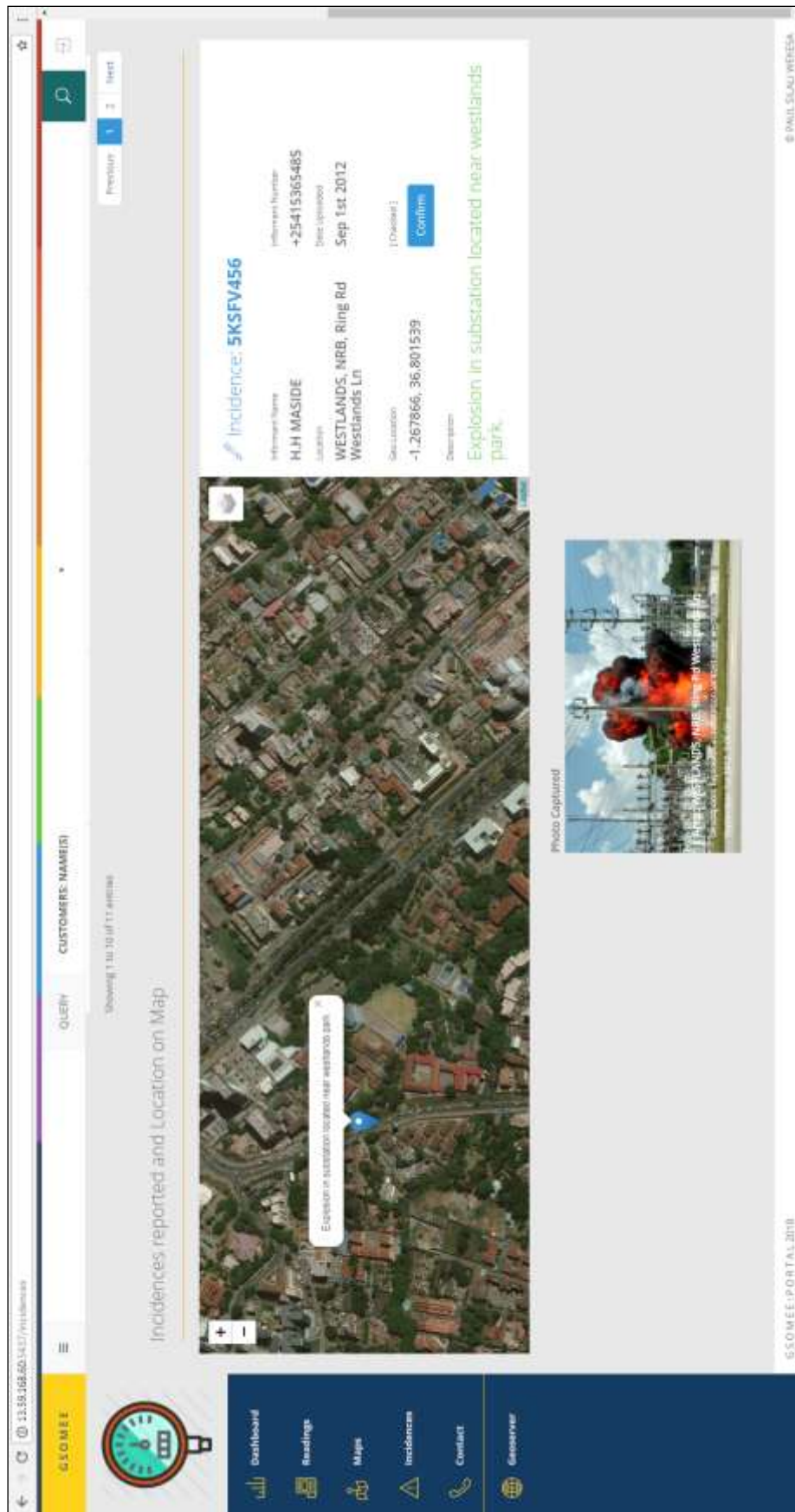


Figure 4.19: Web portal Power Incidences Page Details Link 2

The figure 4.17, figure 4.18 and figure 4.19 above illustrate the Power Incidences Page, with the details of the incidences sent to the portal by the informant. The user can further click on the details link on each incidence reported opening 'incidence reported details and location on map' section.

This section indicates the detail of the incidence sent by the informant, and its location on the map. This enables the emergency teams to easily locate and plan there movement. Attached is also a photo of the incidence that gives a clear image of the scene. This enables the team to interoperate the scene and prepared required tools and equipment.

