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DEVELOPING GEOWEB SYSTEM FOR IMPROVING LOCATION OF ELECTRIC POWER CUSTOMERS

A Case Study of Arusha City

HASANI, YUSUPH HAMISI

BSc Geoinformatics

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DEVELOPING GEOWEB SYSTEM FOR IMPROVING LOCATION OF ELECTRIC POWER CUSTOMERS

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HASANI, YUSUPH HAMISI

A Dissertation Submitted to the Department of Geospatial Sciences and Technology in Partially Fulfilment of the Requirements for the Award of degree of Bachelor of Science in Geoinformatics (BSc. GI) of Ardhi University

CERTIFICATION

The undersigned certify that they have read and hereby recommend for acceptance by the Ardhi University dissertation titled **"Developing Geoweb System for Improving Location of Electric Power Customers in Arusha City"** in partial fulfillment of the requirements for the award of degree of Bachelor of Science in Geoinformatics at Ardhi University.

………………………………	………………………………
Dr. Atupelye Komba	Mr. Gadiel Mchau
(Main Supervisor)	(Second Supervisor)
Date…………………………	Date………………………

DECLARATION AND COPYRIGHT

I, HASANI, YUSUPH H hereby declare that, the contents of this dissertation are the results of my own findings through my study and investigation, and to the best of my knowledge they have not been presented anywhere else as a dissertation for diploma, degree or any similar academic award in any institution of higher learning.

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HASANI, YUSUPH HAMISI

22753/T.2019

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DEDICATION

I dedicate this dissertation to my beloved family; my parents Mr. and Mrs. Hamisi Hasani, whose love, support, and encouragement have been my foundation. Their belief in me has fueled my passion for knowledge and has been instrumental in my journey. Thank you for always standing by my side and being my greatest cheerleaders.

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May Allah bless them.

With deepest love and gratitude,

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ABSTRACT

This study presents the development and implementation of a geoweb system aimed at improving the identification of electric power customers in Arusha city. The geoweb system developed in this study allows the technical and emergency teams at Tanzania Electric Supply Company Limited (TANESCO) to swiftly identify the location of electric power customers. The system can facilitate prompt responses to power outages reported by customers. The current system used by the organization lacks customers' location information which poses challenges for the technical and emergency teams to promptly respond in case of power failures. The developed platform was created using the Waterfall Development Methodology. The geographical user interface developed in this study used OpenLayers, allowing users to perform spatial queries, measure distances and areas, and access detailed attribute information. The platform provides a user-friendly interface, integrating multiple WMS layers, enabling users to query customer information based on various user needs, and facilitating quick responses to power outages. After the completion of the development phase, system testing was conducted to ensure the system's functionality, performance, accuracy, and effectiveness. The testing utilized customer location data obtained from TANESCO to assess the system's ability to accurately identify geographic locations. The study, emphasized the significance of the developed geoweb system in enhancing the identification of electric power customers and improving the overall service quality. Recommendations are made to expand the system's functionalities to include mobile applications for customer engagement, integration of real-time data for dynamic responses, and capacity building for system users.

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ACRONYMS AND ABBREVIATIONS

TANESCO	Tanzania Electric Supply Company Limited
GIS	Geographical Information System
CSV	Comma Separated Values
GADM	Global Administrative Areas
PHP	Hypertext Preprocessor
URL	Uniform Resource Locator
HTML	Hyper Text Markup Language
RIA	Rich Internet Application
API	Application Programming Interface
CSS	Cascading Style Sheets
JSON	JavaScript Object Notation
LBS	Location-Based Services
WCS	Web Coverage Service
WFS	Web feature Service
WMS	Web Map Service
SQL	Structured Query Language
HTTP	Hypertext Transfer Protocol
OGC	Open Geospatial Consortium

CHAPTER ONE
INTRODUCTION

1.1 Background of the Study

The use of Geographic Information Systems (GIS) has become increasingly popular in the electric power industry, as it provides a powerful tool for managing and analyzing the location-based data of power infrastructure. One emerging technology in the GIS field is the geoweb, which refers to the integration of web technologies with GIS to create interactive and collaborative web-based maps (Cindy et al., 2020). This technology provides an efficient platform for storing, sharing, and analyzing geospatial data that can be accessed from anywhere with an internet connection (Zhang et al., 2018).

In the electric power industry, geoweb systems have been used to improve customer location services. The system provided a user-friendly interface that allows customers to report power outages and provide their location information. The system also provided the utility with real-time information on the location and severity of power outages, which helps to improve service and response times (Li et al., 2018).

According to Adel (2015), one of the primary contributions of the advancement and improvement in man's lifestyle over the years has been the ability to use and control energy. The socio-economic and technological development of any nation and society largely depends on the supply of electricity. The growth of the economy of any nation largely depends on the effective management and control of the available generated power that meets the growing demand for electricity supply (Ihiabe et al., 2016).

However, it is important to acknowledge that electric breakdowns can be a potential setback. These breakdowns, if they occur, can pose challenges and obstacles to the socio-economic and technological progress. Ensuring a reliable and uninterrupted supply of electricity becomes crucial to overcoming such setbacks and sustaining the continuous development and stability of a nation or society

When an electric breakdown occurs, the technical and emergency teams need to respond quickly and efficiently to restore power to the affected customers. However, in some cases, reaching the connected customers who have electric breakdowns can be a challenge due to factors such as inaccurate location information and difficult-to-access locations (Farooq, 2018). Emergency and technical team can simplify the process of responding to customers reorting electricity break down through the use of geospatial technology web application.

Through the use of a geospatial web application, the uploaded customer's data to the web application and using its mapping tools display the data on a map. The geoweb system may also include tools for querying and analyzing the data, such as the ability to filter customers by location (Longley et al., 2005).

This study aims to use the available data (substations, transformers, poles, medium voltage line and customers location) to develop a geoweb system for TANESCO at Arusha city. These data elements are essential for creating an effective system that can assist the emergency team and technical staff in managing and responding to various electricity-related situations in the city. Spatial location is typically a major common aspect of all the data in electric power distribution network utility. A geoweb system can locate the exact position of an electric power infrastructure such as substation, feeder lines, electric pole, transformer, and customer's location for displaying them as a softcopy map which helps to respond quickly and efficiently to restore power to the affected customers.

1.2 Problem Statement

The current electric power monitoring and management system for TANESCO at Arusha city does not utilize customer location information. This makes it difficult for technical and emergency teams to quickly identify and respond to issues of electric power failures from the customers for maintenance since most of the time information of power failure comes from the customers which leads to the time delay to reach the targeted area. Therefore, there is a need to develop a geoweb system that will be used to integrate the geographical information of customers and the electric power system for improving identification of customer locations, monitoring, management, and maintenance of any electric power distribution network failure.

1.3 Research Objectives

1.3.1 Main Objective

The main objective of this study is to develop a geoweb system for improving location of electric power customers in Arusha city.

1.3.2 Specific Objective

i. To identify user requirements for the geoweb system in analyzing customer locations in electric power systems
ii. To design the architecture of the geoweb system for analyzing customer location in electric power systems.

iii. To develop an interactive and friendly geographical user interface for both technical and emergency teams or department.
iv. To conduct comprehensive testing of the developed geoweb system to evaluate its performance, functionality, and reliability in improving location identification of electric power customers in Arusha city

1.3.3 Research Questions

i. What are the key requirements for the architecture of a geoweb system for analyzing customer networks in electric power systems?
ii. What are the key design principles that should be considered in developing an interactive and friendly geographical user interface for both technical and emergency teams or departments?

1.4 Scope and Limitations of the Study

Only TANESCO employees will have access to the geoweb system with their identification cards and names will be used. Customers of TANESCO will only be able to use the system by calling the TANESCO office when there is a need for technical and emergency teams to respond to any issues related to the electric power failure or breakdown by mentioning their meter number which will guide the team by giving the direction or location of where the customer is, and through the geoweb system the technical and emergency teams will respond more efficiently and effectively.

1.5 Significance of the Research

Developed a geoweb system will help technical and emergency teams at TANESCO to visualize customer's locations that can help teams to quickly identify and respond more easily to any problems in the electric power system by improving the efficiency and effectiveness of their work and help teams to more effectively plan and coordinate their work during emergency situations. The system will integrate customer's locations and geographical information into the system interface helping to minimize disturbances and minimize time duration to power service and improve customer satisfaction.

1.6 Beneficiaries of the Research

The results of this study will be beneficial to Tanzania Electric Supply Company Limited (TANESCO) in ensuring the technical teams and emergency teams can use the system to quickly and accurately identify the location of the customer and monitor and manage the electric power system more efficiently and effectively to plan and coordinate maintenance activities.

1.7 Study Area

Arusha city is one of the seven districts of the Arusha region of Tanzania, serving as an administrative district situated between latitude 3°33'S and 3°19'S and longitude 36°34'E and 36°45'E. It shares borders with Longido district to the north, Meru district to the east, Kilimanjaro region to the south, and Monduli district to the west. Covering an area of 267 km2 (103 sq mi) and with an average elevation of 1,331 m (4,367 ft), Arusha city is home to various protected areas such as Kijenge Hill Forest and Naura Park, although it lacks a national park. The district experiences an average temperature of 20 °C (68 °F) and an annual rainfall of 837 mm. It is divided into 19 wards and comprises three divisions: Muklat, Moshono, and Enaboishu. According to National Bureau of Statistics (NBS), the national population census of 2022, the population of Arusha city was 2,356,255. This is an increase of 69.2% from the 2012 census, when the population was 1,394,000.

According to the available data, Arusha city has a significant number of electric customers connected to the power supply. Due to the dynamic nature of customer connections, the exact number fluctuates as new customers are added regularly.The geoweb system developed for TANESCO in Arusha city will enhance the effectiveness of attendance management across multiple departments, including Planning, Revenue Protection Unit (RPU), Emergency, Maintenance, Service Line, Construction, Meter, and Substation. By streamlining processes and leveraging GIS technology, the system will contribute to improved service delivery and operational efficiency for TANESCO's departments involved in power distribution. Figure 1.1 show the location of a study area.

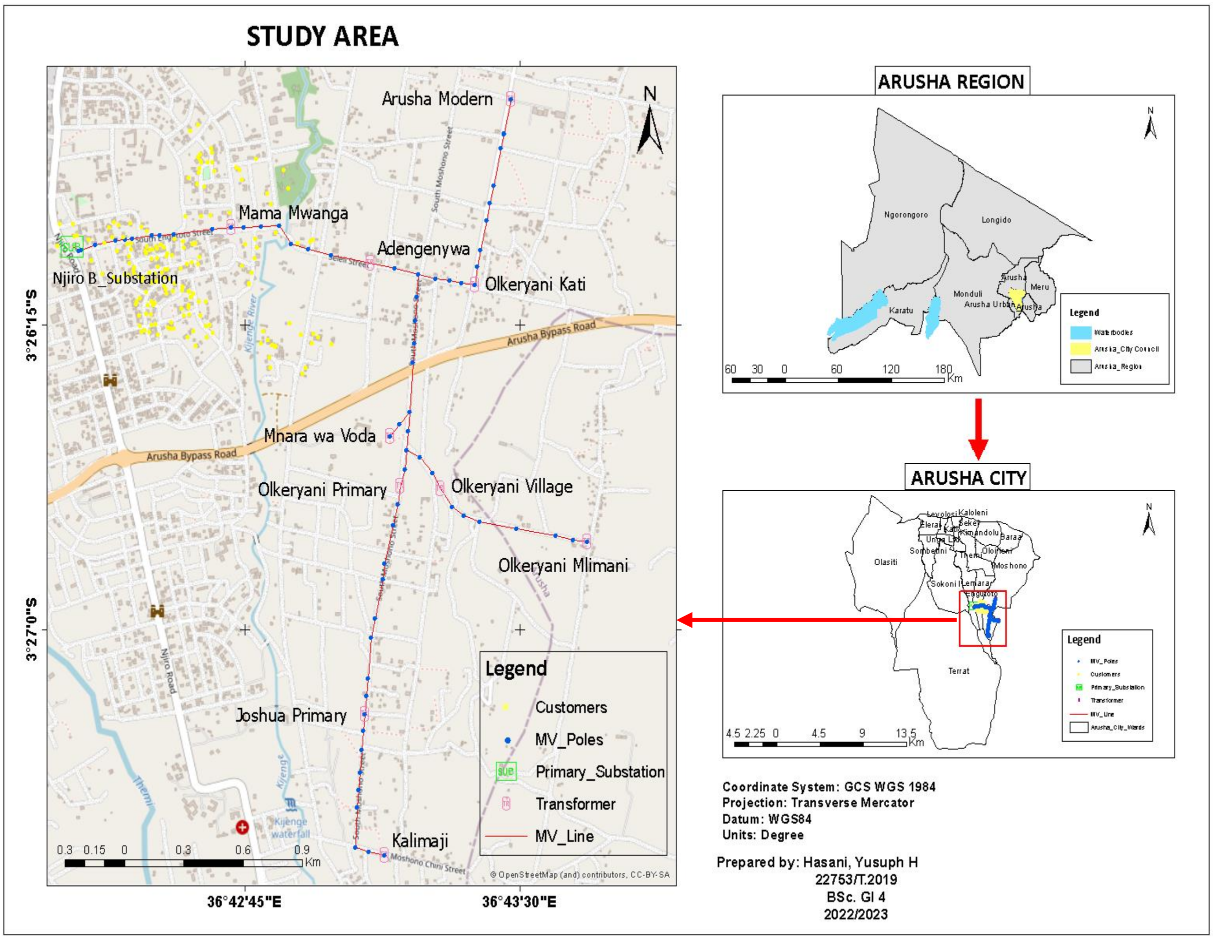

Figure 1.1: Location of Study Area

1.8 Dissertation Organization

This dissertation comprises five chapters, describing in detail all of the techniques, principles, and procedures used to develop a geoweb system for electric power system for improving customer location in Arusha city.

Chapter 1 explains the background of the study which gave rise to the problem. The objectives, research questions, significance and beneficiaries of the research, the scope and limitation, and the description of the study area.

Chapter 2 gives a review of the study. It provides an explanation of all published research and studies regarding the creation of a geoweb system. This chapter shows also how another researcher demonstrates the operation of other developed geoweb systems for electric power.

Chapter 3 covers all the methods and techniques involved in the study. The procedures in the development and configuration of data into the system.

