A Client-Side Workbench for the Analysis of AC Interference on Pipelines

Nat Rungpeng
Thammawit Lerdthanavaranont



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International College
King Mongkut's Institute of Technology Ladkrabang
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Authors

Mr. Nat Rungpeng Student ID: 57090011

Mr. Thammawit Lerdthanavaranont Student ID: 57090039

Approved for submission

.....

(Dipl.Ing Michael Juelich)

Advisor

Date (11 / 06 / 2018)

.....

(Dr. Natthapong Jungteerapanich)

Co-Advisor

Date (18 / 6 / 2018)

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Abstract

A pipeline that carries liquids and gases for hundreds of kilometers is prone to corrosion. Pipelines which are typically made out of steal which are good conductors for electricity. High-voltage AC power line can induce electrical currents on nearby pipelines, which can damage the pipeline's corrosion protection and harm the personnel working near the pipeline.

The intention of this project is to be a first step toward a web application that can be used as a workbench to support the analysis of the interference effects of high voltage AC from power lines on nearby pipelines and assist the user in designing a suitable solution to protect the pipelines. This project is a web-based software system which consists of two parts, the client-side and the server-side. We work on the client-side part of the project. The workbench will be used to support both installed pipelines and in designing a solution for a safe installation of pipelines. Our workbench is web-based, so it can be conveniently used and be able to display selected pipeline interference graphs calculated according to the guideline provided by Schiedsstelle für Beeinflussungsfragen (SfB) in Germany.

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Chapter 1

Introduction

In every country, the use of energy is a necessity. Pipelines are used to transport oil and gases from the sources and distribute through the habitable area. In doing so, we must protect the pipeline with a corrosion protection system to protect it from corrosion. Nonetheless, it is still vulnerable to the effect from by high-voltage AC power lines that are nearby. The effect of high-voltage AC power lines causes damages to the pipeline's corrosion protection due to electrical induction on the pipeline.

Because of this reason, we have come up with the idea of developing a web-based application which acts as a workbench to help prevent such problem by showing the interference graph on selected pipelines. We have developed the client-side part of the project which works with the server-side part. The workbench shows the additional protection needed that is to be added to the particular area effected and can also be used to design the layout of pipelines effectively. The web-based workbench that we have developed can assist energy companies in Thailand, including PTT, which is the largest energy company in the country, in analyzing and designing a pipeline network.

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1.1 Problem Description

Steel pipelines that are commonly used to transport petroleum products, such as oil or natural gas, are prone to corrosion. Two popular and effective solutions to this corrosion problem are

1. Protective coatings and linings
2. Cathodic protection (CP)

Coatings and linings, both internal and external, are a basic method of defending the pipeline against the corrosion. The internal lining provide protection against chemical effects from gasoline, crude oil, and natural gases. The external coating protects the pipeline against corrosion from surrounding environment. Figure 1-1 shows an example of protective coating layers.

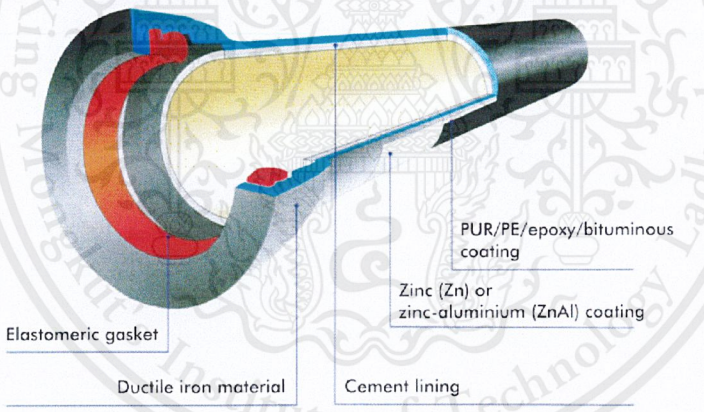


Figure 1-1: Pipeline Coatings and Linings [25]

Cathodic protection system (CP) is a technique used to control and decrease the corrosion rate of the pipe's metal surface by making it the cathode of an electrochemical cell. It does this by injecting DC current into the pipeline [4].

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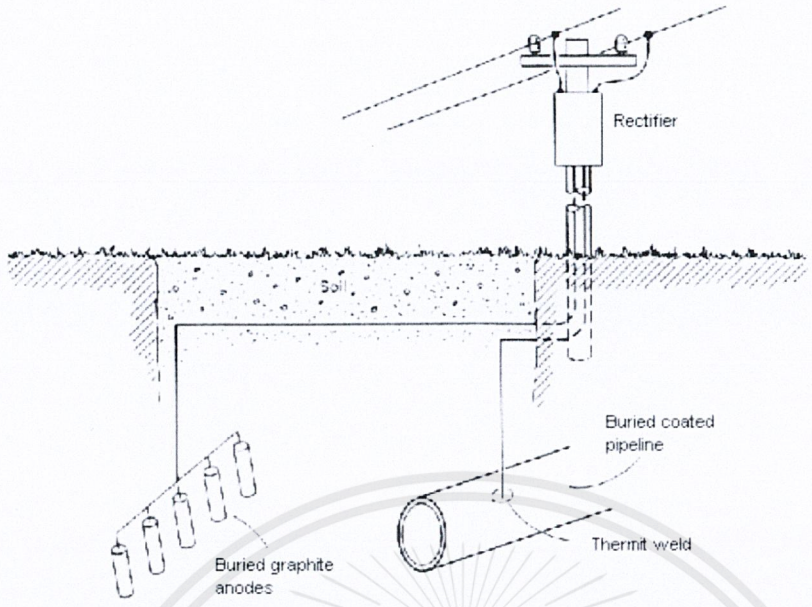


Figure 1-2: Cathodic Protection System [7]

When a steel pipeline runs close to a high-voltage AC power line, the AC current on the power line can induce an AC current on the pipeline [20]. If the induced AC current on the pipeline gets above a certain level, it can cause the following problems:

1. The induced current on the pipeline can pose safety hazard to the person working in contact with or near the pipeline.
2. The induced current can damage the protective coating and lining of the pipeline.
3. The induced current can damage the cathodic protection system, for example, the DC power source, that is equipped on the pipeline.
4. The induced current can damage other equipments installed next to the pipeline.

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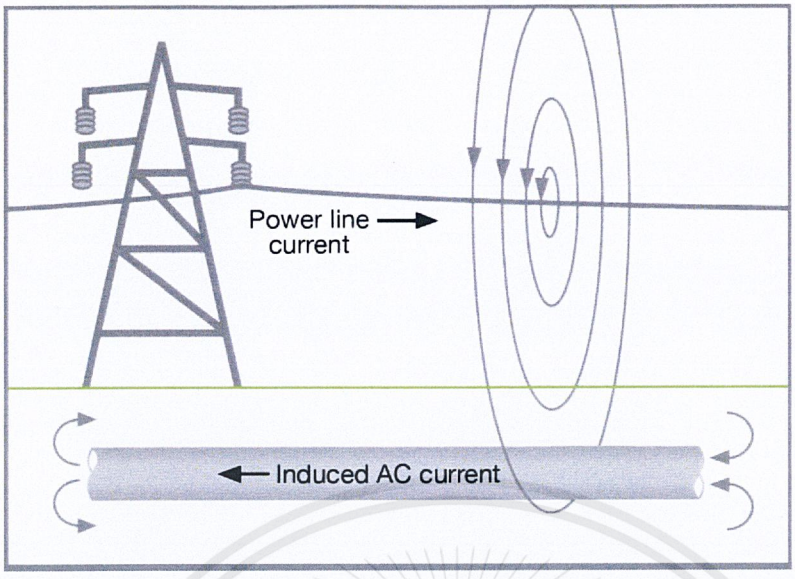


Figure 1-3: Induced Current in Pipeline [21]

To prevent these problems, additional protection devices can be installed on the pipeline to reduce the detrimental effect of the interference from the nearby power line. Since a pipeline network is vast and typically only some parts of the network are potentially affected by the AC interference effect, the company operating the pipeline network needs to determine which sections of the network require protection. This involves complex calculations using various information on the pipeline network, the power-line network, and the surrounding environment. For a large pipeline network, this is time-consuming and prone to errors.

1.2 Objectives

To build a web-based workbench that facilitates the analysis of electrical interference from a power line network on a pipeline network for any energy company. The web application to be developed has five main objectives as listed below:

1. The web application shows an interactive map where the user can zoom, pan, draw lines, etc.

2. The web application can draw electrical interference graphs on a selected pipeline

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for the user to analyze.

3. The web application can save the work in progress and also import various databases of pipelines and power lines.

4. The web application can show properties of pipelines, which are editable by authorized users.

5. The formulas and methods used for the calculation should be based on the German technical rule worksheet DVGP GW 22 (Arbeitsblatt) [8]. Appropriate assumptions to simplify the calculation can be made.

1.3 Scope of Work

We restrict the scope of our work to the following:

1. The prototype web-based workbench should demonstrate its usefulness in the analysis of electrical interferences from a power line network on a pipeline network.