The informant description of the incidence sent by the user from the phone is also displayed on the details window

[6] Contacts Page

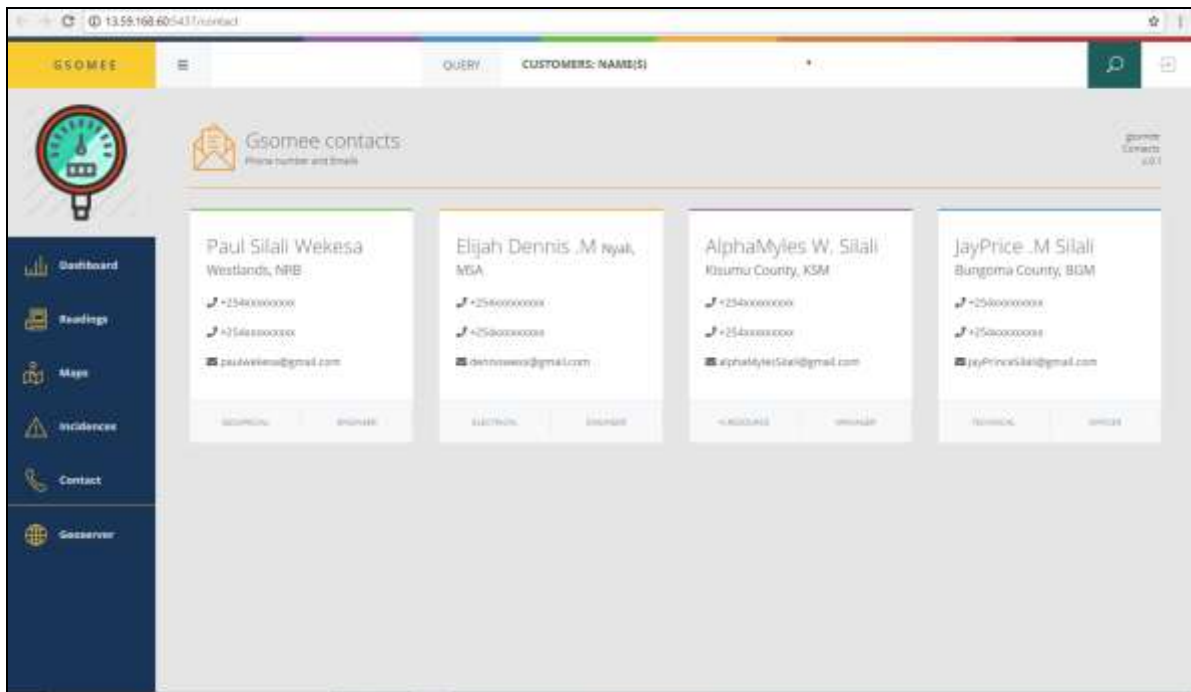


Figure 4.20: Contacts Page

The figure 4.20: below illustrate the contract page that can be modified and customized with contacts of team members to enhance communication within the two function of meter reading and emergency response.

The figure 4.21-26, below illustrate the various ways users can carry out searches on the portal based on;

- Search by Customer Name
- Search by Meter box: Itinerary

For all the searches the meter location was indicated on the map against the readings received.

[A] A Search Option (Search by Customer Name)

[6] A Search Carried out of the customer “PAUL SILALI”



Figure 4.21: Web portal Name Search page

[6] Customer “PAUL SILALI” - Profile link



Figure 4.22: Web portal Customer – Profile page

[6] Customer “PAUL SILALI” (Meter Details and Location on Map) - *Meter Details link*