Chapter 4 provides the analysis and discussion of the results. It shows the results obtained in this study. Chapter 5 contains the conclusion and recommendations for the study.

CHAPTER TWO
LITERATURE REVIEW

2.1 Overview

This chapter provides a literature review on the development of geoweb systems for electric power and location-based services. It explores how researchers have incorporated geographic information into their operations to improve service delivery. The review showcases important approaches and findings that have contributed to the advancement and implementation of geoweb systems in the field of electric power and location-based services

2.2 Geoweb Concepts

Geoweb refers to the fusion of geographic information systems (GIS) and the internet to develop interactive web-based maps and other geospatial applications. This synergy allows users to access, share, visualize, and analyze geographical data in real-time. By integrating diverse datasets, such as satellite imagery, street maps, terrain details, and weather information, the geoweb empowers the creation of immersive maps and applications serving various purposes, including urban planning, environmental management, and disaster response (Haklay, 2010).

The methodology employed to develop the geoweb system, termed “Waterfall Development Method”. The Waterfall model is a linear and sequential approach to software development. It divides the development process into distinct phases, with each phase depending on the completion of the previous one. The phases typically include requirements gathering, system design, implementation, testing, deployment, and maintenance. Waterfall is often used for projects with well-defined and stable requirements (Özcan and Aslan, 2019). The geoweb's popularity has surged in recent years, driven by advancements in web-based mapping technologies, the availability of open data, and the surging demand for location-based services. This trend holds the potential to revolutionize our interaction with the world, creating a more interconnected, accessible, and informative environment (Haklay, 2010). Figure 2.1 illustrates the spectrum from simple mapping and geospatial visualization to full-fledged web services, often referred to as the geoweb.

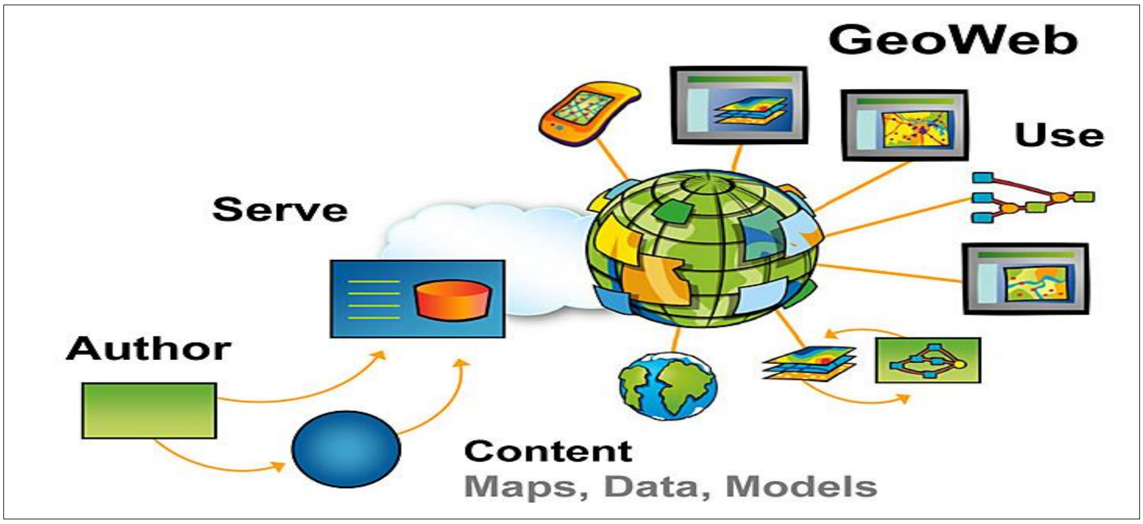

Figure 2.1: Geoservices on the Web

(Source: https://eventsget.com/events/web-based-gis-mapping-80892)

2.2.1 How a Geoweb Work

The basic model of geoweb ought to have the least possible a server and a user client, where the server is a web application server, and the user client is a web explorer, a desktop application, or a mobile application. The server has a URL so that user clients can find it on the web. The client then depends on HTTP advantages to direct requests to the server. The server executes the requested GIS process and directs a reply to the user client, once more by HTTP. The structure of the response might be the HTML that is used by the web explorer client, but it might also be in other forms, for instance, binary image, JSON (JavaScript Object Notation), or XML (Extensible Markup Language) (Farooq, 2018).

2.2.2 Components of a Geoweb Application

In a geoweb application, the database, back end, and front end are important components that work together to provide a smooth and continuous user experience. Here's an overview of what each component comprises in a geoweb system:

i. *Database:* In a geoweb application, the database stores spatial data, such as maps, satellite imagery, and other geospatial information. The database also contains non-spatial data, such as attribute data that describes the spatial features. The spatial data is stored in a format that allows for efficient retrieval and processing of data.

ii. *Back end:* The back end of a geoweb application includes the server, application code, and database that work together to provide the application's functionality. The back end typically handles tasks such as processing user requests, performing spatial analysis, and serving up spatial data from the database.

iii. *Front end:* The front end of a geoweb application is the client side of the application, where the user interacts with the maps and other geospatial data. The front end typically includes the user interface, design, and code that runs in the user's web browser or mobile device. The front end communicates with the back end through APIs or other methods to retrieve and display spatial data (Farooq, 2018). Figure 2.2 illustrates how the geoweb work.

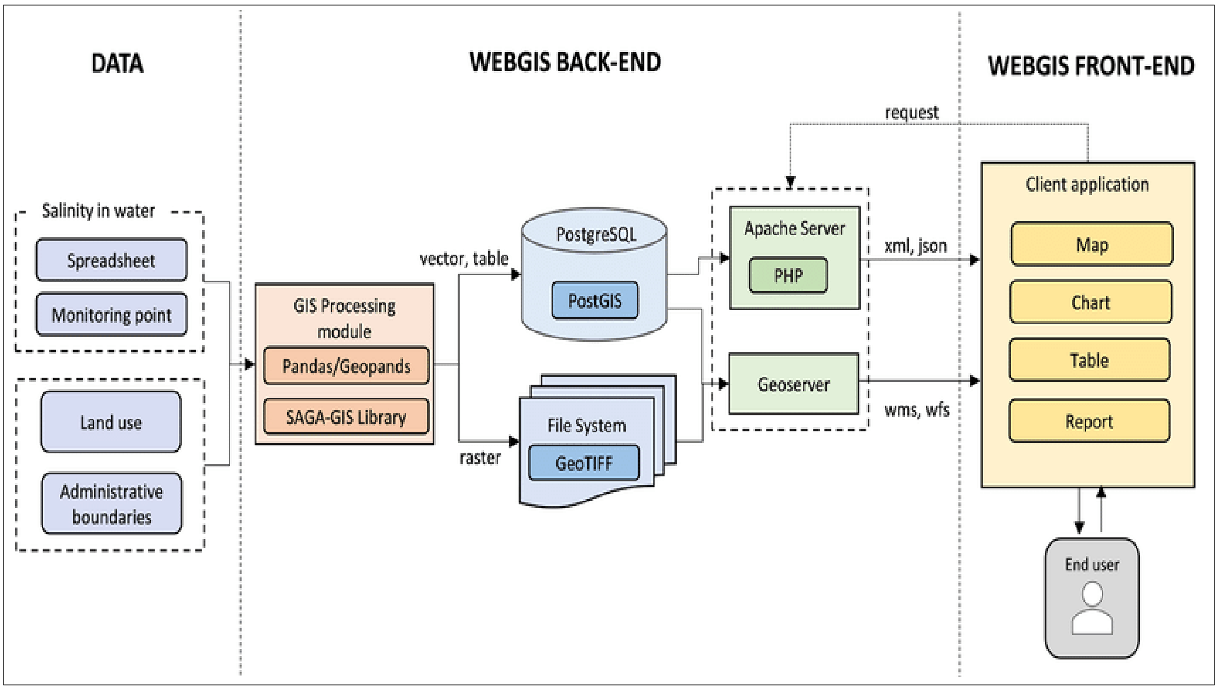

Figure 2.2: How Geoweb Works

(Source: https://researchgate.net/figure/System-architecture-of-WebGIS_fig1)

2.3 Geodatabase Design

The geodatabase design of a utility GIS was crucial to successfully implement the system. Because it is necessary to have sufficient knowledge of how each system works to construct the geodatabase, a significant amount of time was spent designing these geodatabases. (Zeiler, 1999).

Geodatabases have become a critical tool in the electric power industry for managing and analyzing spatial data. One area where geodatabases have shown great potential is in improving customer location for utilities. In this literature review, we explore the key steps involved in designing a geodatabase for electric customers' locations and examine the current state of research on this topic (Wang et al., 2019).

Designing a geodatabase for electric customers' locations involves several key steps, including identifying the purpose and scope, determining the data model, selecting the appropriate geodatabase platform, defining the spatial reference system, populating the geodatabase, implementing data quality control, and developing a data access and visualization strategy (Zhu, 2016).

i. *Identify the purpose and scope of the geodataba*

The first step in designing a geodatabase for electric customers' locations is to clearly define the purpose and scope of the database. This includes identifying the data that needs to be stored, the expected usage of the data, and the intended audience.

ii. *Determine the data model*

The next step is to determine the appropriate data model for the geodatabase. This involves selecting the appropriate feature types, defining the relationships between features, and designing the attribute schema.

iii. *Choose the geodatabase platform*

There are several geodatabase platforms available, such as Esri's ArcGIS, open-source PostgreSQL/PostGIS, and Oracle Spatial. The appropriate platform should be chosen based on factors such as the organization's existing infrastructure, budget, and technical expertise.

iv. *Define the spatial reference system*

The spatial reference system (SRS) is an essential component of the geodatabase, and it is important to select the appropriate SRS based on the intended usage of the data.

v. *Populate the geodatabase*

The next step is to populate the geodatabase with relevant data. This may involve importing data from other sources, such as Excel spreadsheets, or collecting new data through field surveys.

vi. *Implement data quality control*

Data quality control is critical in ensuring the accuracy and reliability of the geodatabase. This involves validating the data, identifying and correcting errors, and establishing data maintenance procedures.

vii. *Develop a data access and visualization strategy*

The final step is to develop a data access and visualization strategy that allows users to access and interact with the data. This may involve developing web applications, mobile apps, or desktop applications that allow users to query and visualize the data.

2.3.1 PostgreSQL

PostgreSQL is a powerful open-source relational database management system (RDBMS) that is widely used in geoweb applications for storing and managing geospatial data.

According to Haklay et al. (2010), PostgreSQL offers a range of advanced features for managing complex geospatial data, including support for spatial indexing, spatial data types, and spatial queries.

One of the key features of PostgreSQL is its support for the PostGIS extension, which provides a set of spatial functions and data types for managing geospatial data. PostGIS allows users to store and manage spatial data in PostgreSQL, perform spatial analysis and processing, and create custom geospatial applications using a range of programming languages (Haklay et al., 2010).

2.3.2 PostGIS

PostGIS is an open-source software extension for the PostgreSQL relational database management system that enables the management and analysis of geospatial data. According to Obe and Hsu (2011), PostGIS adds support for geospatial data types, functions, and indexing to PostgreSQL, allowing users to store, query, and analyze geospatial data using SQL commands. PostGIS offers a wide range of geospatial features, including support for vector and raster data, topology, network analysis, and geocoding.

PostGIS provides a comprehensive set of geospatial functions, such as buffer, intersection, and distance calculations, which can be used to perform complex spatial analysis and processing. PostGIS also offers high performance and scalability, allowing users to handle large and complex geospatial datasets. PostGIS's support for spatial indexing and optimization, along with PostgreSQL's robust transaction management and concurrency control, make it a reliable and efficient solution for managing geospatial data (Hobona et al., 2015). Figure 2.3 illustrate PostgreSQL and PostGIS connection.

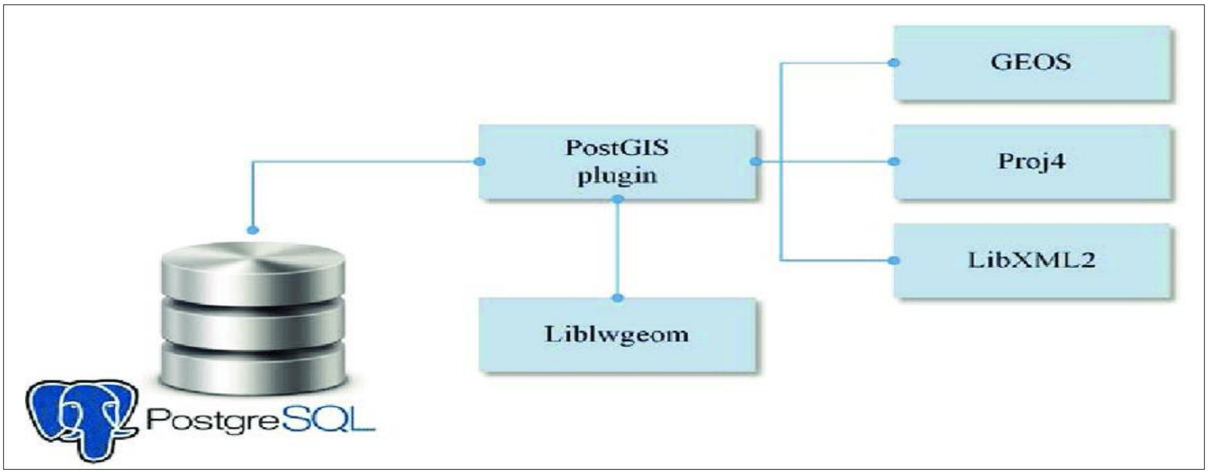

Figure 2.3: PostgreSQL and PostGIS Connection

(Source: https://www.researchgate.net/figure/PostgreSQL-and-PostGIS-connection_fig8)

2.3.3 GeoServer

GeoServer is an open-source server-side software that allows users to publish and share geospatial data and services over the web. GeoServer provides a simple and flexible way to serve geospatial data to a variety of client applications, such as web maps, mobile applications, and desktop GIS software. GeoServer supports a wide range of geospatial data formats, including vector and raster data, as well as various geospatial standards, such as the Open Geospatial Consortium (OGC) standards, Web Map Service (WMS), Web Feature Service (WFS), and Web Coverage Service (WCS).GeoServer's support for these standards enables seamless interoperability with other geospatial systems, allowing users to integrate data from various sources into their applications (Bartoli, 2016).