2. The web-based workbench data will be provided by the energy company only, not by self-collection.

3. In the calculation process, equal altitude for overhead power lines are assumed.

4. The website should support further development in the future.

5. Due to the limitation of electrical engineering background knowledge, we can only follow the implementation in TE-7 SfB 2014 document.

1.4 Related Works

In this section we look at some existing software application that are similar on related to our work. There are several software applications and services in the market that support the analysis of electrical interference on pipelines. However, they are commercial

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solutions that are expensive or not open to the public. The first example can be used to analyze AC interference on many installation utilities such as pipeline and railroad. The second example utilize the geographic information system (GIS) similarly to what we do to help determining important pipeline properties before installation.

1.4.1 Right-of-Way

Right-of-Way, an automated AC interference analysis software application created by SES (Safe Engineering Services and Technology ltd.) for supporting the analysis of the electromagnetic interference between electric power lines and adjacent installations (by inductive, capacitive and through-earth coupling) such as pipelines, railways, and communication lines whether buried or aboveground. The program also contain other software utilities such as circuit plotting, potential graph, and right-of-way mapping modules to help visualize and validate user input data.

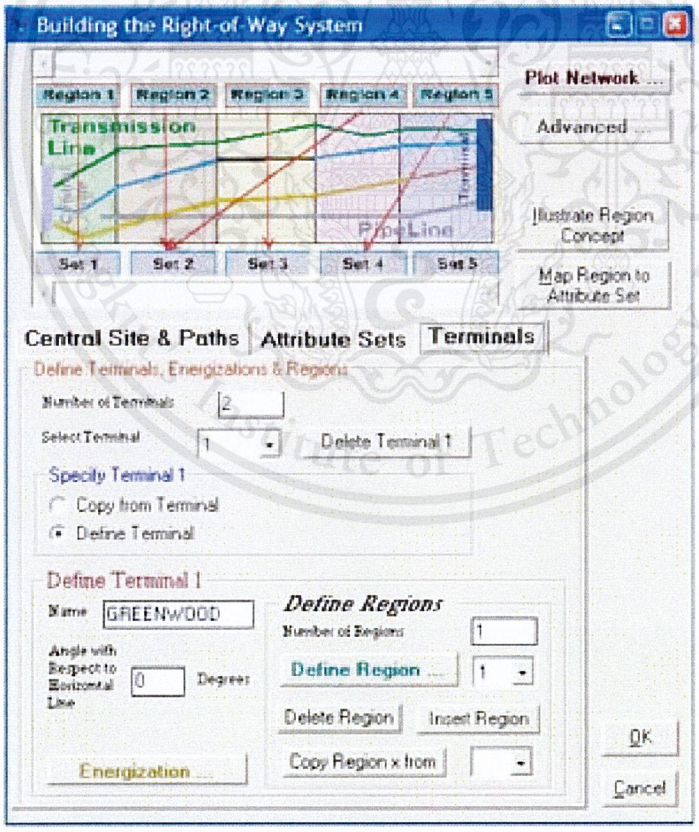


Figure 1-4: A screenshot of Right-of-Way [23]

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1.4.2 Esri Pipeline

Esri Pipeline Referencing, is one of the first a software application developed to pioneer problem of pipeline installations. It runs on ArcGIS, an online mapping tools developed by Esri themselves and is capable of analyzing and visualizing data onto a map for spotting spatial patterns in 3D and in real time. The Esri Pipeline Referencing help evaluate pipeline routes using Lidar and GIS and Strategically leveraging GIS and Geo-spatial Data. The program allows user to manage pipeline networks running high-consequence assessment analysis, manage rights-of-way, and use imagery to put pipes into their right environment by applying location analytics with user-friendly tools.

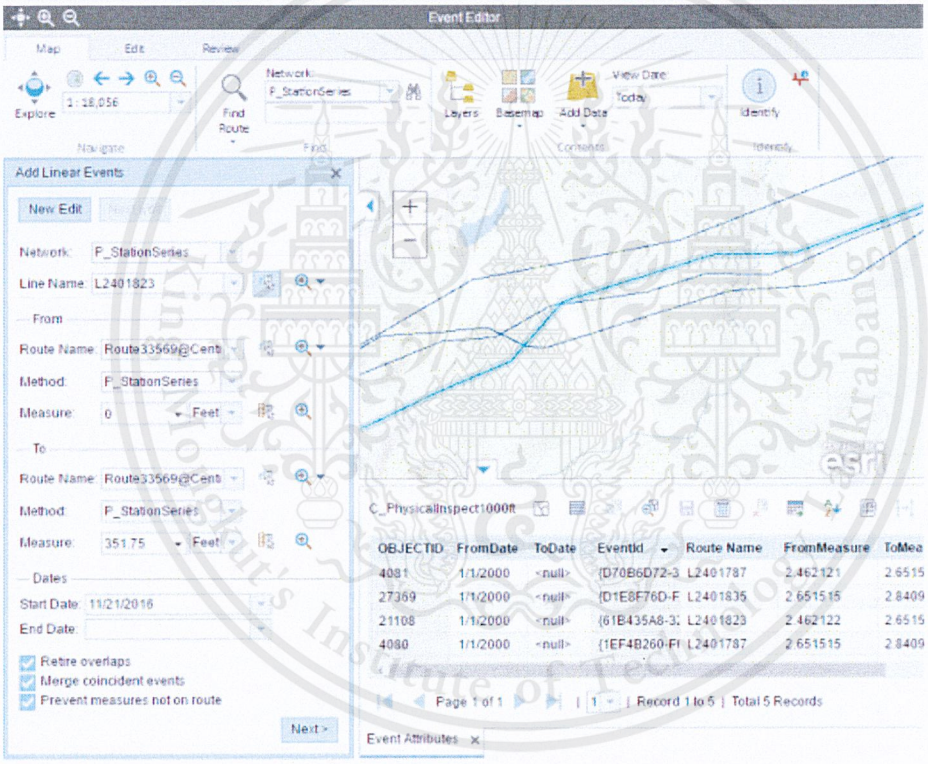


Figure 1-5: A screenshot of Esri Pipeline Referencing [2]

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Chapter 2

Background Knowledge

2.1 Geographic Coordinate System

Surface of the earth can be displayed by using latitude and longitude coordinate system. It illustrates the geographical positions on the surface of the earth.

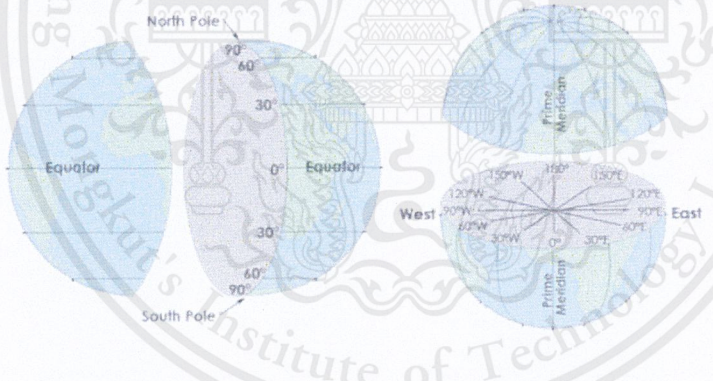


Figure 2-1: Latitude and longitude [19]

The demarcation of the latitude coordinate is done with circles on the globe parallel to the equator. These parallel circles, fittingly enough, are called parallels of latitude. In Figure 2-1, the left globe, shows several parallels of latitude. Latitude goes for 0° at the equator to +90° N at the North Pole or -90° S at the South Pole where the angle is also measured from the center of the earth as shown in the earth graphic to the right [27].

The demarcation of the longitude coordinate is done with lines going up and down

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are called the meridians. A figure to the right shows a few meridians. Longitude ranges from 0° to 180° East and 0° to 180° West. The longitude angle is measured from the center of the earth as shown in Figure 2-1 on the right globe [27].

2.2 Geographic Data

Geographic data is the information describing the location and attributes of things, including their shapes and representation [11]. The object can be either natural such as mountain range, sea, forest or man-made like buildings or roads.



Figure 2-2: Geographic data

In Figure 2-2, the geographic data is represented in the form of point, line, and polygon. Point is a geometric element defined by a pair of x,y coordinates [12]. Line is a shape defined by a connected series of unique x,y coordinate pairs. A line may be straight or curved [13]. Polygon is a closed shape defined by a connected sequence of x,y coordinate

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pairs, where the first and last coordinate pair are the same and all other pairs are unique [15]. These data can be used to analyze various domains through Geographic Information System (GIS).

2.3 Projection

Projection is a method by which the curved surface of the earth is portrayed on a flat surface. This generally requires a systematic mathematical transformation of the earth's graticule of lines of longitude and latitude onto a plane [16].

There are many types of map projection. But since the surface of the earth is distorted, each kind of projection is imperfect in someway and is suitable for some purposes. One of the most commonly used projection is the Mercator projection, which is a kind of cylindrical map projection. Figure 2-3 illustrates this method.