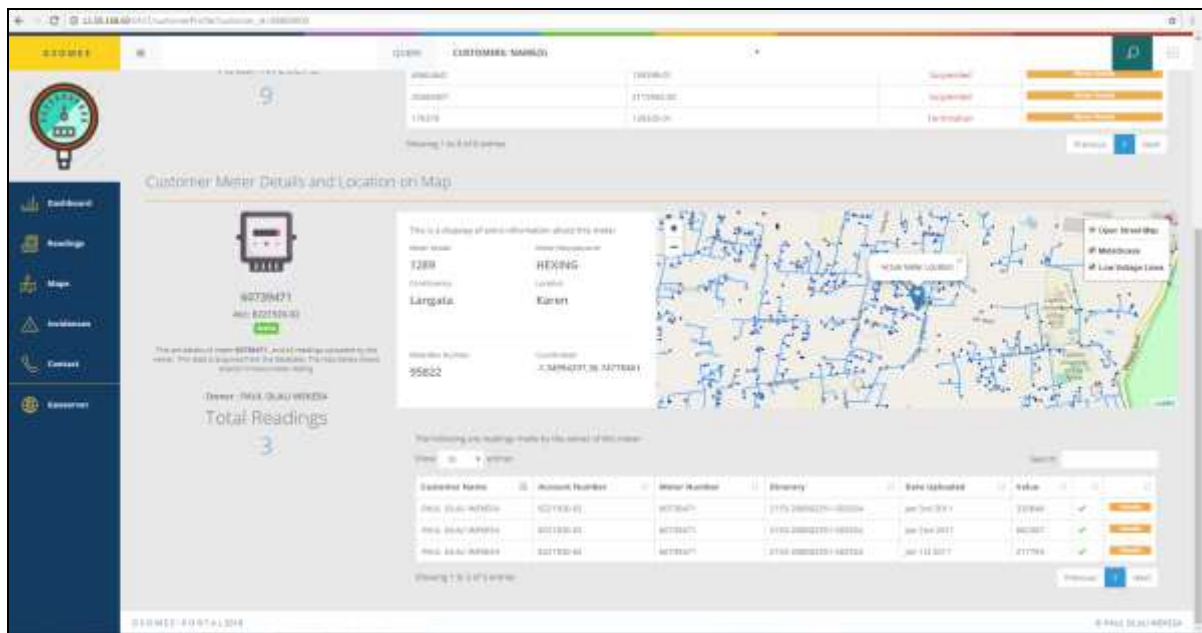


Figure 4.23: Web portal Customer – Meter Details and Location page

[6] Customer “PAUL SILALI” (Meter Reading and Location on Map) - *Meter Details link*

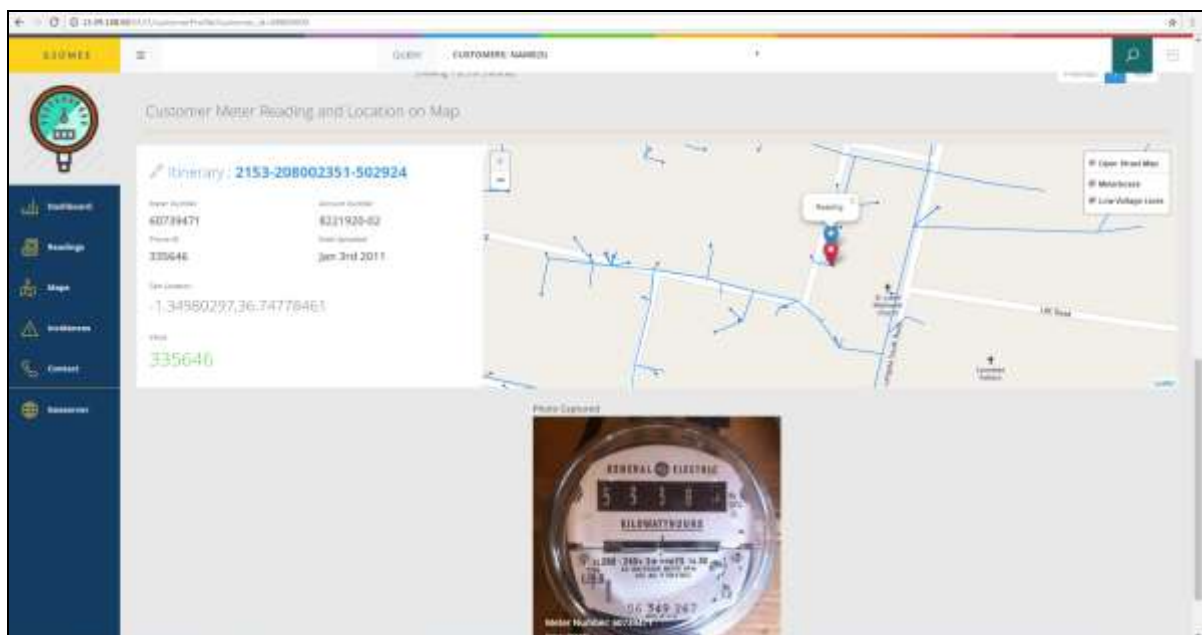


Figure 4.24: Web portal Customer – Meter Reading and Location on Map

[B] A Search Option (Search by Meter box: Itinerary)

[7] Meter box: Itinerary “2153-208002351-502924”