2.4 Geoweb System Development

Geoweb is a type of distributed information system with at least a server and a client. The server is a GIS server, and the client is a web browser, desktop application, or mobile app. To put it simply, a geoweb system known as a "Web GIS" makes use of web technologies to communicate with various system components and disseminate information and functionalities (Kuria et al., 2019).

Geoweb should not be confused with Internet GIS; in as much as they may be used interchangeably in some instances, there is a slight difference between the two. The internet supports many services and the Web is one of the services the internet supports. A system can be termed an internet GIS if it uses more internet services as opposed to being singularly web-based (Kuria et al., 2019).

2.4.1 Rich Internet Application (RIA)

Rich Internet Applications (RIAs) are web applications that have the features and functionality of traditional desktop applications. They are designed to provide a more interactive and engaging user experience and are built using technologies such as HTML5, JavaScript, and CSS. In the context of geoweb, RIAs can be used to create web-based mapping applications that allow users to interact with maps and geospatial data in real-time data feeds that are relevant to the user's location.

RIAs can be used in geoweb to provide users with a more immersive and interactive mapping experience. They can be used to display various types of geospatial data such as satellite imagery, topographic maps, and street maps, and allow users to interact with this data in several ways. For example, users can zoom in and out of maps, pan and tilt the map view, and perform other functions such as measuring distances and areas (Felchesmi, 2015).

2.4.2 Usage of Application Programming Interfaces (APIs) in Geoweb

APIs are an essential component of geoweb, enabling developers to access and manipulate geospatial data and maps. According to O'Sullivan and Unwin (2010), an API provides a set of instructions, protocols, and tools for building software applications that interact with other software systems, allowing developers to integrate and exchange data between different applications. In geoweb, APIs are used to access and manipulate geospatial data and maps, create custom mapping applications, and integrate geospatial data with other software systems.

Web Map Service (WMS) API provides access to geospatial data in the form of image maps, while Web Feature Service (WFS) API allows developers to access geospatial data in vector formats, such as points, lines, and polygons. These APIs enable developers to create custom mapping applications and enhance the user experience with interactive features such as zooming, panning, and querying. For example, the Google Maps API can be used to create custom mapping applications that display specific geospatial data layers or highlight points of interest (O'Brien and Pickett, 2013). Figure 2.4 shows how Application Programming Interfaces (APIs) work.

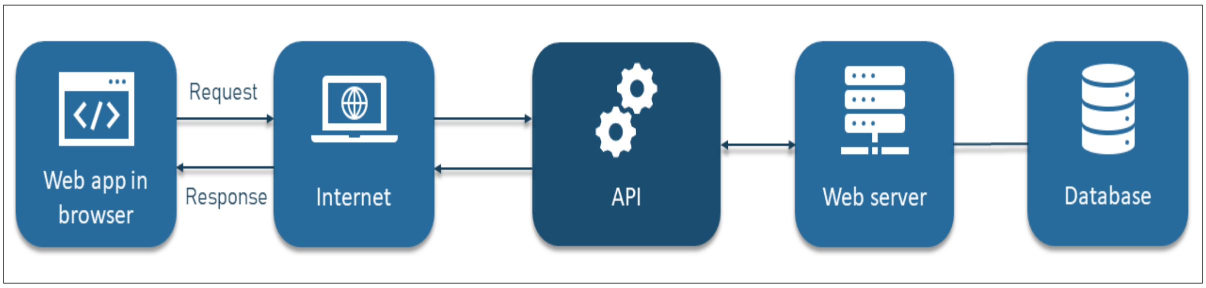

Figure 2.4: How Application Programming Interfaces (APIs) Works
(Source: https://www.altexsoft.com/blog/engineering/what-is-api-definition)

2.4.4 Location-Based Services (LBS) in Geoweb System

Location-Based Services (LBS) are a key feature of geoweb, providing users with location-based information and services on their mobile devices or desktop computers. According to Zhang et al. (2019), LBS leverage location-based data and technologies such as Global Positioning System (GPS) and Geographic Information System (GIS) to provide personalized and context-aware services to users. LBS in geoweb is powered by APIs such as Google Maps API and OpenStreetMap API, which provide developers with a set of tools and protocols for building location-aware applications. These APIs enable developers to integrate location-based data and services into their applications, such as displaying nearby points of interest or calculating the distance between two locations. According to Huang et al., (2019), LBS APIs offer a flexible and scalable solution for businesses and organizations to provide location-based services to their customers.

2.4.5 OpenLayers

OpenLayers is a popular and powerful JavaScript library used in geoweb applications for creating interactive maps and visualizations. It is an open-source project with a large and active community of developers and users and provides a range of tools and features for working with geospatial data. The library provides a range of tools for working with various geospatial data formats, including GeoJSON, KML, WKT, and GML, and can display data from a range of sources, including OpenStreetMap, Google Maps, Bing Maps, and MapQuest.

OpenLayers is modular and customizable, allowing developers to use only the parts of the library that they need for their specific application, and to extend the library with their custom functionality. Another strength of OpenLayers in geoweb applications is its support for geospatial analysis and visualization. OpenLayers provides a range of tools for working with geospatial data, including spatial queries, clustering, and heatmaps (Huang et al., 2019).

2.4.6 Layer Switcher

A layer switcher is a common component in geoweb applications that allows users to toggle the visibility of different layers on a map. It provides an intuitive way for users to interact with the map and customize their view of the data. Layer switchers are a widely used component in geoweb applications, and are often included as part of the user interface. They typically allow users to turn layers on and off, adjust transparency, and change the order of the layers displayed on the map.

Several studies have evaluated the use of layer switchers in eoweb applications, and have found that they can improve the user experience by allowing users to interact with the map more intuitively. In addition, layer switchers can help to improve the performance of the application by allowing users to selectively display only the layers they need, reducing the amount of data that needs to be loaded and displayed (Özcan and Aslan, 2019).

2.4.7 Geoweb Systems on Web Browsers

Geoweb systems on web browsers refer to web-based Geographic Information Systems (GIS) that enable users to access, visualize, and analyze spatial data using standard web browsers. These systems provide a range of functionalities, including map display, spatial querying, and data analysis, making it possible for users to interact with spatial data in a web environment as they can be accessed from any device with an internet connection and a web browser and one commonly used open-source geoweb system for web browsers is OpenLayers (Bartoli and Drogoul, 2016).

CHAPTER THREE

METHODOLOGY

3.1 Introduction

This chapter presents the Waterfall Development Method, a cohesive approach employed to create a geoweb system fusing spatial data with electric customer and utility details. The methodology includes collaborative requirement analysis, geoweb system architecture design, software selection, data collection, geodatabase creation, web development, user interface design, and rigorous testing and implementation of the system was done. Through this methodology, our geoweb system enhances power outage management for TANESCO by swiftly identifying and responding to outages. Figure 3.1 shows a working diagram that summarizes the methodology whereby step-by-step.

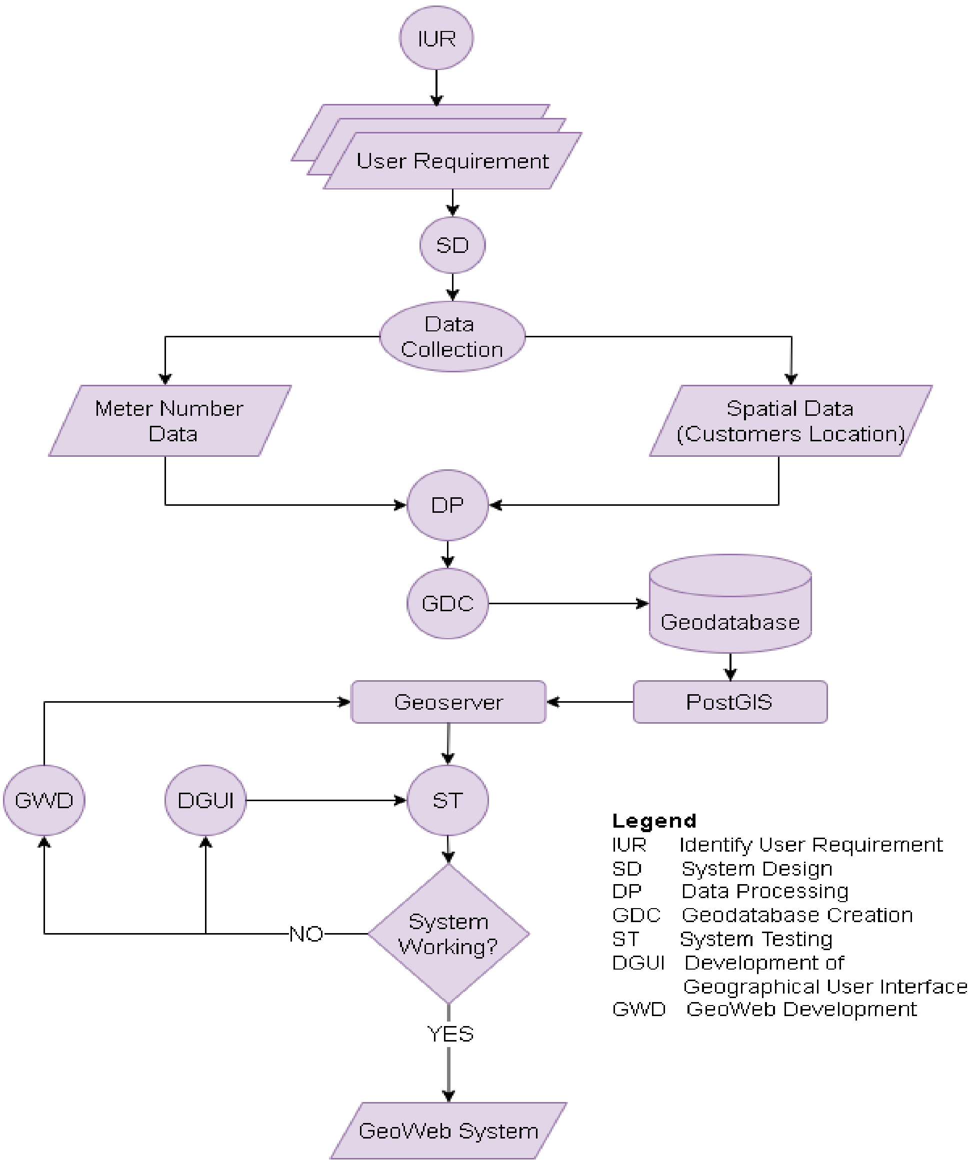

Figure 3.1: Research Workflow for Developing Geoweb System

3.2 Identifying User Requirements

The study of the intended user community served as the basis for the user requirement analysis to improve the identification of electrical customer locations, which revealed potential system features. Collaborating closely with TANESCO officers from the technical and emergency teams, who are responsible for resolving power outages from their customers through the use of GIS systems. They provide valuable insights for the geoweb system to efficiently identify power outages from the customers, aiding quick and accurate response by technical and emergency teams.

3.3 System Designing

The development of a geoweb system was designed to meet both the user requirements and the workflow, which turns into the guide toward accomplishing the target of the study objective. The system had three main parts: database, web GIS back-end, and web GIS front end (see figure 3.2). To obtain the necessary formats that could be used PostgreSQL database and Geoserver, the system required data to be prepared and processed using GIS processing modules. The web GIS back-end consists of a database for spatial data storage and query, and a geodatabase for publishing spatial data and providing access to WMS, WFS, and WCS capabilities, and the Apache/Tomcat server responds to client requests and sends necessary feedback to the client following those requests to provide web content via the Internet.

The web GIS front-end consists of the client application and client-side scripting languages that work together in a browser to control what is displayed and what happens on a webpage and the OpenLayers is an open-source JavaScript library for displaying interactive maps in a web browser.

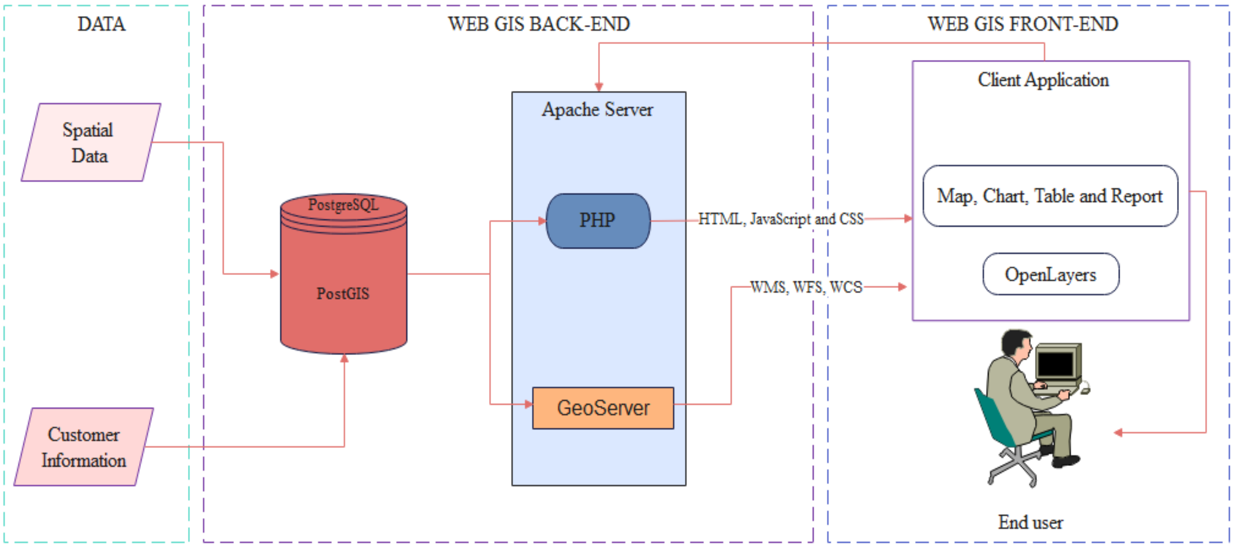

Figure 3.2: System Architecture

3.4 Software Selection

The software that would be used for system development was selected based on its availability and required licenses after the structure of the system was designed. The software package required for developing a web GIS system is listed in Table 3.1.