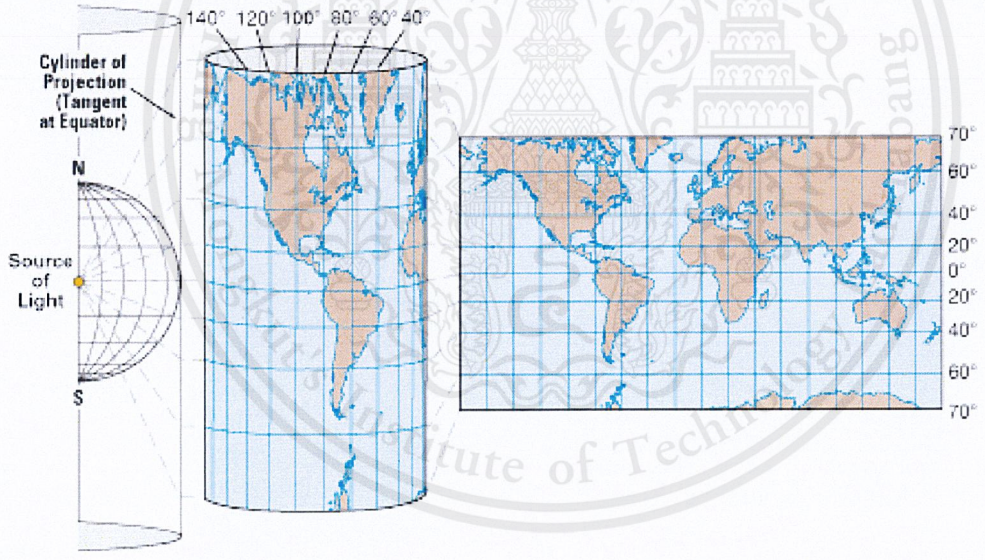


Figure 2-3: Cylindrical projection method [3]

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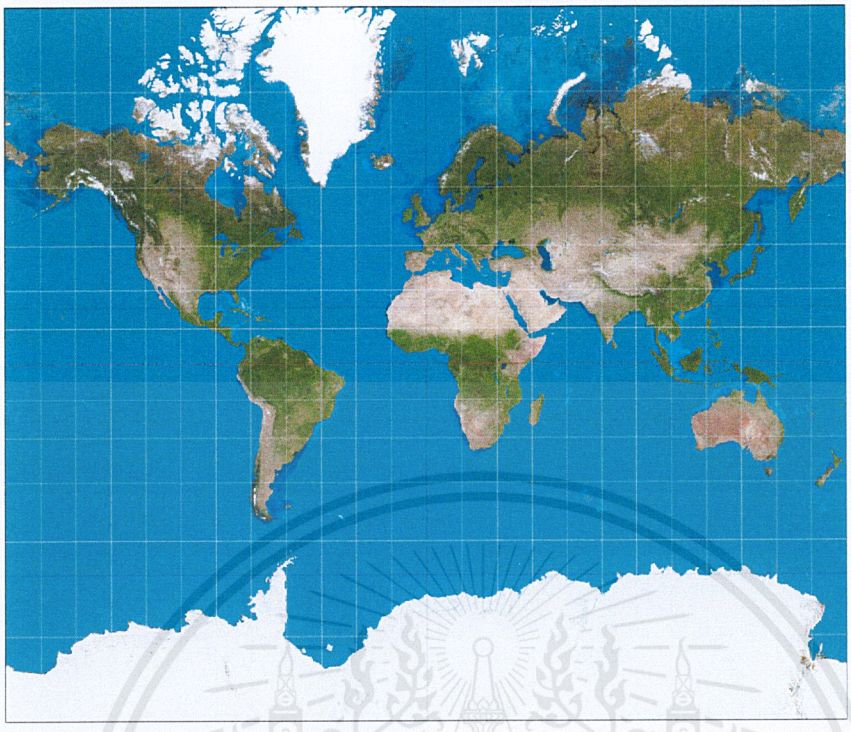


Figure 2-4: Cylindrical projection method [5]

2.4 Pipeline Segmentation

As pipeline and power lines are installed over a long distance, it is likely that these lines contain turning points. Splitting a pipeline into sections which are then used to calculate the electrical interference dependently allows the analysis to be more accurate and reliable since the formulas used for the calculation are designed to be used only when the pipeline and the power line are installed in parallel.

A pipeline can be divided into a number of smaller sections by creating the segments. If the distance between a pipeline and a nearby power line exceed one kilometer, the segmentation can be omitted and will not be included in the calculation as the electrical interference is very low and does not affect the pipeline protection system. Figure 2-5 is an example of pipeline segmentation.

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Figure 2-5: Pipeline Segmentation

2.5 Client-side Application Development

2.5.1 HTML5

HTML stands for Hyper Text Markup Language. HTML5 is the newest version of HTML. In the earlier version, HTML does not support different types of plug-in, so it is difficult for web developers to develop an efficient website which is cross-browser. Today, many major web browsers offer HTML5 support, so HTML5 is the best solution at the moment. We use HTML5 as a basis for our web application.

2.5.2 Vue.js

Most of the code of the web application is written in JavaScript. Vue.js is an extension of JavaScript. Vue.js complies JavaScript to generate HTML component with functions embedded inside. Vue.js makes the code more compact and also easier for web developers to manipulate and use data that is fetched from the back-end. Vue.js is based on the concept of MVVM or Model-View-ViewModel. Model-View-ViewModel or MVVM, is the software architectural pattern which separates the UI part from the business logic part

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and also the data part. It is designed to not depend on a specific user-interface platform. Normally, without Vue.js, auto-update of data has to be manually implemented.

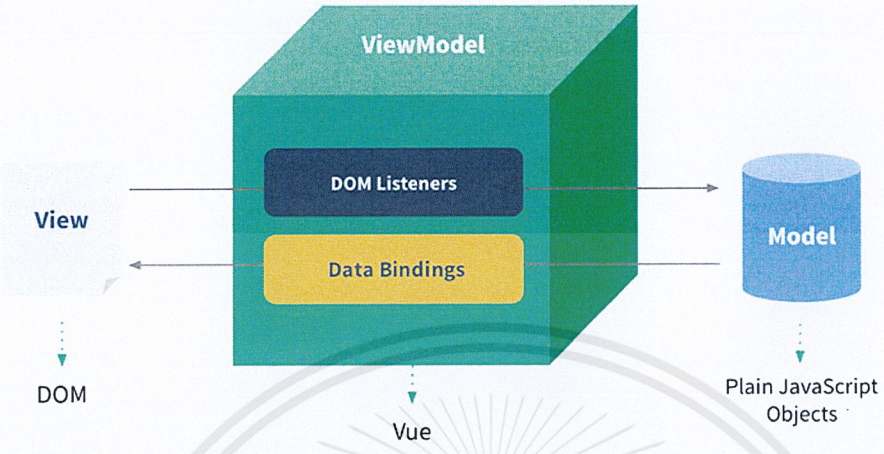


Figure 2-6: Model-View-ViewModel [10]

In Figure 2-6, Vue.js focuses on the ViewModel layer in MVVM. It does all the data binding for the communication between view and model.

2.5.3 AJAX

AJAX stands for Asynchronous JavaScript and XML. It is a combination of the browser built-in XMLHttpRequest, which is used to get request data from a web server, and JavaScript and HTML DOM [1]. In our web application, we use Axios, which is an extension of the AJAX. The reason why we use Axios is because it works best for a small to medium size web application. The reason why we chose Axios over a similar method, called Vue-resource is that Vue-resource is outdated since Vue 2.0 update and is no long maintain and improve.

2.5.4 JSON

JSON is short for JavaScript Object Notation. It is a syntax for storing and exchanging data. JSON consist of two structures. First, a collection of name/value pairs, it is in a form of *object*. Second, an ordered list of values [18]. The data exchange between the

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browser the and server can only be in textual form. JSON format is easy for human to understand and also easy for the server to parse and generate. It can be read and used as a data format by any widely-used programming language.

2.5.5 Leaflet

Leaflet is an open-source JavaScript library for interactive maps. It is used to display map tiles/layers, and to overlay data objects. It is designed for simplicity, performance and usability. It runs on many desktop and mobile platforms with variety of plug-ins. Leaflet is a lightweight map viewer which suits to our web application purpose.