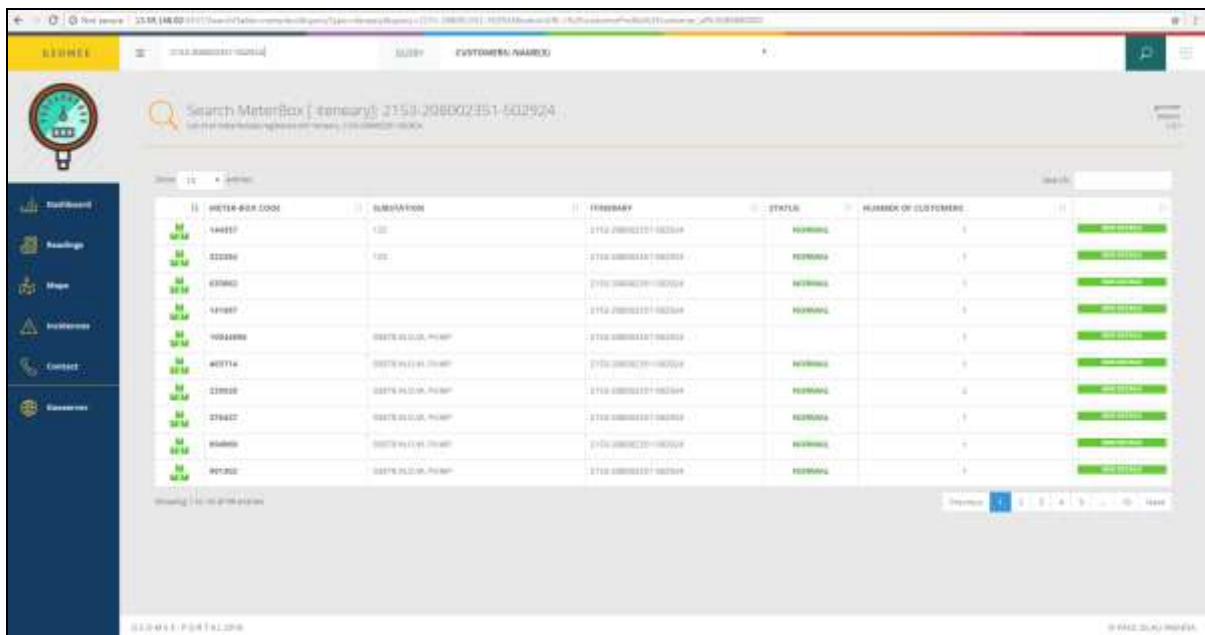


Figure 4.25: Web portal Meter box: Itinerary search page

[C] A Search Option (Search by Meter box: Code)

[8] Meter box: Code "144357" (Meter Details, Meter Reading, and Location on Map)

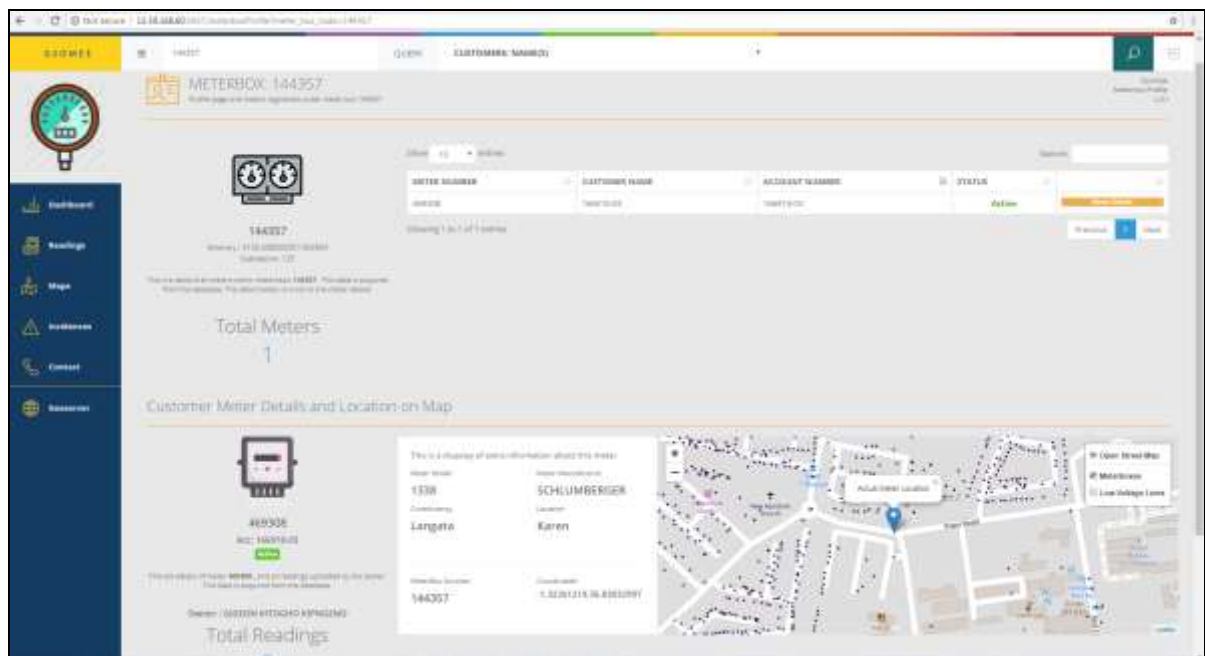


Figure 4.26: Web portal Meter Code: search page.

4.6 Publishing, Sharing and Testing the Application

4.6.1 Publishing and Sharing the Application on AWS Server.

The figure 4.27: below illustrate the sever properties and status on AWS. This server was charged based on the traffic received to the portal. Updates to the portal sent to the server through the IP address provided.