Table 3.1: Software Package

S/N	SOFTWARE PACKAGE	PURPOSE
1	ArcMAP/Quantum GIS	▪ Spatial data creation, analysis, mapping, and visualization of geospatial data
2	PostgreSQL and PostGIS extension	▪ Geo-database creation, location query, and data storage ▪ Data conversation
3	Geoserver	▪ Sharing and publishing existing information and data visualization ▪ Data visualization
4	Visual Studio Code/GitHub	▪ Code editor and management for system developing and debugging
6	Apache/Tomcat	▪ Web Application manager ▪ To serve web pages requested by the client

3.5 Data Collection

Tanzania Electric Supply Company Limited (TANESCO) provided the information that was utilized in the process of creating the system. Data included are substation data, electric poles, power transformer, customer location and customer electric meter number, names, and phone number. Table 3.2 displays the data summary.

Table 3.2: Data Type and their Sources

S/N	DATA	FORMAT	SOURCE	USE
1	Substation data	CSV and Shapefiles	Tanzania Electric Supply Company Limited (TANESCO)-Arusha City.	For the analysis of the production, conversion, transformation, regulation, and distribution of energy

S/N	DATA	FORMAT	SOURCE	USE
2	Electric poles	Shapefiles	Tanzania Electric Supply Company Limited (TANESCO-Arusha City.	For supporting power lines and identification of the phase (three or two)
3	Power Transformer	CSV and Shapefiles	Tanzania Electric Supply Company Limited (TANESCO) - Arusha City.	Identification of the customer connection and consumer need
4	Customer Electric Meter number, Names, and Phone number	CSV	Tanzania Electric Supply Company Limited (TANESCO) - Arusha City.	Identification of the customer's location
5	Customer location	GPX (GPS Exchange Format)	Tanzania Electric Supply Company Limited (TANESCO) - Arusha City.	Identification of the geographic location of customers

3.6 Geodatabase Creation

Geodatabase was created with the use of the PostgreSQL system which is an open-source object relational database with an installation of PostGIS extension that adds support for geographic objects allowing location queries to be run in SQL. Geodatabase was created following these steps below;

i. *PostgreSQL and PostGIS Installation*

PostgreSQL plugin on QGIS was downloaded and runs on port number 5432 which is a default for hosting the database service, PostGIS extension was downloaded using the application stack builder by checking the spatial extension option during the installation of PostgreSQL.

ii. *Loading the Shapefiles into the PostgreSQL Database*

After the installation of PostgreSQL and pgAdmin4 which is an open-source management tool for Postgres provides a graphical interface that simplifies the creation, maintenance, and use of database objects were used in the creation of the “TANESCO_ARUSHA” database in this study. The database was created and the PostGIS extension was added to support GIS capabilities. Shapefiles were imported into the database using the PostgreSQL plugin from

QGIS which hosts the PostGIS shapefile import/export manager that provides a connection to the database for importing the shapefiles from the computer files. Seen figure 3.3(a and b) shows how shapefiles are connected or imported into the database “TANESCO_ARUSHA” database view.

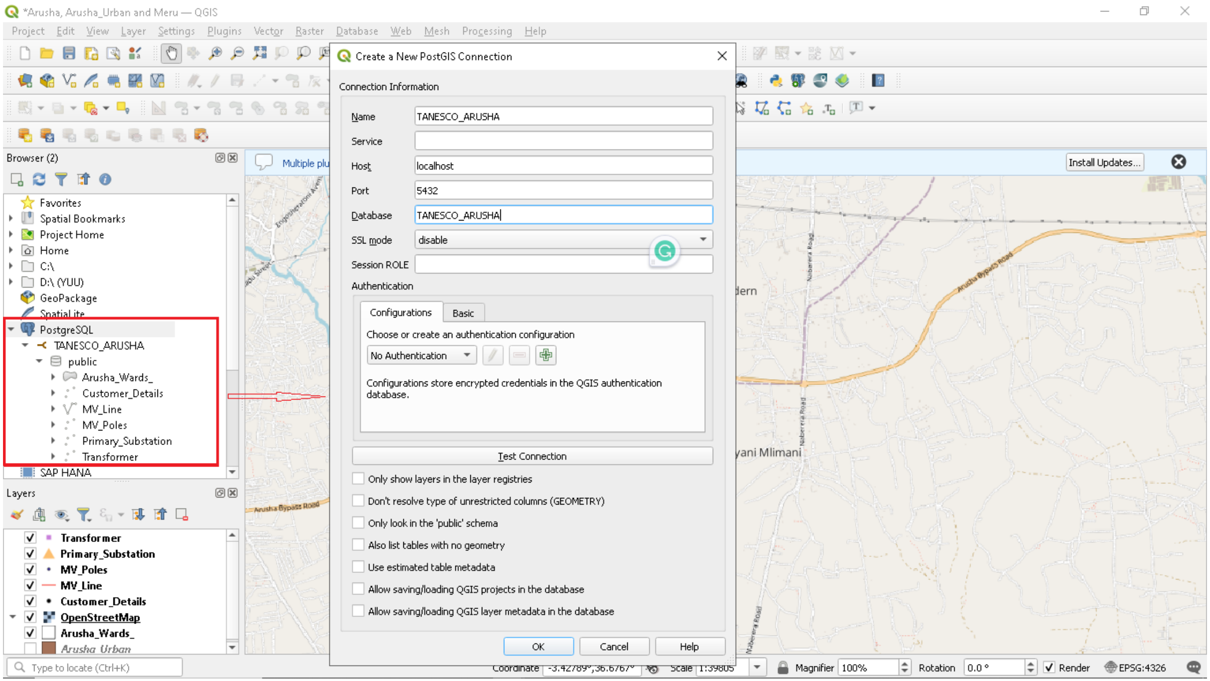

Figure 3.3 (a): PostgreSQL plugin from QGIS

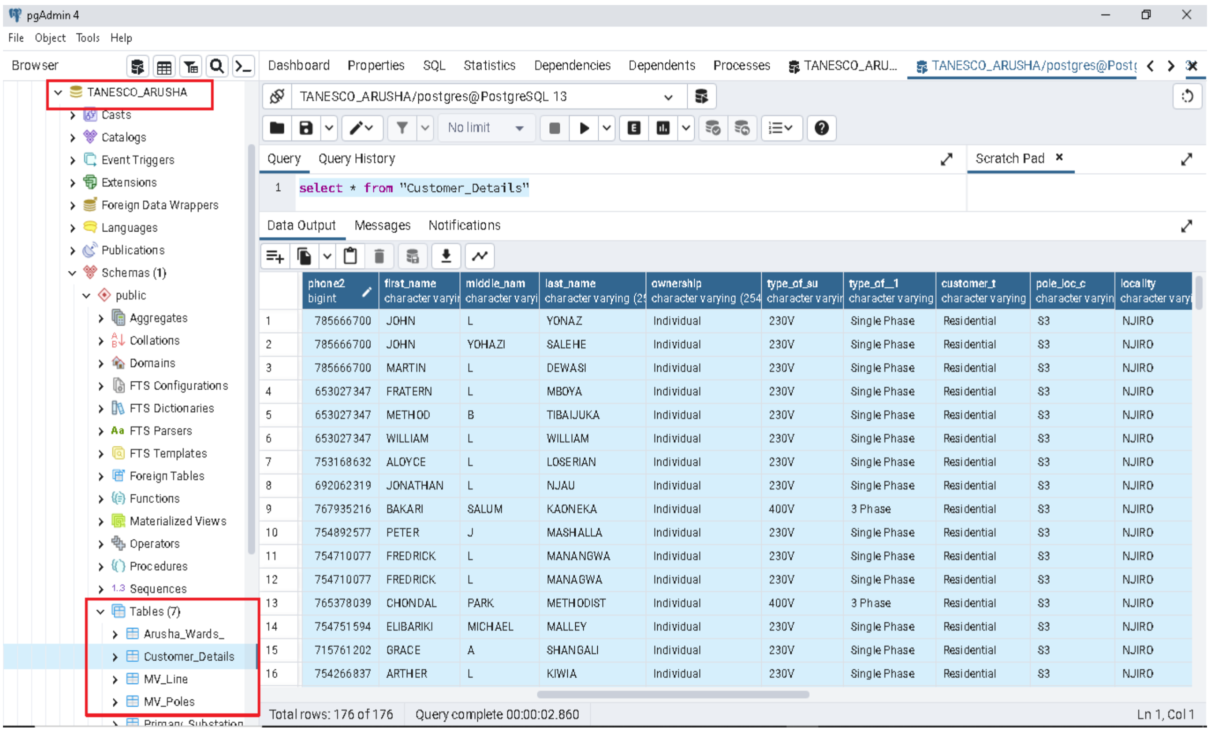

Figure 3.3 (b): PostGIS hosts the shapefile

Using the same database named TANESCO_ARUSHA new customer information and electric utilities with their respective columns were created. Figure 3.4 show the customer information in the PostgreSQL database.

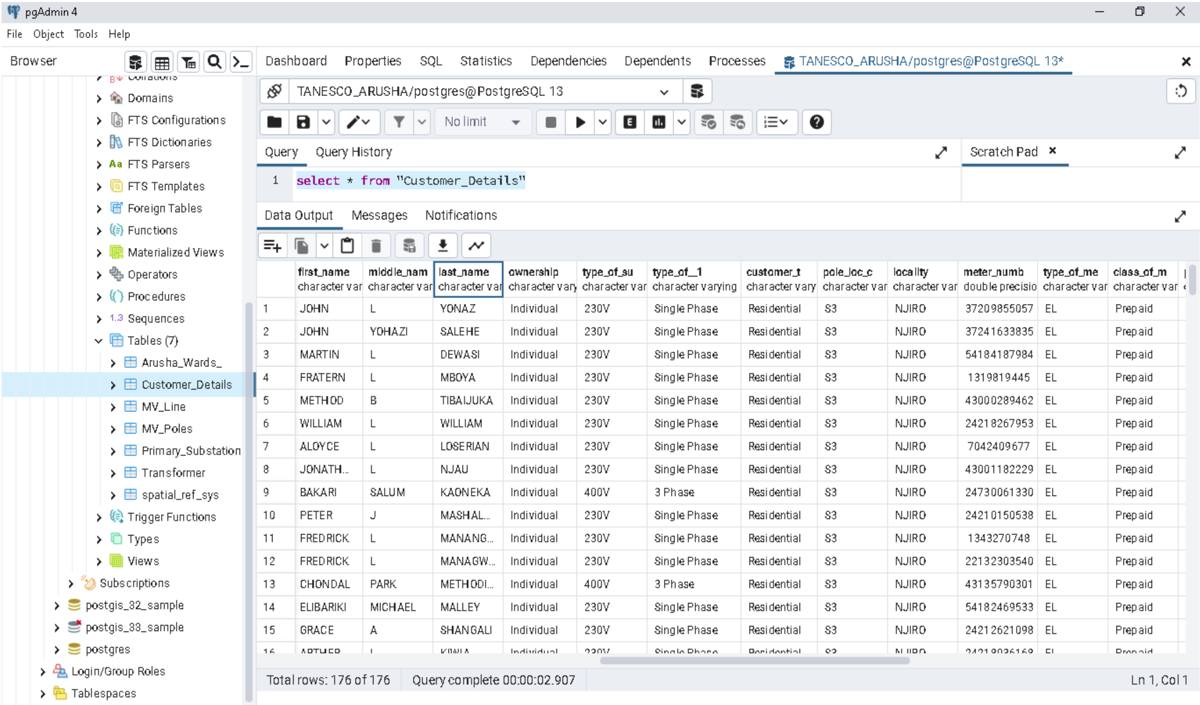

Figure 3.4: Customer information in the PostgreSQL (pgAdmin 4) database

3.7 Web Development

The following steps were taken to develop the web server-side environment:

i. *Installation of Java Development Kit (JDK)*

Java Development Kit (JDK) was downloaded from http://www.oracle.com/ and installed. The installation of a Java runtime environment into the computer system is a necessary kit to run and develop a Java application. See figure 3.5 show the command prompt from the administrator that JDK is successfully installed.

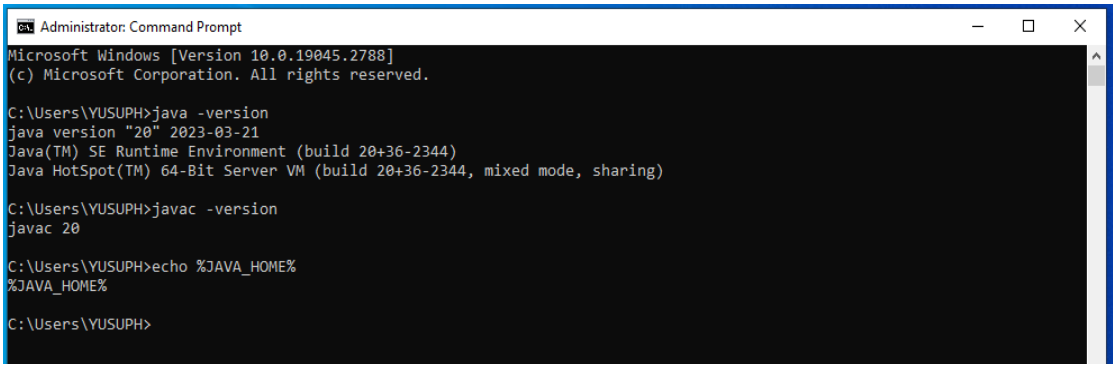

Figure 3.5: Java Development Kit (JDK) command prompt from the administrator

ii. Geoserver and Apache Tomcat Installation

The GeoServer package was downloaded from http://geoserver.org/release/stable/ and installed. Then, the web application manager, Apache Tomcat Server was installed. The GeoServer package was copied and pasted into the Apache Tomcat folder in war format (geoserver. war) so that can be managed by the Apache Tomcat server. To check the state of the software running on this server, the Chrome browser was opened by typing a URL address http://localhost/8082/. After Apache Tomcat agreed to manage the application, GeoServer was started. Figure 3.6 show the status of GeoServer in Apache Tomcat after being started.