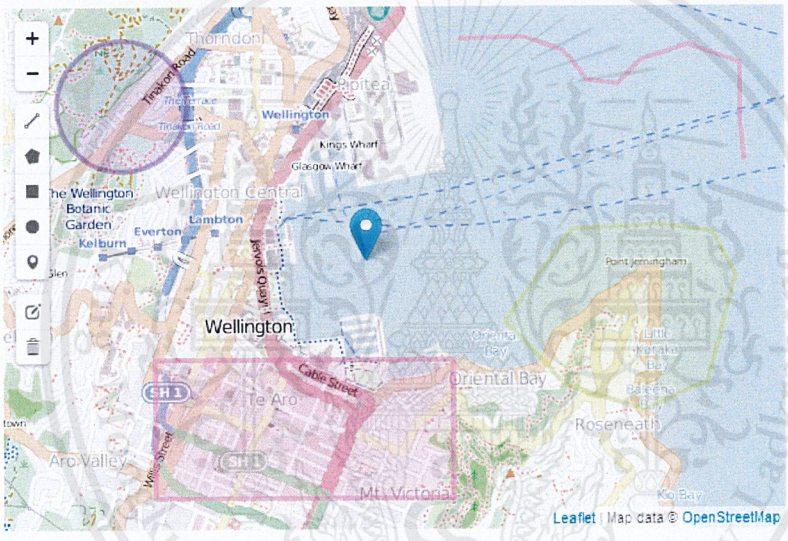


Figure 2-7: An Example of a map displayed using Leaflet [14]

In Figure 2-7, an example of a map displayed using Leaflet which uses OpenStreetMap (OSM), a free editable map data of the world. In our web application, we use OSM as a map layer with the pipelines and AC overhead power lines as overlay object. Leaflet can also load feature data from GeoJSON files format, which can be use to create and style objects with an interactive layer.

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Chapter 3

Requirements Analysis

3.1 System Requirements

3.1.1 Functional Requirements

1. The user can register for a new account to login to the system.
2. The system provides the login/logout function for the registered user.
3. The system provides different functionalities for each user privilege, as shown in the Use Case diagram in Figure 3-1.
4. The system can show the geographic data on the map.
5. The system provides GIS tools for the user, such as
   (a) Search
   (b) Select an object
   (c) Edit properties of an object
   (d) Create an object on the map with editable properties, such as the pipelines and the overhead power lines.
   (e) Create segmentation between pipeline and overhead power line.
   (f) Measure distance between objects.

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6. The system allows the user to load the saved data when starting and continuously saves any changes made by the user to the server-side.

7. The system can display a graph from the result of the interference analysis calculated by the server-side.

8. The system allows user type "Admin" to configure the database of the system directly.

3.1.2 Non-Functional Requirements

1. The system is to be developed using Vue.js framework.

2. The system is to be a single-page web application.

3. The system is to be responsive.

4. The system is to be compatible across different web browser devices including

   (a) Firefox v60.0.1

   (b) Safari v10.1.2

   (c) Google Chrome v66.0.3359.181

   (d) Microsoft Edge v42.17134.1.0

5. The system is to be reliable, displaying everything precisely and object position on the map will be geographically somewhat accurate.

6. The system will not use more than 50 MB of storage space and 1 GB of main memory.

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3.2 Use case Diagram

Figure 3-1 shows the use case diagram for the system.

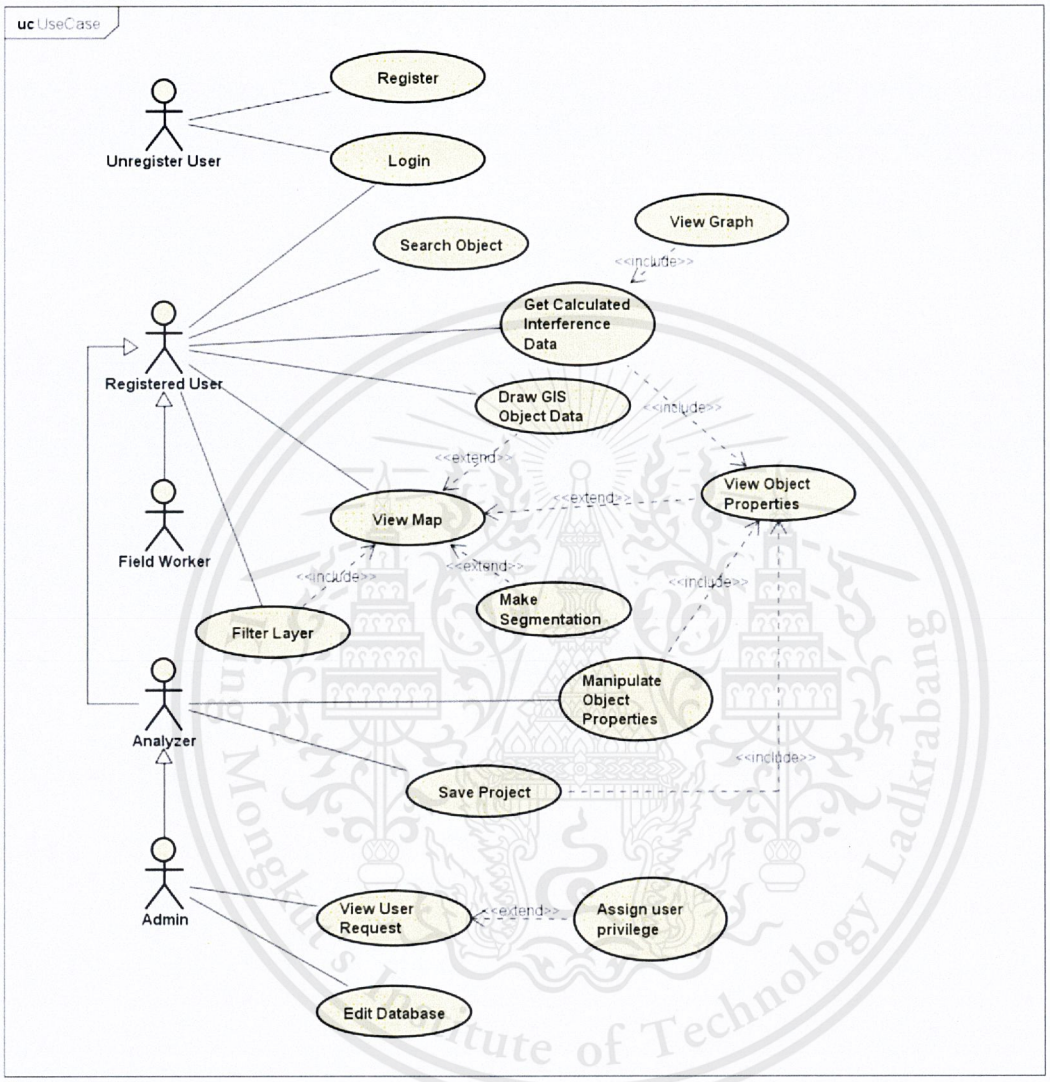


Figure 3-1: A use case diagram for the client-side application

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3.2.1 Use Case Descriptions

The following use case descriptions describe each use case in Figure 3-1 in detail.

Use Case:	Register
Actor(s):	Unregistered User
Description:	This use case provides a new user with registration form. When the user clicks on the register button, they are required to fill in their login credential.

Use Case:	Login
Actor(s):	Registered User
Description:	This use case allows the registered user to use the application. The user must login to the website by using their login credential.

Use Case:	View Map
Actor(s):	Registered User
Description:	This use case gives the user to visualize the map. The map will be displayed when the user successfully login to the system. The map will also be a container for geographic objects to be placed on.

Use Case:	Filter Layer
Actor(s):	Registered User
Description:	This use case provides the user to filter out which layer to be displayed on the map.

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Use Case:	Make Segmentation
Actor(s):	Registered User
Description:	This use case gives the registered user a function to create segmentation between pipelines and overhead power lines. By doing so the user can analyze the interference by Earth fault or Operation type. By making a segmentation, user will select a location to draw the segment lines. The program will automatically create segment lines between the closest pipeline and power line.

Use Case:	View Object Properties
Actor(s):	Registered User
Description:	This use case allows the user to view object properties. The user can view the object properties by clicking on the object itself. Some of the object properties cannot be changed.

Use Case:	Get Calculated Interference Data
Actor(s):	Registered User
Description:	This use case provides the user with a function to get the result of the calculated interference data from the server-side.

Use Case:	View Graph
Actor(s):	Registered User
Description:	This use case provides the user with a function to visualize and analyze the interference on segments of a pipeline. Once the data of the pipeline is acquired, the user can visualize the high influence area which is displayed on the graph.

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Use Case:	Draw GIS Object Data
Actor(s):	Analyzer
Description:	This use case allows the user with analyzer privilege to create object on the map. Each object created may either be pipelines, overhead power lines, or segment lines in our project.

Use Case:	Save Project
Actor(s):	Analyzer
Description:	This use case gives the user to automatically save their progress when some data is modified. The geographic data is saved to the server-side.

Use Case:	Manipulate Object Properties
Actor(s):	Analyzer
Description:	This use case provides user with analyzer privilege to modify geographic data on the map. Once the object has been selected, a properties window will appears for the analyzer to configure the value of each data field.

Use Case:	View User Request
Actor(s):	Administrator
Description:	This use case is only for Administrator role to look into which user sends a registration request to the server.

Use Case:	Assign User Privilege
Actor(s):	Administrator
Description:	This use case gives the Administrator to assign roles of the user such as field worker or analyzer.