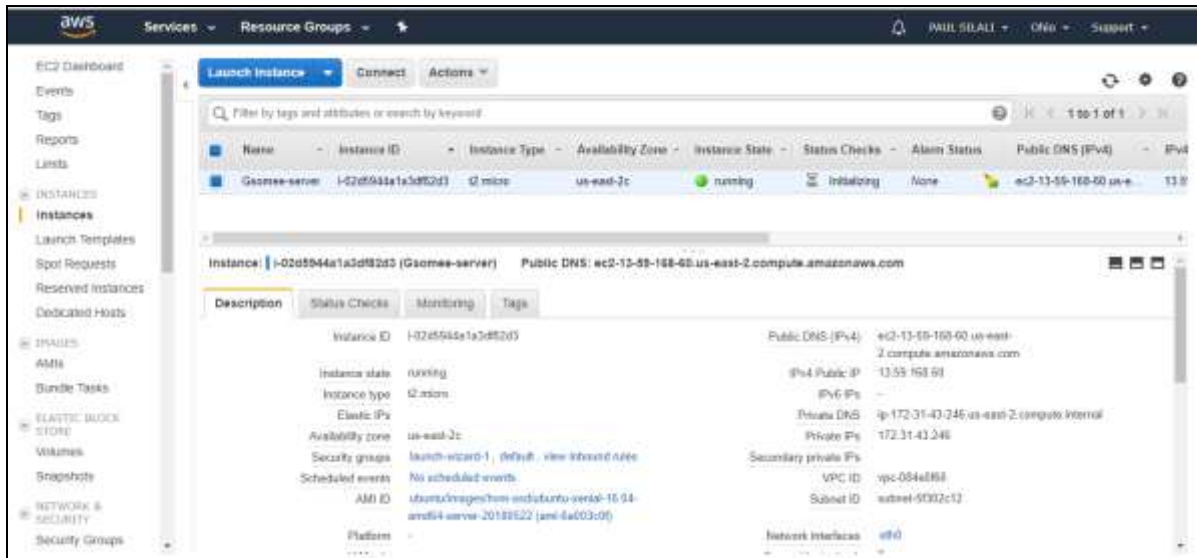


Figure 4.27: Published Web portal on AWS server

4.6.2 Testing the Mobile Web Application Remotely

A limited number of random users were requested to download the application and test it on their personal phones. The users were drawn from a group of selected friends and classmates. The group that was selected to test the mobile application had varying skills in using mobile applications, they were approached and asked for their opinion on the application. Application testing was done to rate different aspects of both the web and mobile application including functionality, the graphical user interface, user-friendliness and whether users easily understood the general concept of the system.

4.7 Discussion and Analysis of the Results

The results indicate that the web portal tool developed provides refined information for different categories of users. The meter reading team are able to find out useful information on the customer account details, readings submitted by the customers, the location of the customer at the time the reading was taken, and a picture of the meter indicating the reading. This kind of information requires a web browser and access to the internet.

On the other hand, the mobile application feedback from the users indicated that the application was user-friendliness, with simple functionality and an impressive graphical user

interface. Most of the users easily understood the general concept of the system. The visualization of data both spatial and non-spatial on a web platform underscores the importance of spatial information. Utilization of a spatial enabled DBMS such as PostgreSQL allows one to store both spatial data (electrical power lines, actual customer meter locations, and the customer reading location) and non-spatial data (customer account details) in a central location and in one platform. This has the benefit that data security is not compromised should one need to configure users and their permissions on the relational database.

The deployment of the web portal tool to the cloud provides for a wider community of users. This additionally offers the capability for high availability and scalability of the solution. Many systems have failed due to a high number of users accessing the application. The cloud provides for the solution to scale in and out depending on usage. Additionally, the effect of downtimes prevalent in enterprise systems is minimized.

4.8 Challenges in Implementing the Application

(1) GPS Inaccuracy

The Android GPS precision while recording and submitting both meter readings and power incidences are largely dependent on a number of factors: The type of phone, network provider signal strength and presence of obstructions and buildings.

(2) GPS Battery Power consumption

There is a slight increase in the power consumption of a phone every time the GPS module (Location option) is used. The Location option on the Android platform consumes the phone's battery at a high rate. At the time of using the application on the phone, the user is required have the GPS module on.

(3) Proving the Credibility of the Reported data

The credibility of the reported data was hard to prove. Since the application is open to the public, any malicious user can decide to post an inaccurate incidences report to the portal. A way to sieve the accurate from inaccurate incidence reports was a challenge while implementing this application on the incidences part. On the Meter reading part, the user has to input the account, which is verified in the system in order to proceed with taking the reading.

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

This chapter will highlight an overview on the suggestions for future research, recommendations and conclusive remarks on the project when matched to the general and specific objectives. This project aimed at developing a complementary mobile and web-based application for recording and sharing electricity customer meter reading and power incidence data.

5.1 Conclusions

The developed mobile and web application met the stipulated objectives by demonstrating how the meter readers, the meter supervisors, and the emergency teams can retrieve the vital information they require for their operation on a timely basis. The web portal application can enable users to identify the location of incidences and reading on the map. The measure, digitize, zoom and pan tools on the displayed map enabled users of the system to interact with the dynamic map to obtain desired information. The map, therefore, served a vital role in equipping the user with direction information and orientation during fieldwork visits.