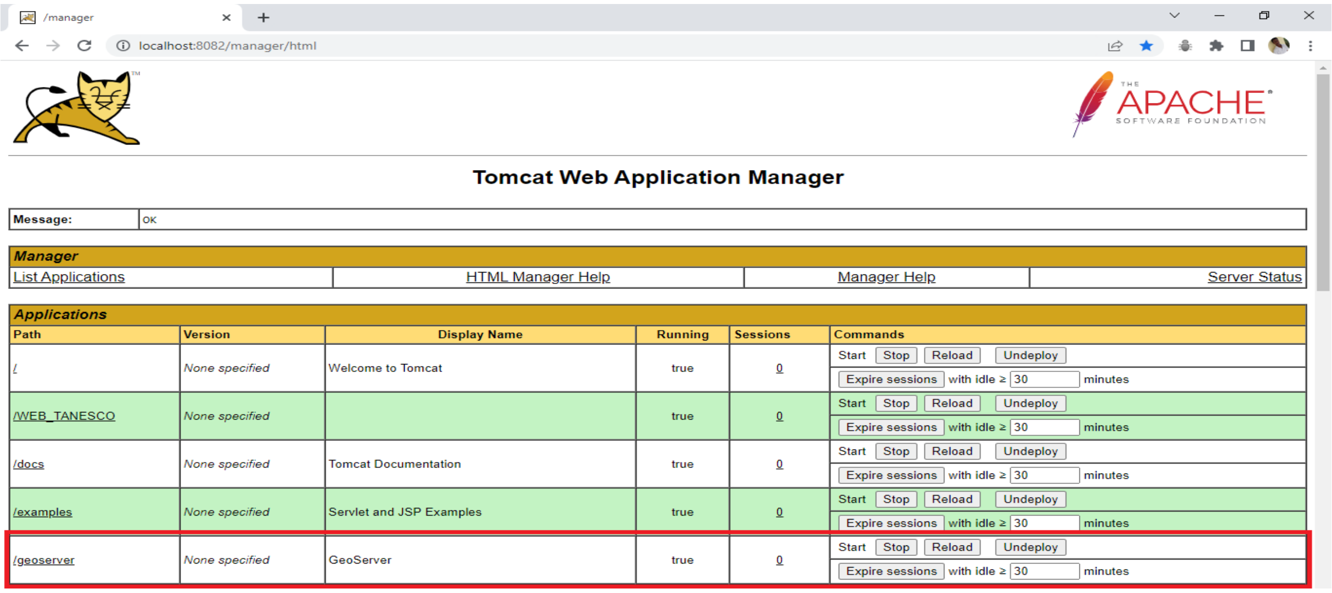

Figure 3.6: The GeoServer running in Apache Tomcat after being started

Geoserver was started and opened into a web browser with a default URL address http://localhost:8082/geoserver/web/ and logged in using a username “admin” and password “GeoServer” which is the default. Figure 3.7 shows published layers in GeoServer.

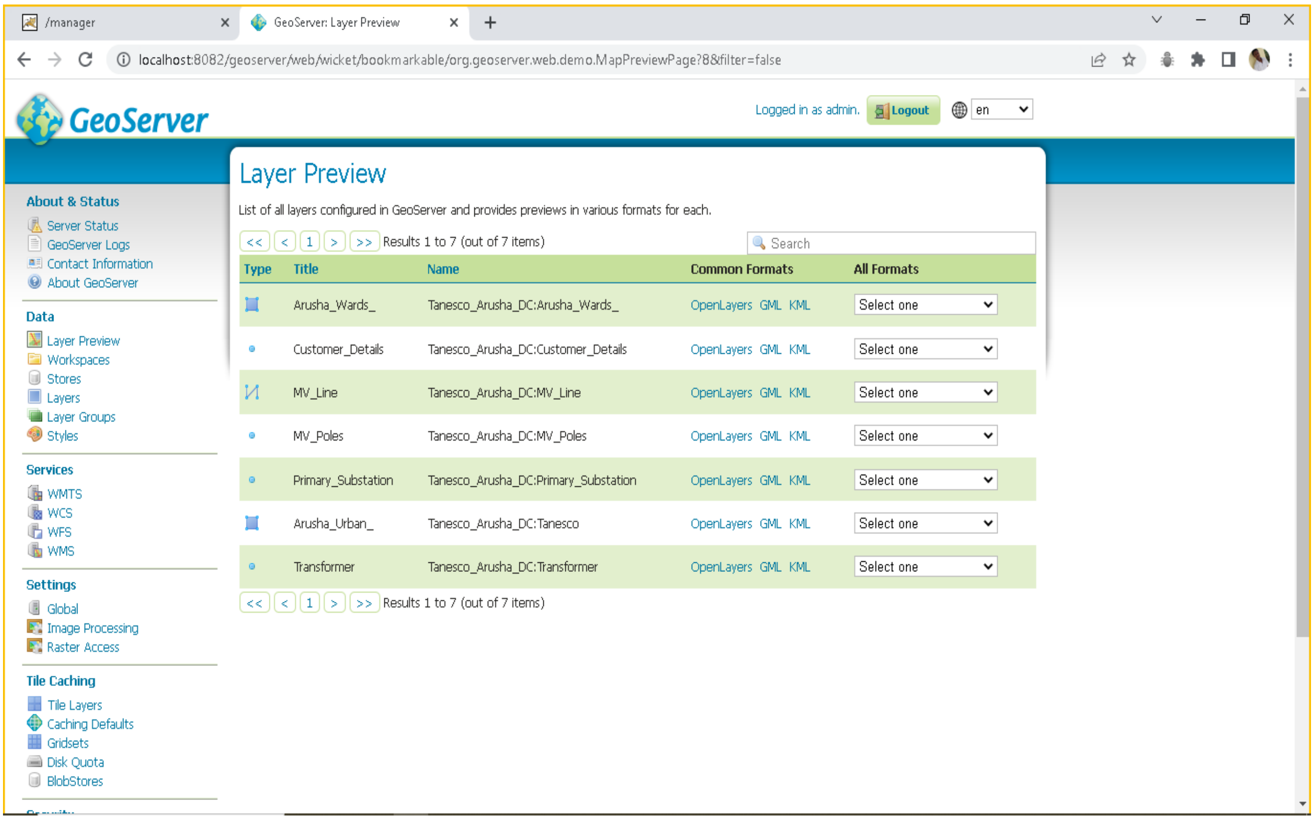

Figure 3.7: Published Layers in GeoServer

3.8 Development of the Geographical User Interface

The geographical user interface was developed by published layers in the GeoServer and were added to QGIS software as Web Map Services (WMS) after making the localhost connection with the GeoServer. The QGIS2web plugin was installed in QGIS and was used to import basic map views. In QGIS2web, inbuilt controls such as zoom in/out, location, measure, layer selector, and geocoder search were added and enabled.

The published layer was previewed in the web browser. Then after, the index.html file of the map was opened so that edits can be done to make the web map more interactive and understandable to meet the final results.

3.8.1 Creation of Web Page and Configuration of OpenLayers

During this stage, a web page is created using a visual studio code editor by opening HTML, CSS, and JavaScript files for loading in a web browser. To display the map in the web browser, OpenLayers files were loaded into Visual Studio Code, the relative path from the contained folder was copied, and the links were run.

3.8.2 Layers Configuration and Deployment

This system's geospatial layers were deployed from GeoServer by configuring the JavaScript file in the visual studio code editor using URL links. The layers used in the system are substation data, feeder lines, electric poles, power transformer, customer location, and customer electric meter number, names, and phone number.

3.8.3 Layer Switcher Control and User Support Functionalities

Layer switcher control was added to give access to the user for turning on and off layers to meet the necessities for reviewing the guide. The system now includes home, full screen, zoom in and zoom out, the ability to identify distance and area measurement, and attribute query functionality to give the user a wide range of options for exploring the data.

3.8.5 Viewing the System over the Web Browser

The system can be viewed in a web browser using the URL address http://localhost/TANESCO_ARUSHA/index.html. following the synchronization of the local directory with that on the server. Figure 3.8 show system viewing over the web browser.

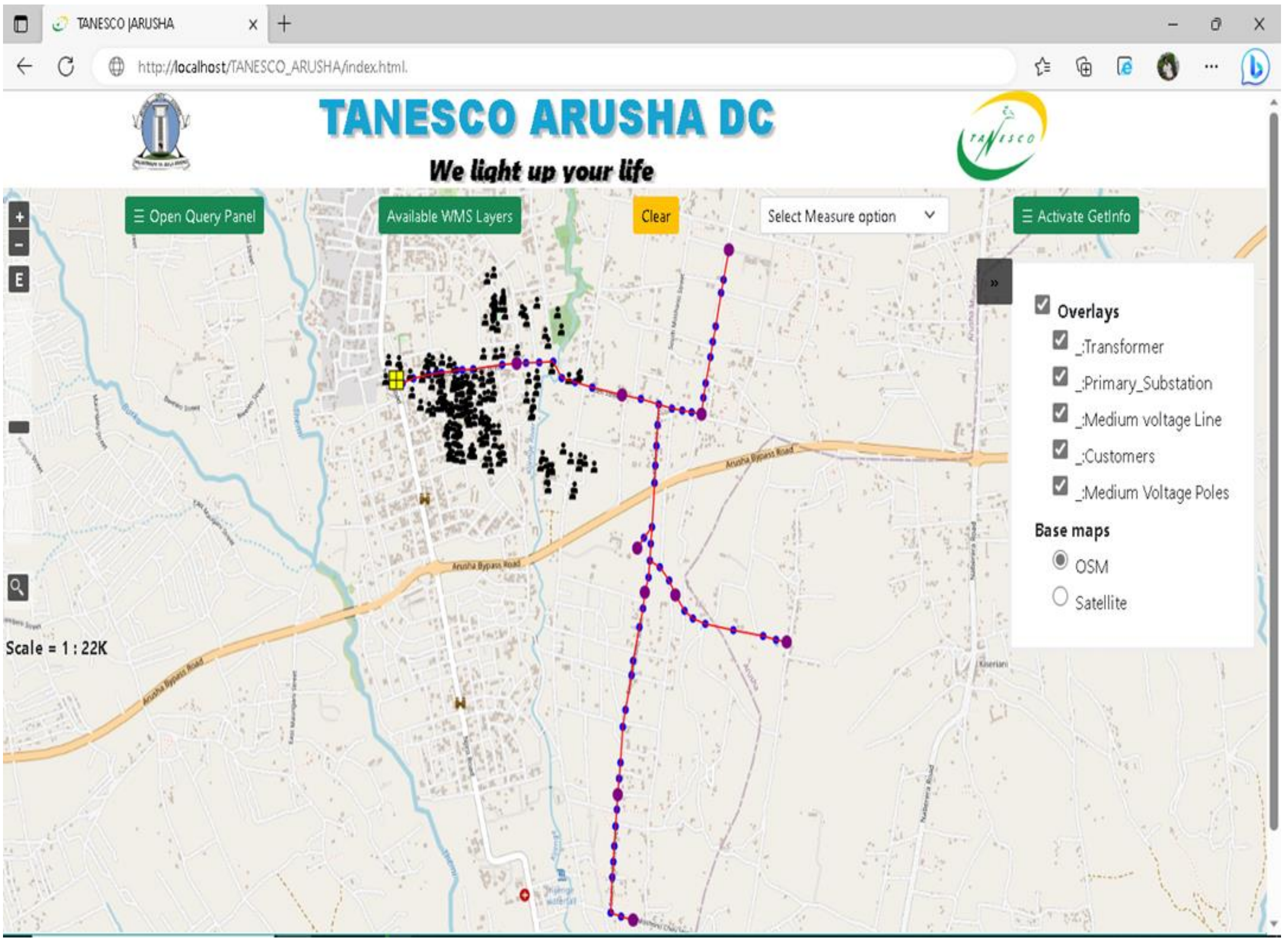

Figure 3.8: System viewing over the web browser

3.9 System Testing and Debugging

The performance of the system was tested by checking the response of all functionalities and evaluating the performance of the geoweb system and mobile application to ensure they meet the intended requirements. The testing process includes various stages, such as unit testing, integration testing, and system testing. These tests are conducted to verify the proper functioning of individual components, their seamless integration, and the overall system behavior.

Debugging is an essential aspect of the testing process and involves identifying and resolving any issues, errors, or defects that may arise during system usage. It requires systematic troubleshooting, error tracking, and problem resolution to ensure the geoweb system and mobile application work as intended.

CHAPTER FOUR

RESULT, ANALYSIS AND DISCUSSION

4.1 Introduction

This chapter represents the results obtained from operations performed during the implementation of the research methodology and the discussion are presented according to the intended objective of this research. The result obtained is a developed geoweb system for electric power in improving customer location at Arusha city.

4.2 Geoweb System for Locating Customer of Electric Power

The output of this research is a geoweb system specifically developed for improving the identification of the location of electric customers in Arusha city. The system allows users, particularly the Department of Emergency and Technical at TANESCO, to easily access electric customer information through a web-based platform by simply using a standard web browser (Refer to figure 4.1). With the geoweb system, users can easily retrieve and view relevant data regarding electric customers in the city. By identifying the location of the customer, it helps the Department of Emergency and Technical at TANESCO to easily respond to power outages reported by customers.The geoweb system incorporates various tools and features that assist users in querying and performing interactions with the information displayed on the map.

Users can perform spatial queries and visualize customer locations based on different parameters. The user interface of the geoweb system is designed to be intuitive and user-friendly, providing a seamless experience for users. The developed geoweb system serves as a valuable tool for the technical and emergency teams at TANESCO, enabling them to make informed decisions and effectively address customer-related issues in Arusha city. By swiftly identifying the location of customers, the system facilitates prompt response and resolution of power outages reported by customers, enhancing the efficiency and effectiveness of the emergency and technical teams' operations. The department of emergency and technical at TANESCO will be the main user of this system, benefiting from its functionalities and capabilities in managing power outages and providing enhanced customer service.