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Chapter 4

Software Design

This chapter provides an overview of our system which has been designed according to our requirements. We explain the system architecture and its components and the services provide by the server-side that are used by our system.

4.1 System Architecture

Figure 4-1 shows the system architecture.

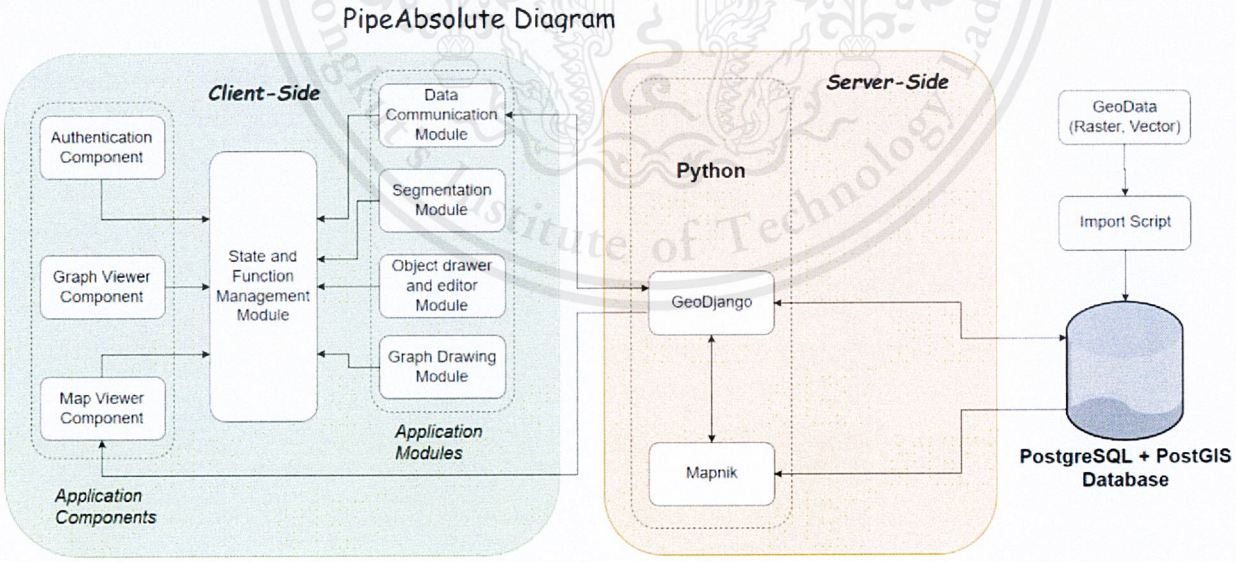


Figure 4-1: System architecture diagram for the client-side and server-side system

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4.1.1 Authentication Component

To use the program, all the user must first register their identity through the website by submitting the login credential. Figure 4-2 shows the various modules in the component. The submit request for registration must be admitted by the administrator. The login credential will be sent to the *State and Function Management Module* wrapping *vuex* functionality where the information will be sent through *Data Communication Module* by *axios* towards the database for authentication. If the authentication is successful, the back-end will reply back with a session token which allows the user to make a modification to the system data. The token is periodically sent by the client-side to the server-side, so that the server-side can check whether the user is still using the application.

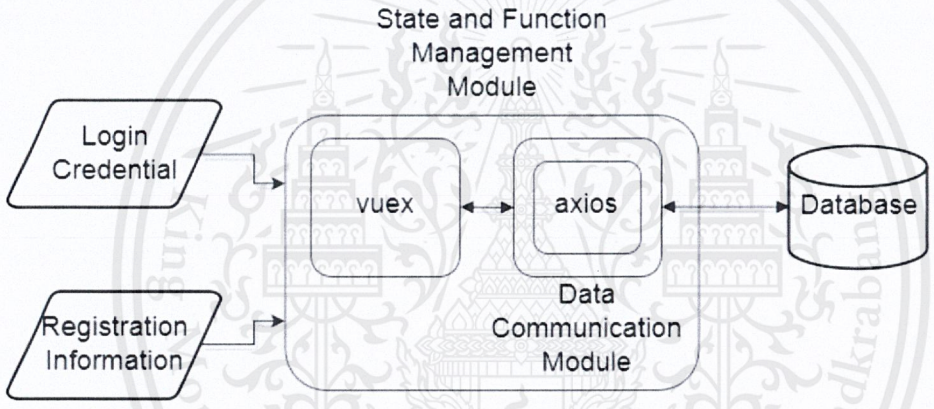


Figure 4-2: Authentication component

4.1.2 Map Viewer Component

The map viewer is resposible for displaying a map. Figure 4-3 shows the interaction of various module in the component. The system uses *leaflet* to render tiles map from the server-side which allows the GIS object or the pipeline and power line to be created on. *Leaflet.draw* helps the user to create a GIS object by providing them tools to draw a pipeline and a power line as well as create segmentation. These GIS objects will become visible on the map when created. The pipeline and power line together can be divided into segments so the interference can be analyzed.

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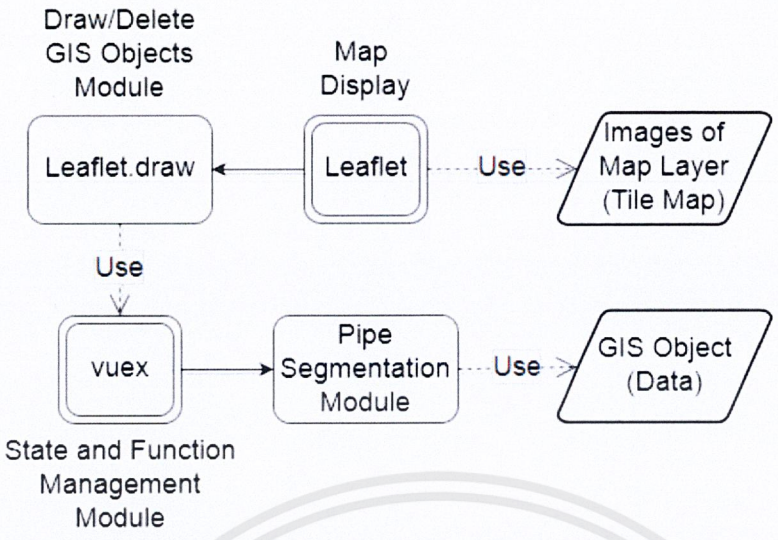


Figure 4-3: Map viewer component

4.1.3 Graph Viewer Component

The electrical interference of high-voltage overhead power lines that affect on pipelines can be visualized in the form of a graph and a table. The result of the calculation, received from the server-side, displayed as a graph which is rendered by *Chart.js* module. *Chart.js* module is wrapped by *Vue-chart-js* module so that it can be easily integrated into *Vue.js*. The result of the calculated electrical interference is also displayed in the form of a table to help the user access to the individual points on the graph. This is done by using *Vue-good-table* module which is a wrapper for *Grid* module in *Vue.js*.

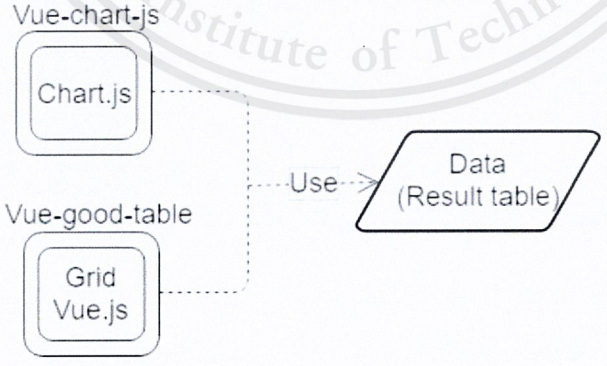


Figure 4-4: Graph viewer component

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4.2 Services

This project focuses on the client-side of the web application. For this reason, we have to communicate with the server-side through services so that both the client-side and the server-side agree on the same services for communication. There are seven services which are shown below.

4.2.1 Authentication and Session Service

The client-side will send the user information to the server-side when the user logins to the system. The acknowledgement of the user session is done by sending a login token to the server-side.

Request Method: POST/GET

Input	**Output**
User login information	User credential, session token
Data type: Object	**Data type:** Boolean

4.2.2 Tile Map Service

The web application requires Tile Map Service from the server-side to display the map. The service requires three inputs: *zoom level*, *x coordinate*, and *y coordinate*. *Zoom level* is the current level of zooming of the map. It will be sent along with the x and y coordinates to the server-side. The output will be in the form of the URL of the image file of the map tiles, which will be rendered by the *Leaflet* library.

Request Method: GET

Input	**Output**
Zoom level, x coordinate, y coordinate	Image file
Data type: Integer, Float, Float	**Data type:** PNG

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4.2.3 Calculation Service

After the user has selected the sections of a pipeline and a power line, the data of the selected sections will be formed into JSON format, as an input for this service. The output will be a result table with the calculated electrical interference data.