The mobile application power incidence reporting platform is aimed at improving the resolution of these incidents and ultimately contribute to maintaining a constant supply of power to the customers. This application allows users to report any incident witnessed that occurs on the electrical network as they go by there day to day duties. Majority of the users also indicated that the application is generally user-friendly and easy to understand. The research objectives can thus be said to be achieved because the application had good reception among the target users that participated in the testing process.

There exists an opportunity to tap into this area in KLPC today because of the increased penetration of smartphones and also the increased interest of the company to reduce the number of power outages. This application seeks to improve the outage management by using information from the public. With the application, the emergency team can prioritize on how to use the available resources to tackle the outages e.g. the optimal routes to the customer or probable location of the fault can be viewed on the map from where the crew is thus saving on time. All these will reduce the time of resolving the incidences, help in keeping accurate information on incidences, delighting customers and improving the efficiency of work.

The opportunity that exists in Kenya concerning sharing of information by the public to institutions and government agencies has not be tapped. This is enhanced especially with the increase in the number of smartphones with Android OS. Thus the mobile application comes in handy to provide a solution to the way users report and share meter readings and incidents.

5.2 Recommendations

Geo-technology was used in place of the conventional hard-copy maps to display, share and report information. This was accomplished by using open source software's to display, query and analyze information relating to meter reading and power incidences. The web has the ability to disseminate spatial information to a wide audience. The information disseminated through this application can be used by KPLC personnel, the public and other decision-makers and interested stakeholders in the electricity distribution.

It is recommended that this application is replicated through all the other constituencies in Kenya to support power outage management in the company. Other utilities can use this application to better respond to customers when they face service interruptions and customer to report meter reading. The utilities can range from water and sewerage companies, telecommunication companies to oil and gas distribution companies among others.

The recommendations that can be drawn from the research are that the authorities and government should recognize and embrace the efforts of mobile applications in trying to improve service delivery in utility companies. It should also support such efforts through funding and integration of applications with the relevant departments. The application can be extended to be installed on other mobile phone operating systems such as the iOS based on the user base and mobile device penetration so as to get access to huge audiences.

5.3 Suggestions for Future Research

Based on user feedback the application can continuously be improved to cater for users changing needs. Further research should be done in future to enhance functionalities of the application and thus ensure user retention. There needs to be more research on how to verify the authenticity of the reported power incidences because the incidents are just reported by anyone with the application installed on their mobile phone. A verification and screening mechanisms can be introduced for these reported incidents to guarantee the accuracy and reliability of the data. There also need for further research on how the mobile application can be developed on iOS is a mobile operating system for Apple and the same linked to the web portal.

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APPENDICES

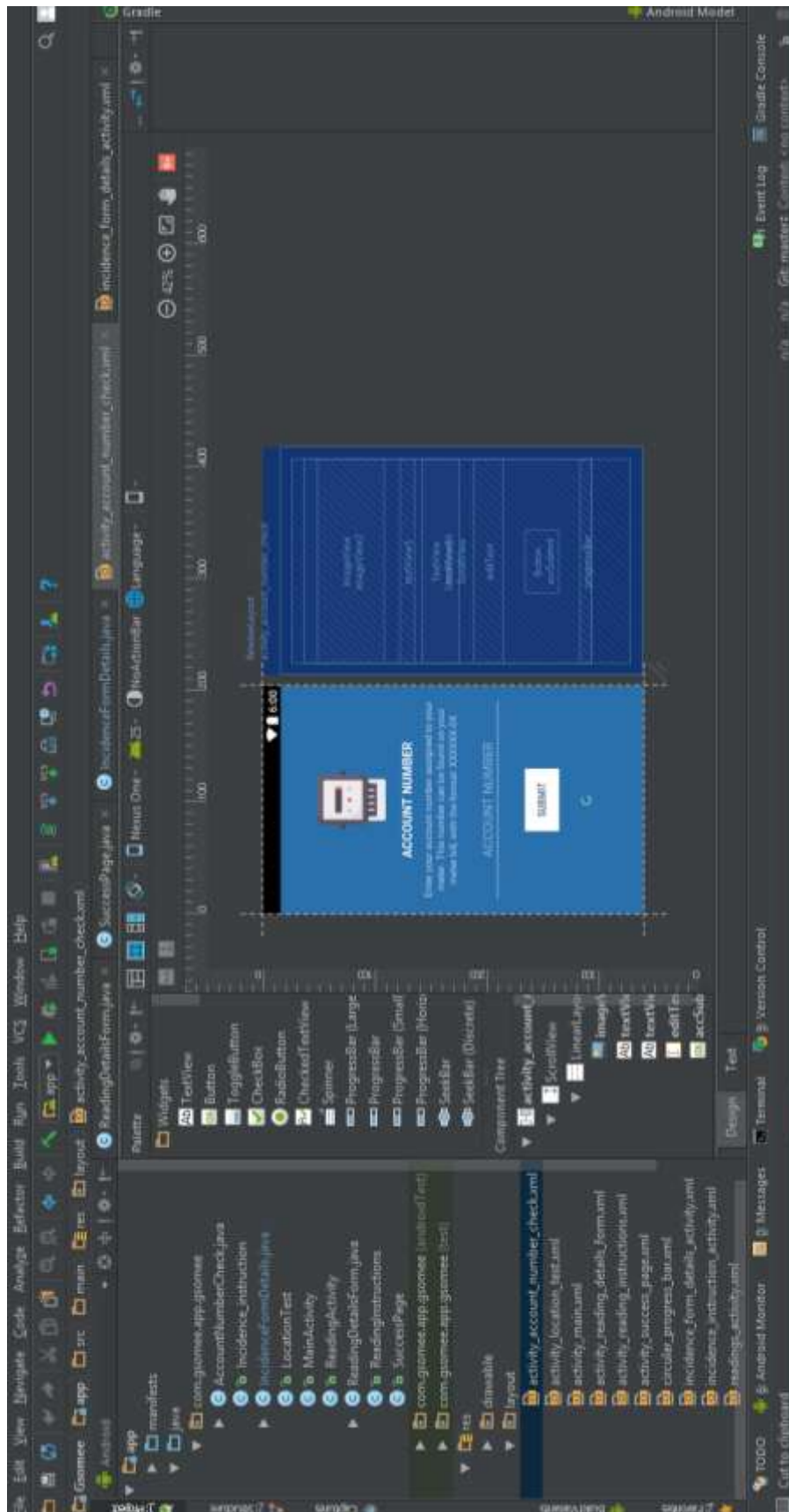
Appendix A Developing an Electrical Network Geodatabase