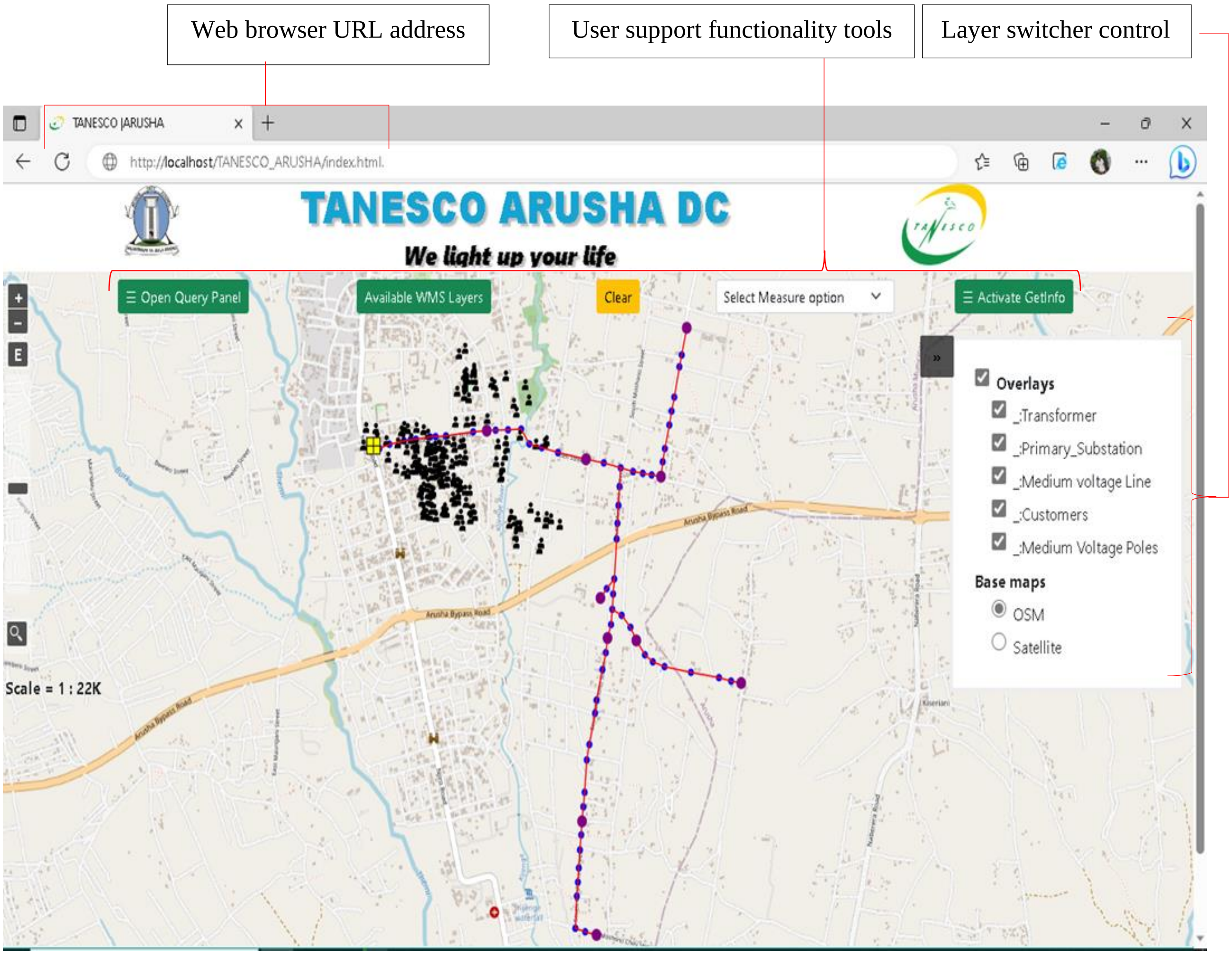

Figure 4.1: Geoweb system for identification of the location of electric customers in Arusha City

4.2.1 Available WMS (Web Map Service) Layers

The geoweb system enables the user to incorporates various WMS layers that can be added and fetched from the geoserver, enriching the functionality and data visualization capabilities of the system. These WMS layers play a crucial role in providing valuable context and supporting information to the technical and emergency teams. The WMS layers include customers, substation, medium voltage poles, power transformer, and medium voltage lines. These layers are essential for effective power outage management and restoration.

The customer layer provides information about consumer locations and details, facilitating efficient communication during outages. The substation layer helps prioritize restoration efforts by evaluating proximity to affected customers. The electric poles layer enables the identification of potential issues in the distribution network. The power transformer layer offers insights into transformer availability and condition. The medium voltage line layer aids in diagnosing power interruptions and planning restoration strategies. Leveraging these WMS layers enhances situational awareness and decision-making for efficient power outage management and restoration. Figure 4.2 Shows the available WMS layer on the geoweb system.

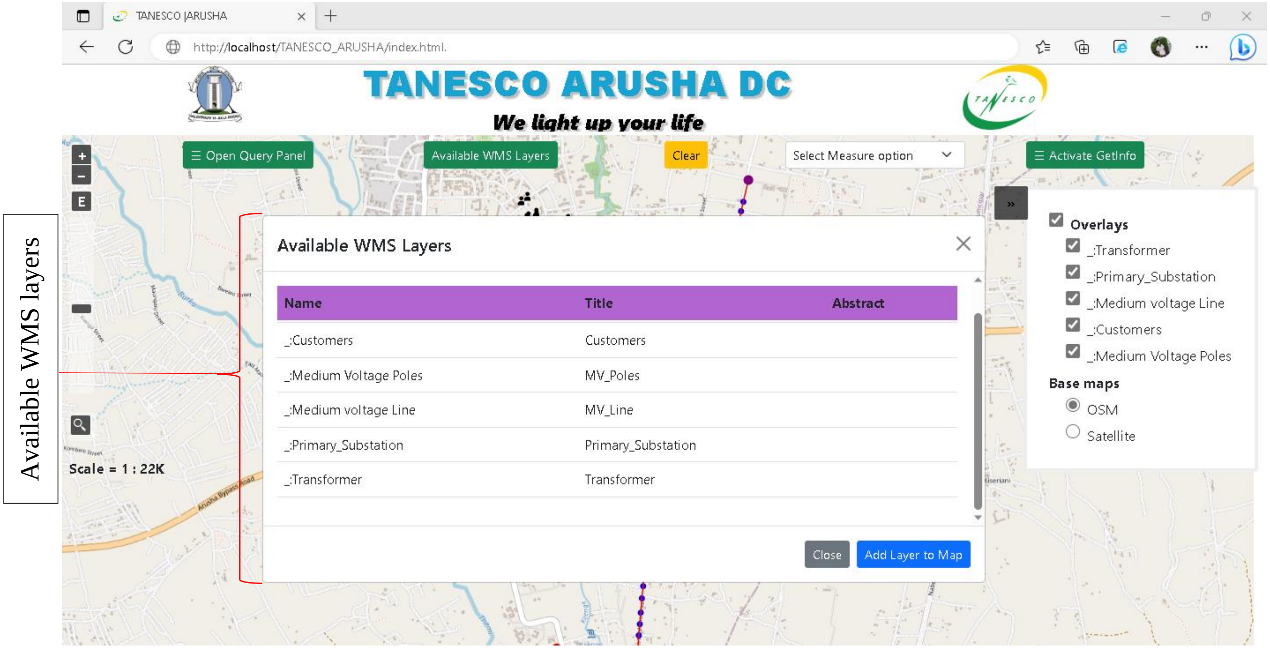

Figure 4.2: Available WMS layer on the geoweb system

4.2.2 Layer Switcher Control, Zooming in and out and Fit to extent

The users will have the ability to control the view of map features by zooming in and out, as well as fit to extent or full-screen controls. The identify functionality allows for the display of attribute data for all spatial data present in the system. The layer switcher control incorporates the layers integrated into the system, along with their respective attributes. This feature enables users to toggle the visibility of layers, focusing on specific ones as needed. Figure 4.3 illustrates the layer switcher control, zooming functionality, fit to extent option and search for button for any location. Figure 4.3 shows the layer switcher control, Zooming in and out, and fit to the extent and search for the button.

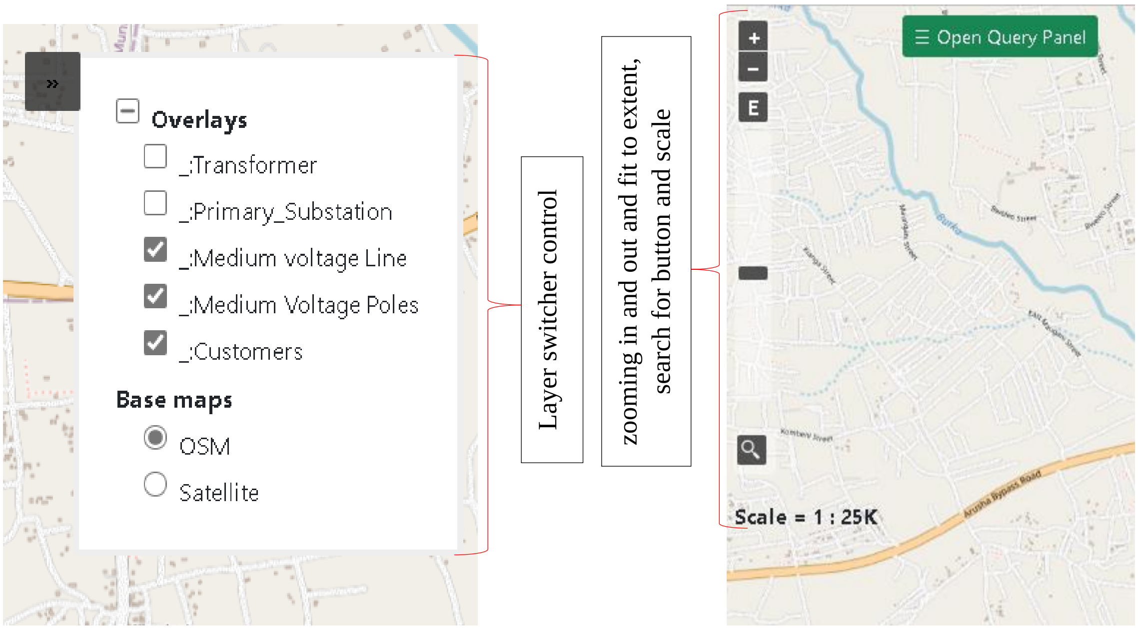

Figure 4.3: Layer switcher control, zooming in and out and fit to extent and search for button

4.2.3 Attribute Query

The system allows the user to extract some useful information from the respective layers by displaying the selected attribute which facilitates the display of required information for identification of the location of electric power customers, assisting the technical and emergency teams in restoring power during outages. The system allows querying customer information using various parameters such as customer names, phone numbers, meter numbers, or localities through the query panel.

Within the query panel, several functions are available. Firstly, users can select a layer, such as the customer layer to focus the search. Secondly, an attribute can be chosen, for example, the meter number. Thirdly, users can specify a value comparison operation, such as 'less than or equal to.' Lastly, the load layer function enables the geoweb system to navigate to the selected layer and provide the precise location of the queried customer. This feature enhances the efficiency of the technical and emergency teams by enabling them to promptly locate customers positions and serves as a valuable tool for improving the response time and overall service quality during power outages. Figure 4.4 shows the attribute query functionality.

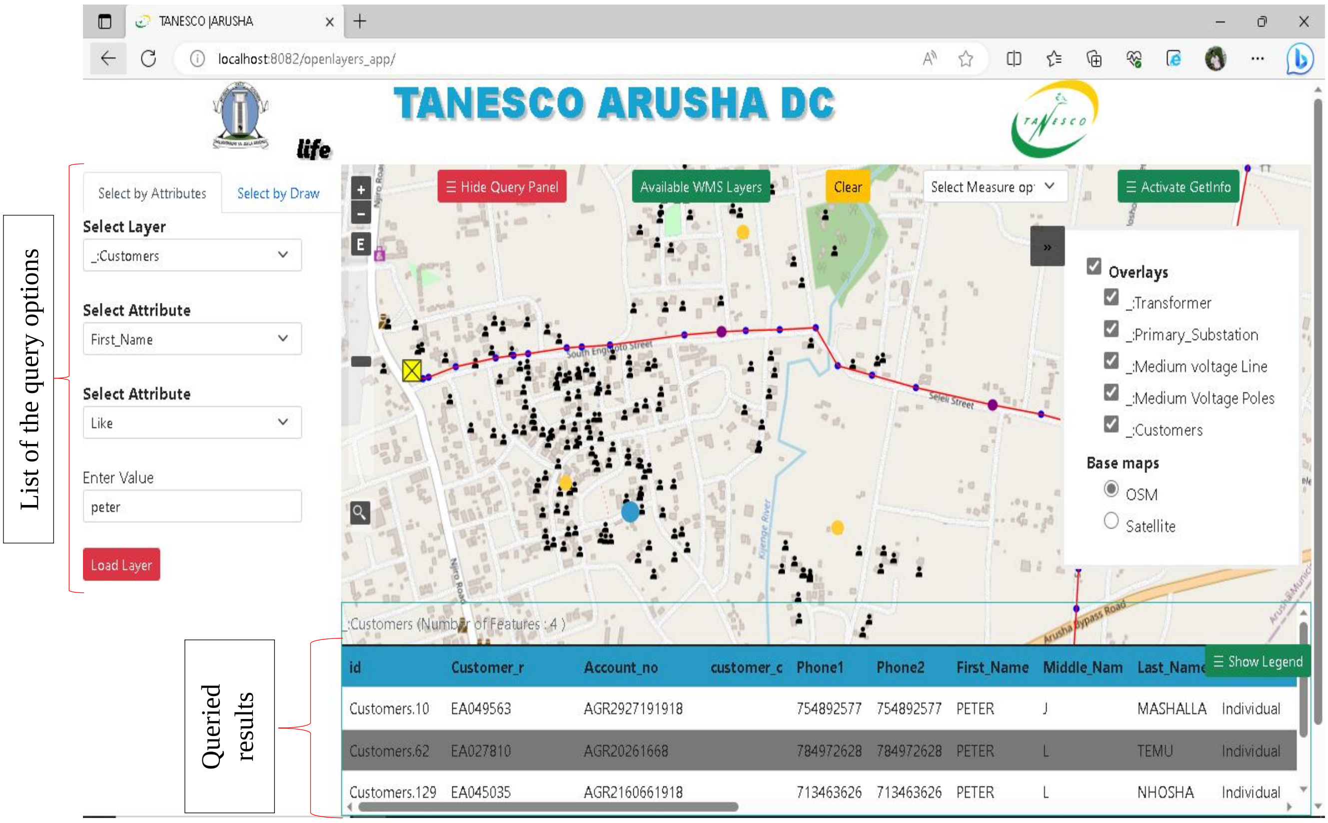

Figure 4.4: Attribute query functionality

4.2.4 Clear Functionality

In the developed geoweb system, a clear button is incorporated to facilitate the removal of all layers that have been added from the geoserver to the system. This functionality provides users with the ability to reset the map to its initial state and remove any additional overlays or layers that may have been added during the course of their analysis. Figure 4.5 shows the clear button functionality.