Request Method: GET

Input	**Output**
Table with object properties	Result table
Data type: Object	**Data type:** Object

4.2.4 Search Service

The user can enter a string to be searched such as the name of a pipeline, the name of a power line or the name of some other geographic object. The program will return all the possible results.

Request Method: GET

Input	**Output**
Search string	List of Geographic objects
Data type: String	**Data type:** Geographic object

4.2.5 Get Geographic Object Service

In this service, the server will return the saved geographic objects.

Request Method: GET

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4.3 Graphical User Interface Design

A good web application should have a nice design as well as well-organized functions. Such design makes the user feel convenient to use while being able to use all the features of the application. Our client-side web application is not an exception. The interface of the web application consists of 4 main components, which can be illustrated in Figure 4-5.

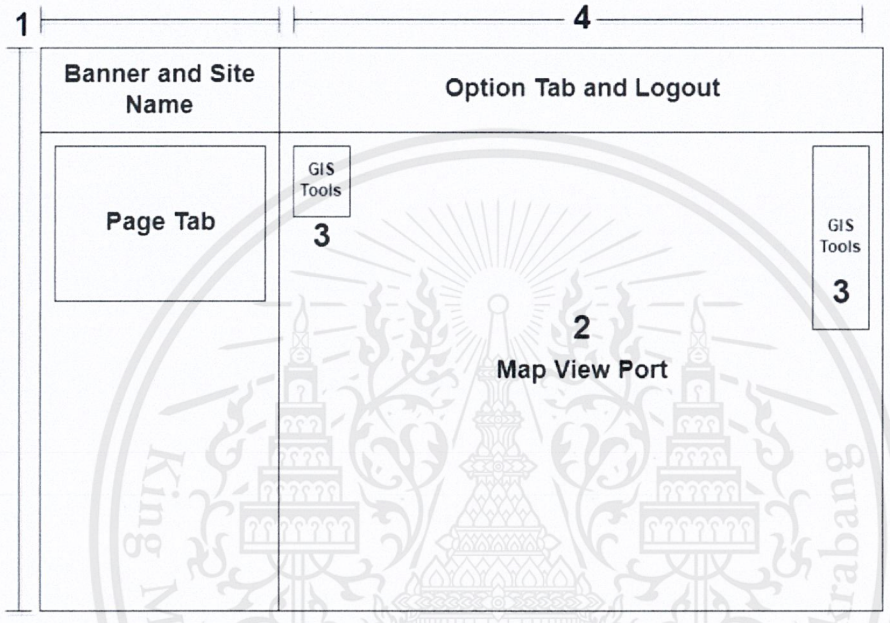


Figure 4-5: The design of web application structure

We can elaborate Figure 4-5 in depth as follows:

- The side bar to the left of the page (denoted as 1) is one of the components that the user will use frequently as it is programmed to display the page navigation between the map and the graph page. The block at the top-left corner of the page is where the name of our application logo will be placed.
- The map is located in middle of the page (denoted as 2). The map view port is one of the most important components in the program since the user will interact with the map most of the time. The interactions include move the view of the map, zoom in/out, and select an object on the map such as a pipeline and an overhead power line. The map view port also contains the GIS tool bar (denoted as 3), which

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provides the user with tools to create, edit, or delete objects. The user can create a pipeline, a power line, and a segment line. The property panel of each object on the map will be shown when the object is clicked by the user. The property panel covers the middle of the map view port. The object properties can only be edited by the user of types analyzer and administrator. Edited properties will be automatically updated to the server after the editing finishes.

- The top navigation bar contains buttons for performing some other web application actions (denoted as 4). These actions are "Save all properties" to the server, "Load GIS data" from the server, and "Logout the user session".

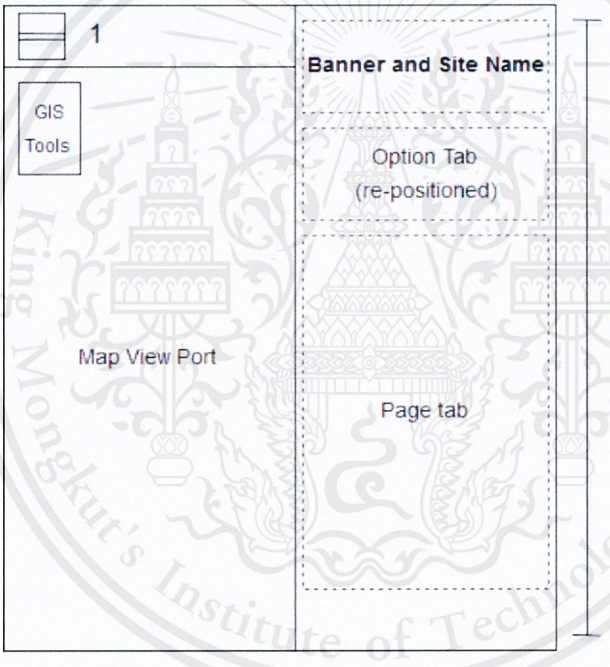


Figure 4-6: The design of the web application under a smaller view

Figure 4-6 shows what our application looks like on a smaller screen. The menu can be accessed by clicking the button with the hamburger icon located in top left corner (denoted as 1).

- By clicking on the hamburger button (denoted as 1), a side panel (denoted as 2) which contains components from the sidebar and the option tab in the normal view

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of the application (from figure 4-5 denoted as 1 and 4 respectively) will push the map view port slightly off to the left of the screen. This helps organize the user interface when the program is used on a smaller screen.

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Chapter 5

Software Development

In this chapter, we will discuss the system development in details, including how we can display the map on our web page with layers and how we can manage geolocations. In addition, we also include methods we use for data manipulation such as 'GET', 'POST', and 'DELETE'. Finally we will discuss how some of the major client-side modules work.

5.1 Map

Leaflet requires a container to render a map, for instance, a div element on the web page that contains the map. It automatically locates a div with the id "map" to render the map. All the map initialization can be configured from the constructor properties or defined by *L.Control* method outside the constructor.

The partial code below shows how we can display the map on the web browser.

```
1 <template>
2   <div id="map" class="map"></div>
3 </template>
```


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The code below shows how we can display a map with different layers.

```
1  this.map = L.map("map", {
2          zoomControl: false,
3          layers: [this.tilelayer, this.geoSegment, this.geoLine, this.geoPower]
4        }).setView([13.736717, 100.523186], 12);
```

L.map has no method to modify the map attributes. The map functionalities are controlled by *L.Control*. There are two types of control, a *zoomControl* and applying layers group. *zoomControl* is used for zoom in/out of the map (at *line* #2). Applying layers group is used to toggle layers (at *line* #3). At *line* #4, *map.setView* specifies the center point of the view through a longitude and latitude coordinate with a zoom level when the map is first rendered.

5.1.1 Tile Layers

Tile layers (sometimes referred to as Tile Overlays) allow the map to superimpose images on top of map tiles. This is an effective way to add data such as points of interest or object information.

Tile layers are useful when we wish to add extensive imageries, typically covering a large geographical area, to the map. By contrast, ground overlays are useful when we wish to fix a single image at one point on the map.

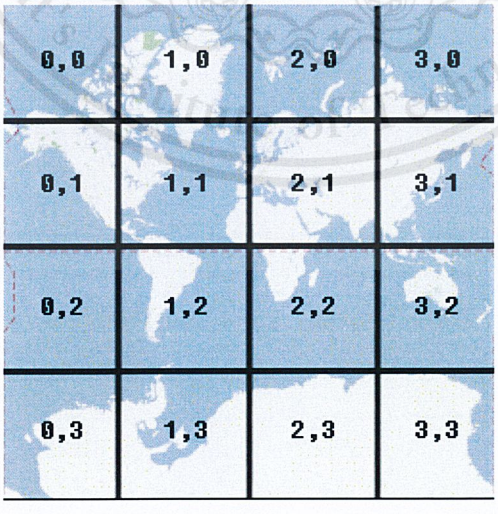


Figure 5-1: Tile map layer coordinate [26]

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In Figure 5-1, each map tile is 256x256 pixels. At zoom level 0, the entire world is rendered in a single tile. Each zoom level increases the magnification by a factor of two. So, at zoom level 1 the map will be rendered as a 2x2 grid of tiles, or a 4x4 grid at zoom level 2, a 8x8 grid at zoom level 3, and so on.

```
1  this.tilelayer = L.tileLayer(
2      "https://maps.wikimedia.org/osm-intl/{z}/{x}/{y}.png",
3      {
4          maxZoom: 18,
5          attribution:
6          '&copy; <a href="http://www.openstreetmap.org/copyright">OpenStreetMap</a>'
7      }
8  );
```

The code above shows how we register our Leaflet tile layer images to a specific tile map service provider, giving them credits if necessary by *attribution* (at *line #5*), before adding the tile layer to our map.