Appendix A1 Sample Styling Sheet for Medium Voltage Lines (SLD File)

```
C:\Users\PAUL SILALI\Desktop\MY_DATA\ [ 2 ] EDITED SHAPEFILES FORM ARC_GIS\SLD FILES\MEDIUM_VOLTAGE_LINE_SECTION.sld - Sublime Text (U
File Edit Selection Find View Goto Tools Project Preferences Help
web-map.js x MEDIUM_VOLTAGE_LINE_SECTION.sld x index.html x
1 <?xml version="1.0" encoding="UTF-8"?><sld:StyledLayerDescriptor xmlns="http://www.opengis.net
http://www.opengis.net/gml" xmlns:ogc="http://www.opengis.net/ogc" version="1.0.0">
2 <sld:UserLayer>
3 <sld:LayerFeatureConstraints>
4 <sld:FeatureTypeConstraint/>
5 </sld:LayerFeatureConstraints>
6 <sld:UserStyle>
7 <sld:Name>LANGATA MEDIUM VOLTAGE LINES</sld:Name>
8 <sld:FeatureTypeStyle>
9 <sld:Name>group0</sld:Name>
10 <sld:FeatureTypeName>Feature</sld:FeatureTypeName>
11 <sld:SemanticTypeIdentifier>generic:geometry</sld:SemanticTypeIdentifier>
12 <sld:SemanticTypeIdentifier>simple</sld:SemanticTypeIdentifier>
13 <sld:Rule>
14 <sld:Name>default rule</sld:Name>
15 <sld:LineSymbolizer>
16 <sld:Stroke>
17 <sld:CssParameter name="stroke">#FF0000</sld:CssParameter>
18 <sld:CssParameter name="stroke-opacity">0.9</sld:CssParameter>
19 <sld:CssParameter name="stroke-width">1.2</sld:CssParameter>
20 </sld:Stroke>
21 </sld:LineSymbolizer>
22 </sld:Rule>
23 </sld:FeatureTypeStyle>
24 </sld:UserStyle>
25 </sld:UserLayer>
26 </sld:StyledLayerDescriptor>
27
28
```