Figure 4.5: Clear button functionality

4.2.5 Distance and Area Measurement

The system created with the measurement options enables the user to measure distance distances between different points or along lines on the map. For instance, it can be used to determine the length of an MV (Medium voltage) line or the distance between two electric poles. The Area measure option enables users to calculate the area enclosed by a polygon drawn on the map. This feature is particularly useful for evaluating the size of a power substation or determining the spatial extent of an affected area during maintenance or outage incidents.

Both measure options contribute to the overall functionality of the geoweb system by providing quantitative measurements related to the electric power infrastructure. They enable users to perform spatial analysis, estimate resource requirements, and support decision-making processes. Whether it's measuring the length of power lines for maintenance planning or determining the area coverage of a substation for capacity assessment. Figure 4.6 illustrate the distance and area measurement.

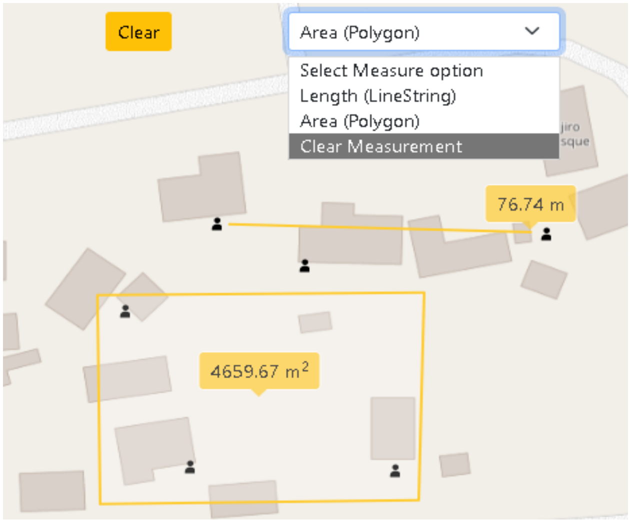

Figure 4.6: Distance and area measurement

4.2.6 The GetInfo Functionality:Streamlining Access to Detailed Attribute Information

The 'GetInfo' button in the geoweb system empowers users to interact with the displayed features and layers on the system, enabling them to retrieve related attribute information easily. One significant functionality of the 'GetInfo' button, which, when activated, allows users to retrieve detailed attribute information about specific features or layers within the system. By simply clicking on a particular feature or layer on the geoweb interface, a pop-up window appears, displaying relevant and comprehensive attribute data associated with that specific feature. Figure 4.7 shows the GetInfo button, providing detailed attribute information.

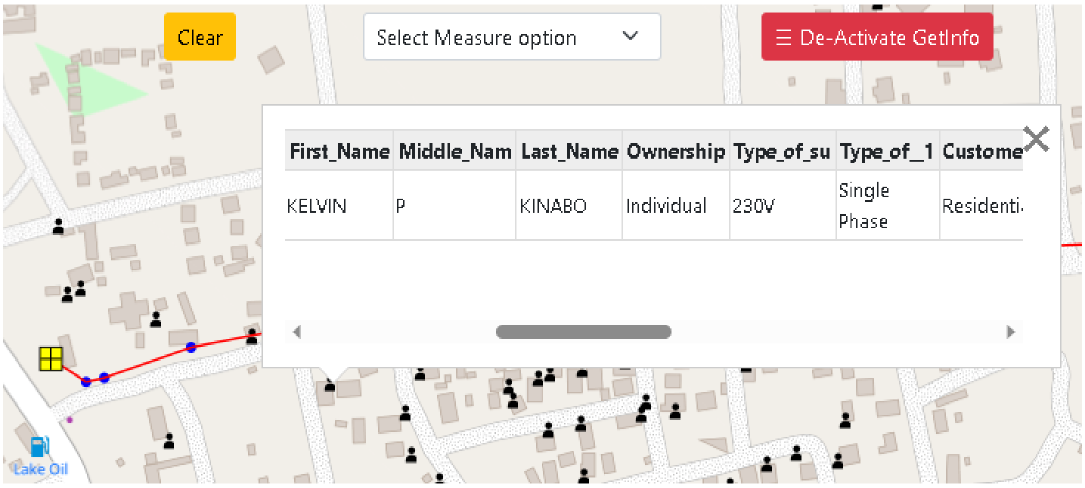

Figure 4.7: GetInfo button functionality

4.2.7 The Layers Button: Enhancing User Control and Flexibility in the Geoweb System

The 'Layers' button allows users to switch the added layers on and off as needed. This flexibility enables users to focus on specific components of the electrical infrastructure and providing a clearer and more manageable view of the data. This button serves multiple purposes to enhance the user experience. Firstly, it enables users to access a comprehensive list of added layers within the system. Users can view the available layers and choose which ones to display on the geoweb system providing a clearer and more manageable view of the data.

Sendondly, it provides users with the ability to change the base maps used within the geoweb system that offers options for selecting different base maps, such as OpenStreetMap (OSM) or satellite imagery. This feature allows users to choose the most suitable base map for their analysis or visualization needs, whether it is a detailed street map from OSM or a satellite view for better understanding of the surrounding area. Figure 4.8 (a and b) illustrate layers button in different base maps views.

Figure 4.8 (a): Layers on OpenStreetMap (OSM) view

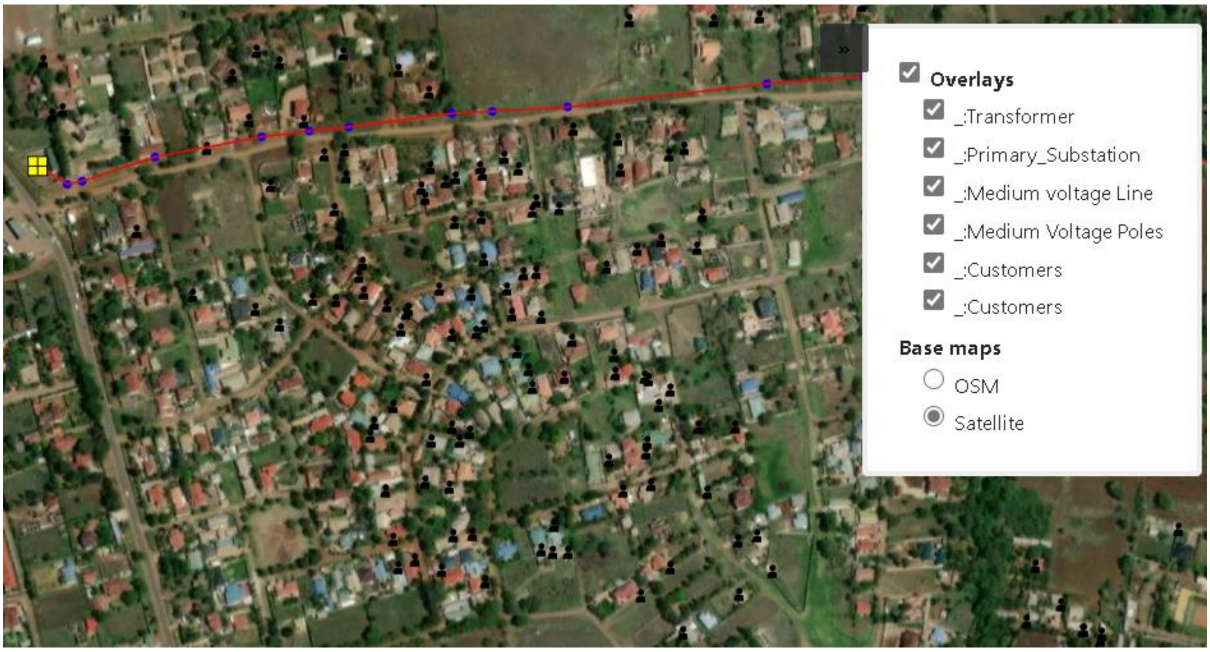

Figure 4.8 (b): Layers on satellite view

4.3 Discussion

Development of a geoweb system for electric power has proved to be a significant step towards improving the identification and management of customer locations. This research has successfully created a web-based platform that can enables users to access electric customer information easily and efficiently. The department of emergency and technical at TANESCO in Arusha city can swiftly identify the location of customers, leading to prompt responses and resolutions of power outages reported by customers. The system functionality and capabilities enhance the efficiency and effectiveness for emergency and technical teams operations.

Furthermore, the system integration with various departments will promotes collaboration and data sharing, enabling a more coordinated approach to managing electric power. The system it provides a robust foundation for enhancing service quality, optimizing resource allocation, and improving overall customer satisfaction. The successful implementation of this research contributes to the advancement of geospatial technologies in the field of electric power management, paving the way for more efficient and effective power infrastructure systems in the future.

CHAPTER FIVE
CONCLUSION AND RECOMMENDATION

5.1 Conclusion

This research aimed to develop a geoweb system for improving the location of electric power customers in Arusha city. The successfully developed geoweb system can create a comprehensive solution for the technical and emergency teams at TANESCO in identifying electric power customers. The geoweb system serves as a valuable tool for TANESCO in managing electric power distribution networks, improving response times, and enhancing customer service. It supports decision-making processes for power outage management and restoration, facilitating the retrieval of customer information based on various parameters and enhancing the emergency and technical teams' response to electric power outages.

The geoweb system marks a significant advancement in the application of geospatial technologies in the electric power industry, paving the way for more efficient and effective power infrastructure systems in the future. The successful implementation of this research contributes to the growth and stability of Arusha city's electric power supply and supports the socio-economic development of the region.

5.2 Recommendation

The geoweb system developed has been limited to only employees at TANESCO and it is accessed through a web portal on the company's internal network, further studies should be conducted to expand the geoweb system by developing a mobile application for electric customers. This application would provide customers with real-time access to information about power outages, including the status of the technical and emergency teams working on resolving them. Additionally, customers should be able to report power outages directly through the mobile application, enabling faster response times and more accurate data collection.

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APPENDICES

DEVELOPING GEOWEB SYSTEM FOR IMPROVING LOCATION OF ELECTRIC POWER CUSTOMERS IN ARUSHA CITY

USER MANUAL

CONTENTS

LIST OF FIGURES

1 Introduction

Welcome to the user manual for the geoweb system, a powerful tool developed specifically for TANESCO at Arusha city. This comprehensive guide will walk you through the functionalities and features of the geoweb system, enabling the technical and emergency teams to swiftly identify the location of electric customers and expedite the restoration process during power outages reported by customers. The geoweb system provides access to a range of crucial data for efficient outage management, including information on substations, transformers, medium voltage (MV) poles, MV lines, and customers. By harnessing this valuable data, your teams can accurately pinpoint the source of outages and coordinate timely restoration efforts.

2 About the GeoWeb System

The geoweb system is an advanced solution designed to address the unique challenges faced by TANESCO in Arusha city when it comes to locating and resolving power outages promptly. Leveraging cutting-edge geospatial technology and real-time data integration, the geoweb system provides an intuitive and robust platform for seamless collaboration between customers, technical teams, and emergency responders.

3 Contacts

To request access or make inquiries regarding the use of the system, as well as provide feedback on the design and functionalities of the application, please contact us through the dedicated email address: yusupkarera@gmail.com, or reach out to us via phone at +255 675494394/+255623300433

4 System Overview

The geoweb system have the following key features and benefits

i. Query Panel
ii. Available WMS (Web Map Service) Layers
iii. Layer Switcher Control, Zooming, and Fit to Extent
iv. Distance and Area Measurement
v. Clear Functionality
vi. Legend Display
vii. GetInfo Functionality
viii. Layers and Base Map Selection
ix. Mouse Position Identification

5 Getting Started with the Geoweb System

This guide will walk you through the steps to access and utilize the system effectively. Whether you are a TANESCO employee in Arusha city or a registered user, this section will help you get started with the Geoweb system.

5.1 How to Access the System

To access the geoweb system, follow these steps:

a. Open any internet browser (e.g., Internet Explorer, Firefox, Chrome, etc.).

b. In the browser's address bar, type the following URL:

http://localhost/TANESCO_ARUSHA/index.html.

c. Press Enter or Return to load the geoweb system's login page

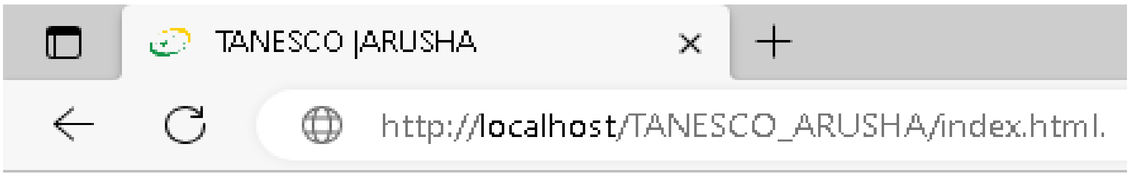

Figure 1: Using Internet Explorer browser

5.2 How to Register

TANESCO employee in Arusha city may register to access the system and to become a user of the geoweb system (see figure 2).

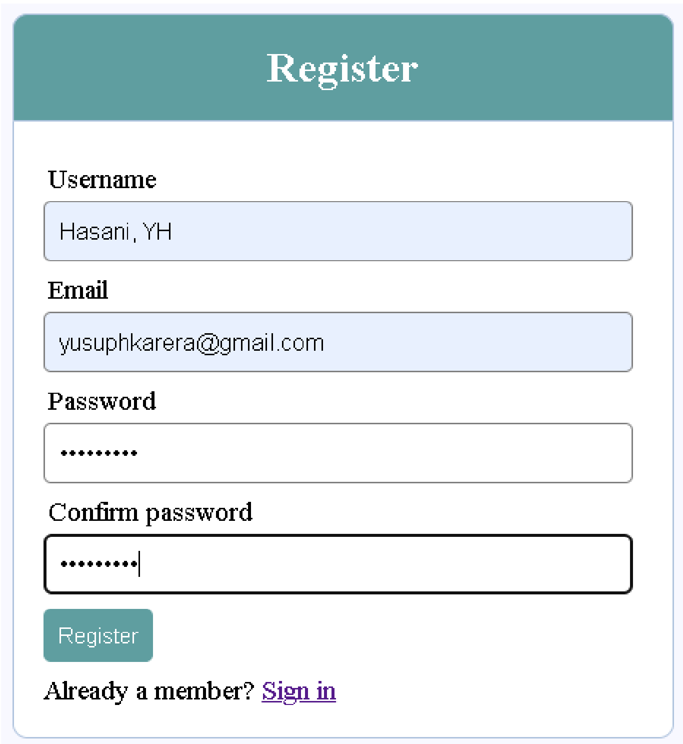

Figure 2:Registering page

5.3 How to login

Once you have registered and obtained your login credentials, the user will able to login and access geoweb system.