5.1.2 Layers

A layer represents the GIS data which contains groups of points, lines, or areas (polygon), called features, representing a particular class or type of real-world entities such as pipelines or overhead power lines. A layer contains both the visual representation of each feature, such as a location, and a link from the feature to its database attributes. Maps in a geographic information system are made by combining multiple layers.

```
1  L.Draw.PolylineA = L.Draw.Polyline.extend({
2      initialize: function(map, options) {
3              this.type = "Pipeline";
4              L.Draw.Feature.prototype.initialize.call(this, this.map, options);
5      },
6      addHooks: function() {
7              L.Draw.Polyline.prototype.addHooks.call(this);
8
9            if (this._map) {
10               this._tooltip.updateContent({
11                   text: "Click map to place Pipeline."
12               });
13           }
14     }
15 });
```


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Referring to the partial code above, this is an example of creating a layer in Leaflet that can be used in multiple scenarios. *Line #1* initializes variables to become a layer object, in this case a polyline, while *line #2* to *line #5* configure where it is going to be used and what properties it will show when placed on the map area. *Line #6* to *line #15* define how it will behave when placed on the map. This can occur when it is being created or during user interaction. An example of this can be seen on *line #9* to *line #12* where after the user clicks on the draw button, the map will notify the user to "Click map to place Pipeline".

5.1.3 Geolocation

Leaflet provides developers with a geopositioning plug-in called *leaflet.locatecontrol*, that listens to changes in the geographic position of the device which the application is running on.

```
1  import LeafletLocateControl from 'leaflet.locatecontrol'
2
3  var lc = L.control.locate({
4    strings: {
5      position: 'topright',
6      title: "Locate my position",
7      flyTo: true,
8      locateOptions: {
9        enableHighAccuracy: true
10     },
11 }}).addTo(this.map);
```

The *L.control.locate* provides fully customizable options available to any developer. Most options are derived from *L.control*, which is a Leaflet controller for layers and layer groups. On *line #9* under *locateOptions*, the *enableHighAccuracy* option allows the Leaflet locater to use the GPS signal instead of searching for an IP address. Without the GPS signal, actual location may not be accurate. This is because, in some country, the Internet service provider (ISP) does not provide their user with a unique public IP address.

In Figure 5-2, when the user clicks on the 'Get current location' button, the program will automatically pans the view of the map and pins a circle marker to where the user's device location is.

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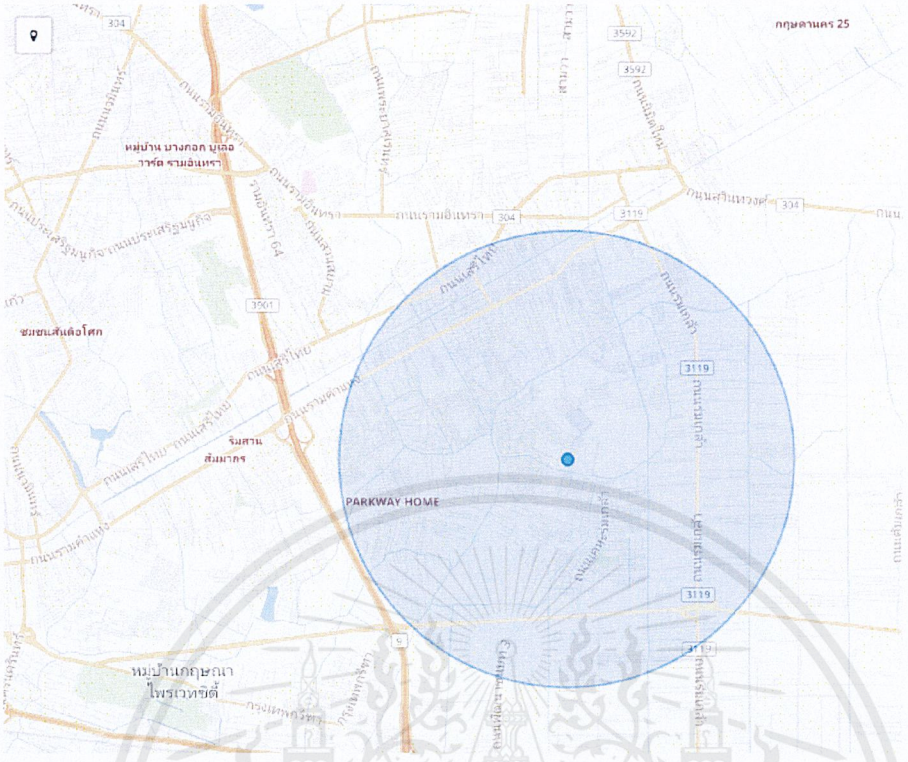


Figure 5-2: Example of showing the current location without using the GPS signal

5.2 HTTP request

The Hypertext Transfer Protocol (HTTP) is designed to enable communications between clients and servers. HTTP works as a request-response protocol between a client and a server. As in this project, the web browser is the client, and an application on a computer that runs scripts which produce a response customized for the client request to the website will be the server.

Two commonly used methods for a request-response between the client and the server are: GET and POST.

5.2.1 GET, POST, and DELETE

In our project, there are two common methods and one additional method that we use frequently when we implement a function to interact with the server; these are GET, POST,

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and DELETE.

- **GET:** HTTP GET request method is used to make a request for obtaining data from the server without sending any attachment. For example, the following code shows GET method 'fetchGeoData()' function from our program.

```
1   fetchGeoData ({commit}) {
2         console.log('Fetching Data')
3         axios.http.get(URL, { headers: { Authorization: AuthStr }})
4         .then(res => {
5           console.log(res)
6           commit('storeGeoData', res)
7         }, res => {
8           console.log(res.error)
9         })
10      }
```

Line #1 shows the method name with a parameter. The parameter *commit* here is used to acknowledge by the library Vuex (a library for stage management) that there will be changes made to the state of Vuex. *Line #3* initiates the HTTP GET method to a specific URL with the included user authorization credential when the user logins to the system. *Line #4* to *line #9* represent the returned response which indicates whether the request is a success or a failure. Here, if the response is a success then the application will run the code from *line #4 to line #6*. The *commit* function is responsible for storing the data obtained from the database.

- **POST:** HTTP POST request method is used to submit an entity to the specified location, often causing a change in the state of the server. This includes updating the GeoData properties, submitting authentication, or other related processes that required data to be attached. The following code shows POST method function from our program.

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```
login ({commit}, authData) {
      axios.post('/verifyPassword?key=AIzaSyAGdJ1fsnwFyemIhEPrrzrDTrGv-Cnsc2A', {
        username: authData.username
        password: authData.password,
        returnSecureToken: true
      })
        .then(res => {
          console.log(res)
          commit('authUser', {
            token: res.data.idToken,
            userId: res.data.localId
          })
          router.push({name: 'Maps'})
        })
        .catch(error => {
          console.log(error)
        })
    }
```

- **DELETE:** HTTP DELETE request method deletes the specified resource on the database as shown in the following code.

```
deleteGeoData ({commit}) {
  axios.delete(URL, { data: {requestData} })
  .then(res => {
    console.log(response.data));
    })
    .catch(error => {
    console.log(error);
    });
  }
```

5.3 JSON data

The following code shows an example of GeoJSON data. This is a fraction of the pipeline data to be sent to the server.

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```
1  {
2      "type": "FeatureCollection",
3      "features":
4          {
5              "name": "pipeline 1",
6              "category": "pipeline",
7              "slug": "pipeline-1",
8              "geometry":
9              {
10                 "type": "LineString",
11                 "coordinates":
12                     [
13                       [100.98016552632,14.57987687769],
14                       [101.01150921631,14.58343612513],
15                       [101.01455802095,14.58465608457]
16                     ]
17             },
18             "properties":
19             {
20                  "thickness": "thickness.val()",
21                  "voltage": "pipevoltage.val()"
22             }
23         }
24 }
```

Line#8 to *line#17* states that this JSON data is in the GeoJSON format where the coordinates of the object being specified is embraced by the square brackets.

5.4 Sectioning

Sectioning pipelines and high-voltage overhead power lines is an essential process for calculating the influenced voltage within the pipeline. Small sections are divided manually by the user because it requires the user with experiences to know where to draw a line section. The data for each sections will be pushed into the input table and sent to the server for the calculation.