Appendix B Developing a Mobile Application

Appendix B1: Mobile Application Development on Android Studio



Appendix C Developing a Web Application Locally

Appendix C1: Web Map Page HTML Code

```
<! DOCTYPE html>
<html lang="en">

<% include partials/head %>

  <body class="fixed-navbar sidebar-scroll">
    <style>
      .map {
        height: 400px;
        width: 100%;
      }
    </style>
    <% include partials/headerbar %>

    <!-- Main Wrapper -->
    <div id="wrapper">

      <% include partials/flash %>
      <!-- Begin: Header -->
      <div class="row">
        <div class="col-lg-4"></div>
        <div class="col-lg-8"></div>
      </div>
      <div class="normalheader ">

        <div class="row">
          <div class="col-lg-12">
            <div class="view-header">
              <div class="pull-right text-right"
style="line-height: 14px">
                <small>Gsomee
                  <br>Map
                  <br>
                  <span class="c-white">v.0.1</span>
                </small>
              </div>
              <div class="header-icon">
                <i class="pe page-header-icon pe-7s-
map-2"></i>
              </div>
              <div class="header-title">
                <h3 class="m-b-xs">
                  MAP
                </h3>
              </div>
            </div>
          </div>
        </div>
      </div>
    </div>
  </body>
</html>
```

```

                                <small>
                                Loaenfvkae nraejgn jegi sk abe
akej
                                </small>
                                </div>
                                </div>
                                </div>
                                <hr style="border-color:#f6a821
!important;margin-bottom: 0px !important">
                                </div>
                                </div>
                                </div>
                                <!-- End: header -->
                                <div class="content">

                                <div class="row">
                                <div class="hpanel hgreen">

                                <div class="border-right border-left">
                                <section>
                                <div id="map" class="map"></div>
                                </section>
                                </div>
                                <div class="panel-body">

                                </div>

                                </div>
                                </div>

                                </div>

                                <% include partials/footer %>

                                </div>

                                <% include partials/scripts %>
                                <script src="https://openlayers.org/en/v4.6.5/build/ol.js"
type="text/javascript"></script>
                                <script>
                                var OpenLayer = ol;

                                // OpenStreet Base map
                                var OSM = new OpenLayer.layer.Tile({

```

```

        source: new OpenLayer.source.OSM()
    });

    // layers from GeoServer (format WMS)
    var lv_lines = new OpenLayer.layer.Image({
        //extent: [-13884991, 2870341, -7455066, 6338219],
        source: new OpenLayer.source.ImageWMS({
            url: 'http://localhost:8080/GeoServer/gsomee/wms',
            params: { 'layers':
'gsomee:langata_low_voltage_lines' },
            ratio: 1,
            serverType: 'GeoServer'
        })
    });
    // layers from GeoServer (format WMS)
    var mv_lines = new OpenLayer.layer.Image({
        //extent: [-13884991, 2870341, -7455066, 6338219],
        source: new OpenLayer.source.ImageWMS({
            url: 'http://localhost:8080/GeoServer/gsomee/wms',
            params: { 'layers':
'gsomee:langata_medium_voltage_lines' },
            ratio: 1,
            serverType: 'GeoServer'
        })
    });
    // layers from GeoServer (format WMS)
    var meterboxes = new OpenLayer.layer.Image({
        //extent: [-13884991, 2870341, -7455066, 6338219],
        source: new OpenLayer.source.ImageWMS({
            url: 'http://localhost:8080/GeoServer/gsomee/wms',
            params: { 'layers': 'gsomee:langata_meterboxes' },
            ratio: 1,
            serverType: 'GeoServer'
        })
    });
    // layers from GeoServer (format WMS)
    var secondary_substation = new OpenLayer.layer.Image({
        //extent: [-13884991, 2870341, -7455066, 6338219],
        source: new OpenLayer.source.ImageWMS({
            url: 'http://localhost:8080/GeoServer/gsomee/wms',
            params: { 'layers':
'gsomee:langata_secondary_substation' },
            ratio: 1,
            serverType: 'GeoServer'
        })
    });
    // layers from GeoServer (format WMS)
    var primary_substation = new OpenLayer.layer.Image({

```



```

        //extent: [-13884991, 2870341, -7455066, 6338219],
        source: new OpenLayer.source.ImageWMS({
            url: 'http://localhost:8080/GeoServer/gsomee/wms',
            params: { 'layers':
'gsomee:langata_primary_substation' },
            ratio: 1,
            serverType: 'GeoServer'
        })
    });
    var map = new OpenLayer.Map({
        layers: [OSM, mv_lines, secondary_substation,
primary_substation],
        target: 'map',
        projection: 'EPSG:21037',
        units: 'm',
        view: new OpenLayer.View({
            center: [4090085, -149884],
            zoom: 12
        })
    });
</script>
</body>
</html>

```

Appendix D Publishing, Sharing and Testing the Application

Appendix D1: Server connection and Configuration

Server Configuration for creating a new database

```

wekesa@ip-172-31-43-246: /var/www/geoserver
wekesa@ip-172-31-43-246:/var/www/geoserver$ sudo -u postgres createdb -O wekesa GSOME_DATABASE
wekesa@ip-172-31-43-246:/var/www/geoserver$

```

Server Configuration for installing Node.Js

```

wekesa@ip-172-31-43-246:~$ sudo apt-get install nodejs

```

Server Configuration for installing JRE for GeoServer

```

wekesa@ip-172-31-43-246: ~
wekesa@ip-172-31-43-246:~$ sudo apt-get install openjdk-8-jre

```

Server Configuration for installing postgresql_postGIS

```

wekesa@ip-172-31-43-246: ~
wekesa@ip-172-31-43-246:~$ sudo apt-get install postgresql postgresql-contrib postgis

```