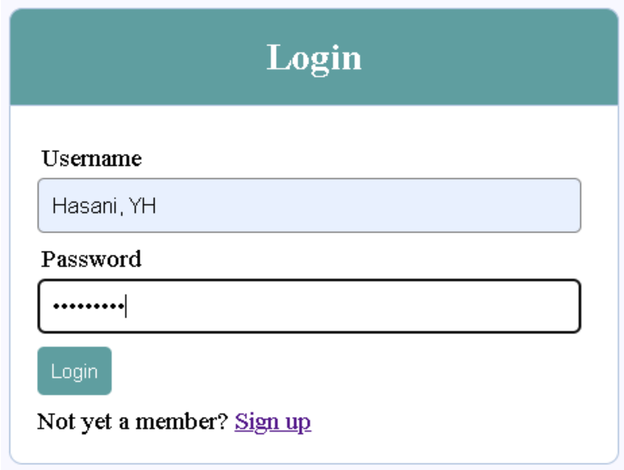

Figure 3: Login page

5.4 Query Panel

The system provides a query panel that allows users to extract useful information from respective layers by displaying selected attributes. This functionality facilitates the identification of the location of electric power customers by presenting the required information in a convenient manner (see figure 4).

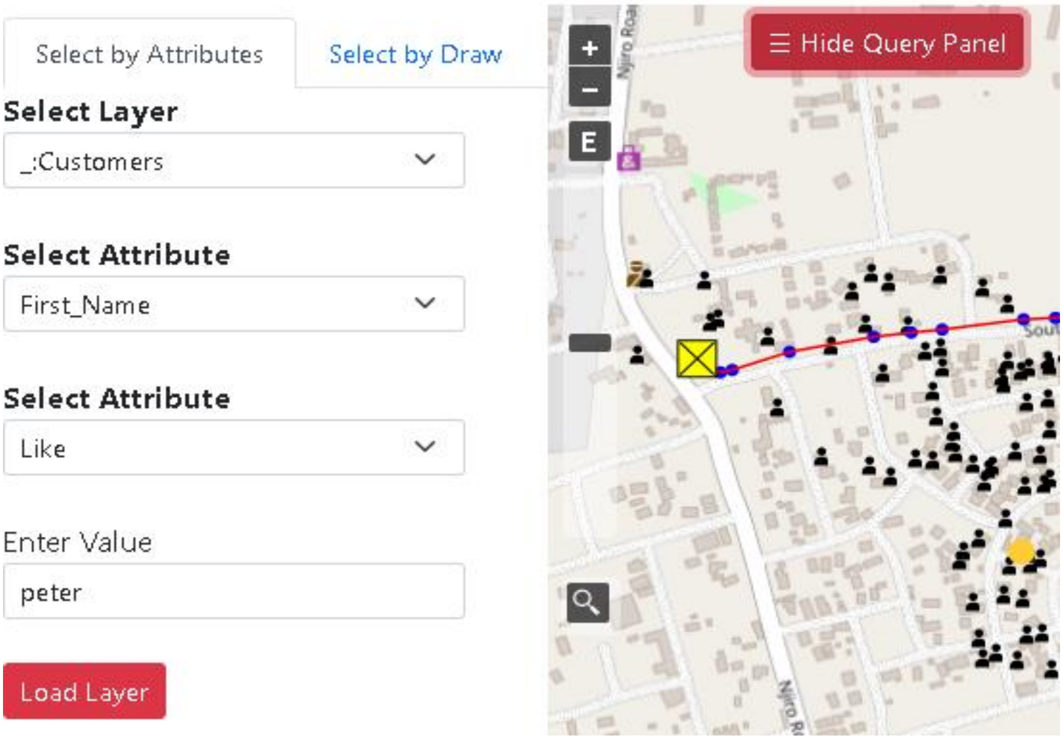

Figure 4: Query panel

5.5 Available WMS (Web Map Service) Layers

The GeoWeb system incorporates various WMS layers, including customers, substations, medium voltage poles, power transformers, and medium voltage lines. These layers provide essential geographic data that aids in locating and addressing power outages effectively (see figure 5).

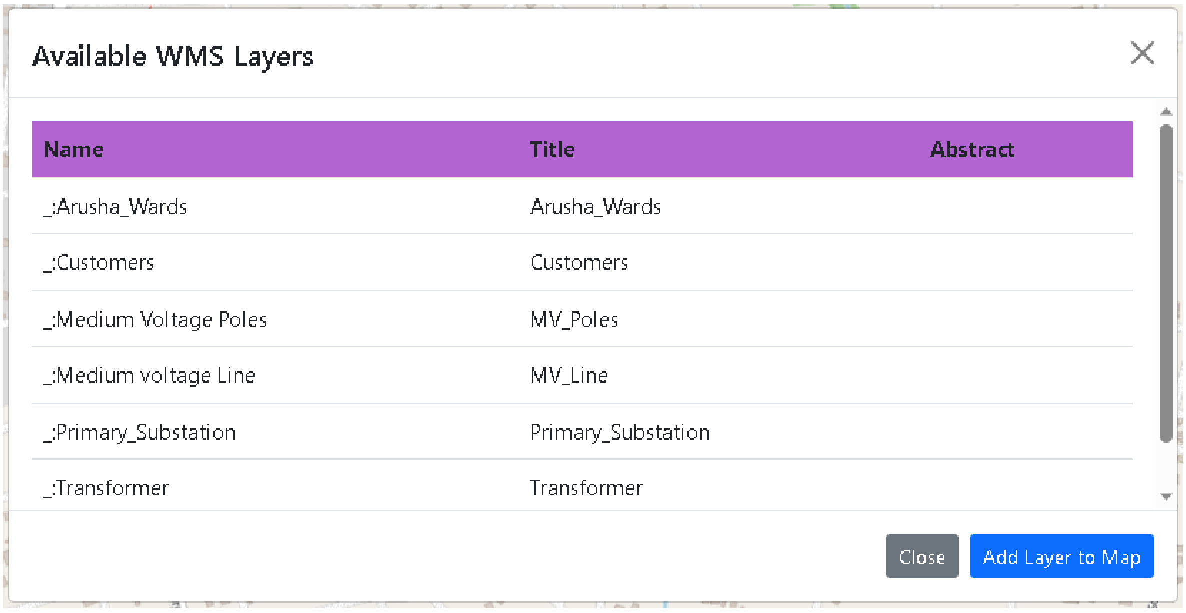

Figure 5: Available layers in a geoweb system

5.6 Layer Switcher Control, Zooming, and Fit to Extent

Users have the ability to control the view of map features through the layer switcher control, which allows them to switch added layers on and off as needed. They can zoom in and out of the map and utilize the fit to extent functionality for a comprehensive view. These tools enable efficient navigation and analysis of the spatial data within the system (see figure 6).

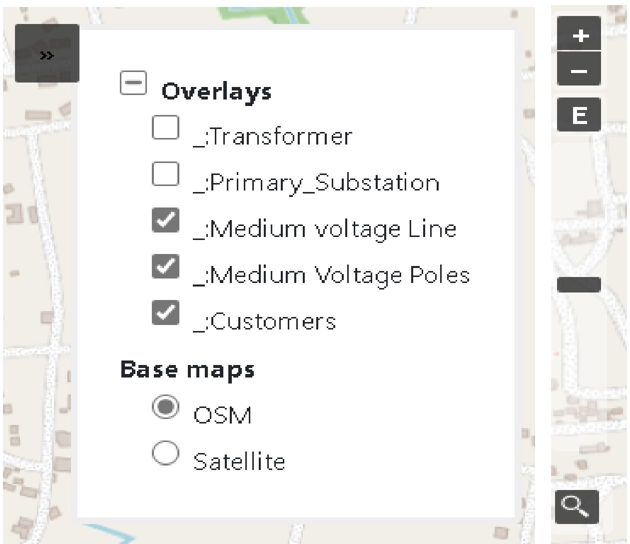

Figure 6: Layer Switcher Control, Zooming, and Fit to Extent

5.7 Distance and Area Measurement

The GeoWeb system offers distance measurement functionality, enabling users to measure distances between different points or along lines on the map. Additionally, the area measurement option allows users to calculate the area enclosed by a polygon drawn on the map. These tools assist in spatial analysis and planning during power outage restoration processes (see figure 7).

Figure 7: Distance and area measurement

5.8 Clear Functionality

It allows users to remove all added layers from the GeoServer, effectively resetting the map to its initial state. This feature eliminates any additional overlays or layers that may have been added during the course of analysis, providing a clean and focused interface (see figure 8).

Figure 8: Clear functionality

5.9 GetInfo Functionality

To pop up the attribute data of spatial features such as customers, poles, transformers, medium voltage lines, and substations (see figure 9).

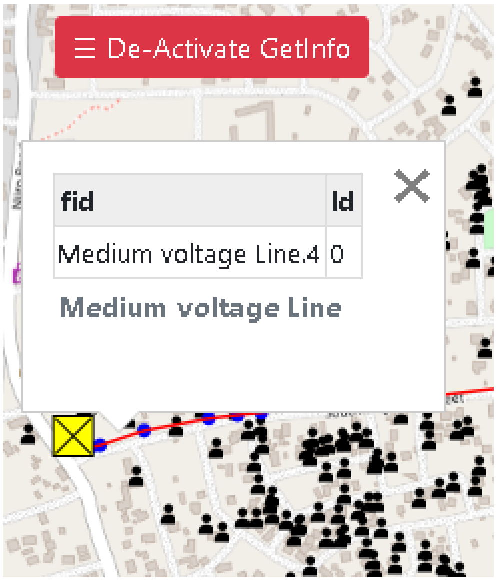

Figure 9: GetInfo functionality

5.10 Layers and Base Map Selection

The GeoWeb system enables users to switch added layers on and off as needed, allowing for flexible visualization and analysis also users can change the base maps used within the system, choosing from options such as OpenStreetMap (OSM) or satellite imagery (see figure 10).

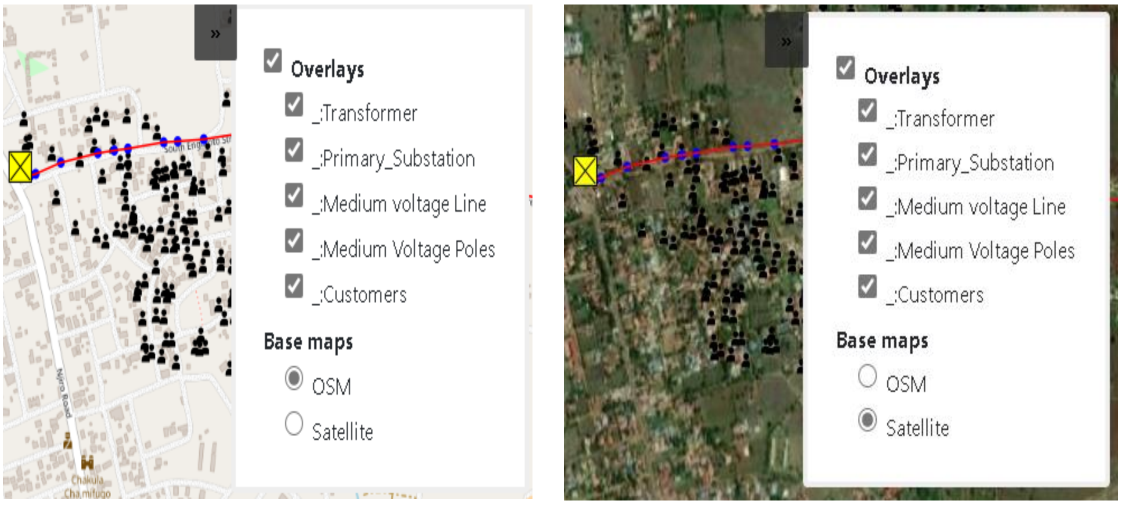

Figure 10: Layers and base map selection

5.11 Mouse Position Identification

The geoweb system incorporates a mouse position functionality that displays the latitude and longitude coordinates of the cursor's location on the map. This feature enables precise identification and referencing of specific locations during analysis and reporting (see figure 11).

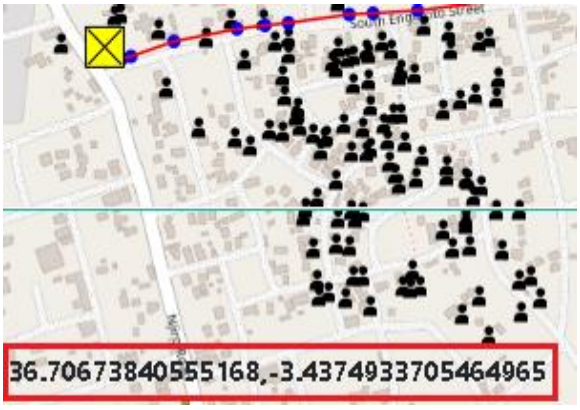

Figure 11: Mouse position identification

5.12 Legend Display

The system includes a legend that shows the information and symbology of the added layers. This feature provides a visual guide to interpreting the map and understanding the representation of different elements and attributes (see figure 12)

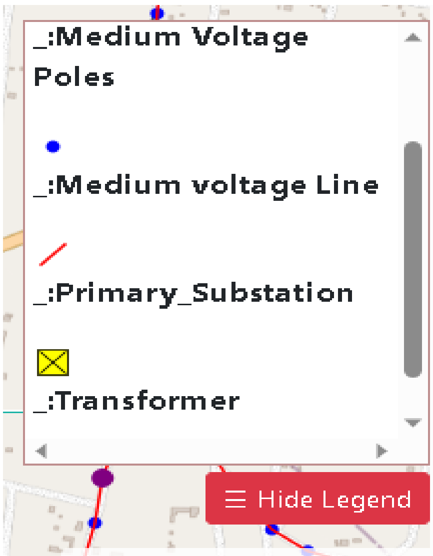

Figure 12: Legend display