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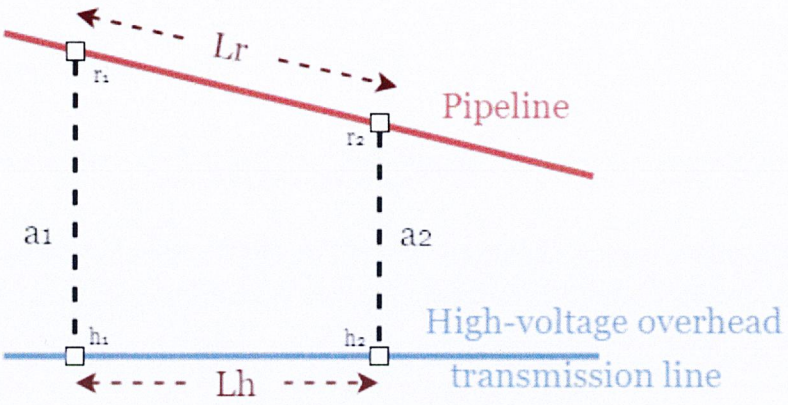


Figure 5-3: Sectioning parameters

In Figure 5-3, when the user clicks on *r1*, point *h1* will be automatically generated. Similarly for *r2* and *h2*. Each section consists of four points (*r1*, *r2*, *h1*, *h2*) which are the identifying parameters of a section. These parameters are used for the calculation to be performed at the server.

```
1  {
2      "json_data":
3         {
4           "so0-so1":
5             {
6               "section_pipeline_id": 13,
7               "section_powerline_id": 14
8             },
9            "so1-so2":
10            {
11              "section_pipeline_id": 15,
12              "section_powerline_id": 16
13            }
14        }
15 }
```

The above JSON object is an example of the input object to be sent to the server for the calculation. *Line#6* and *Line#7* represent the id of the pipeline segment and the id of the power line segment which are necessary for the calculation. At *Line#4*, *"so0-so1"* is the name of the section.

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```
{
 "so0-so1":
   {
     "LH": 0.5478044635468792,
     "LR": 0.574612309050653,
     "Sum_LR": 0.574612309050653,
     "a": 315.06035918217896,
     "a1": 412.94012104831216,
     "a2": 240.38117118774778,
     "column5": 5.2,
     "column9": 4.959751546610935,
     "column10": 2.8499342885156564,
     "column11": 2.8499342885156564
   },
  "so1-so2":
   {
     "LH": 0.5059451280983626,
     "LR": 0.5283339061387512,
     "Sum_LR": 1.1029462151894043,
     "a": 142.68400730492596,
     "a1": 240.38117118774778,
     "a2": 84.69351338957884,
     "column5": 10,
     "column9": 9.557725125343463,
     "column10": 5.0496702492731975,
     "column11": 7.8996045377888535
   }
}
```


The above JSON object is a sample of the output that we receive from the server-side. *Line#2* is the name of the section and *line#4* to *line#13* contains the data that will be displayed on the graph and table.

5.5 Graph

One of the main objectives in our project is to visualize the electrical interference data in the form of a graph and a table. The input table will be obtained after the user has finished the pipeline segmentation process. The input table will be sent to the server to be filled with the results from the calculation. The server will return the result table to the web application so that it can be displayed as a graph and a table.

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```
// LineChart.js
import { Line, mixins } from 'vue-chartjs'
const { reactiveProp } = mixins

var graph_title = "Induced longitudinal field stregth & longitudinal stress";
export default {
  extends: Line,
  mixins: [reactiveProp],
  props: ['options'],
  mounted () {
    var graph_option = {
      title: {
        display: true,
        text: graph_title
      },
      bezierCurve: true,
      responsive: true,
      maintainAspectRatio: false,
      scales: {
        xAxes: [{
            gridLines: {
              zeroLineColor: 'rgba(0,0,0,1)'
            },
            scaleLabel: {
              display: true,
              labelString: 'Km',
              color: "black"
            }
          }

        ],
        yAxes: [{
            id: 'y1',
            gridLines: {
              zeroLineColor: 'rgba(0,0,0,1)'
            },
            scaleLabel: {
              display: true,
              labelString: 'V/(km kA)'
            },
            ticks: {
              beginAtZero:true
            }
          },
          {
            id: 'y2',
            gridLines: {
              zeroLineColor: 'rgba(0,0,0,1)'
            },
            scaleLabel: {
              display: true,
              labelString: 'V/kA'
            },
```


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```
54              ticks: {
55                beginAtZero:true
56              }
57            }
58          ]
59        }
60      }
61      this.renderChart(this.chartData, graph_option)
62    }
63  }
```

The above code is an example of the setting for displaying the graph. There are two y-axes, which are labeled as *V/(km kA)* and *V/kA*, and the x-axis is labeled as *Km*. In our project, we use *vue-chartjs* library as a wrapper for *Chart.js* to display the data with an interactive graph. The *LineChart.js* file will render the graph according to the configuration. The file *LineChart.js* will act as the configuration file for the graph. The data that will be displayed on the graph will come from the file that uses *LineChart.js*.

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Chapter 6

Project Results

This chapter will walkthrough the key functionalities of the application with screenshots, explaining the user interface, as well as briefly discussing the limitations.

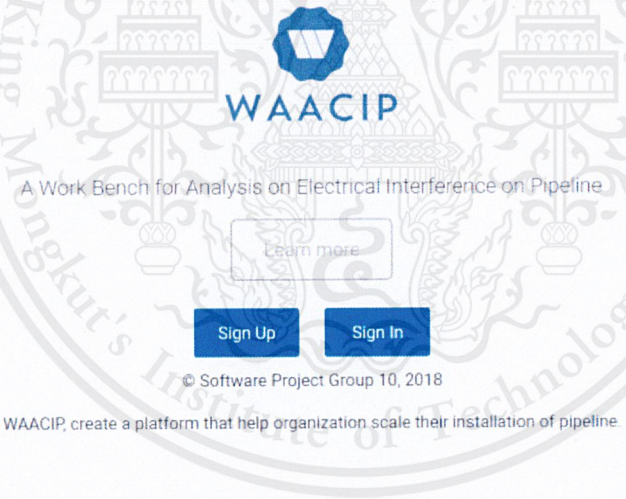


Figure 6-1: Landing page after the user enters the site

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6.1 Our GIS Web Application

We are responsible for the development of the client-side web application. We aim to deliver the application that is easy to use and has a user friendly UI. We provide essential sets of GIS tools and other related tools for the user to use.

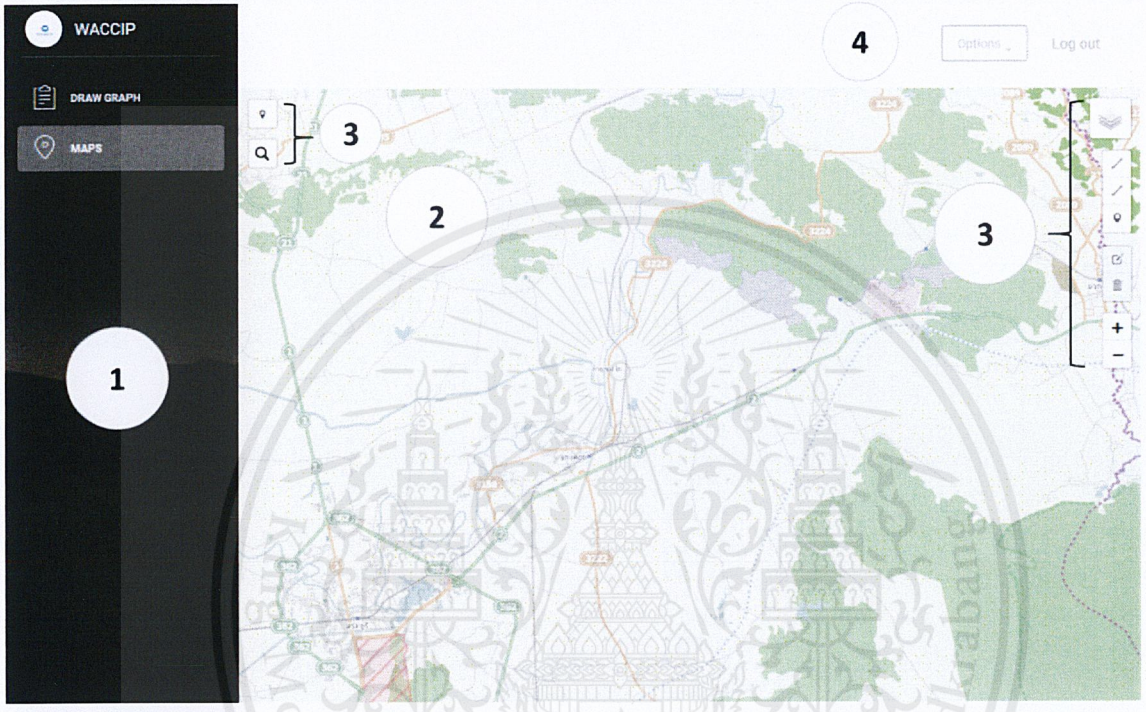


Figure 6-2: Map page where the user will interact with the map

Figure 6-2 shows the interface of the web application after the user has already passed the authentication. As mentioned in Chapter 4 (section 4.3 Graphical User Interface Design), the sidebar (1) is on the left hand side of the screen. Most of the space in the middle is reserved as a viewer for the map (2). The GIS tool bar (3) is located on the right of the screen and next to the right of the sidebar. Lastly, the top option bar is located at (4).

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Figure 6-3: Map page under the mobile view

As the user might use this application on the mobile platform, we develop a responsive website as shown in Figure 6-3 that can be used on the go by the user, for instance, the field worker who may want to recheck the data before working on the field. The functionalities of the application remain the same. The application does not support a mobile platform that has the screen resolution lesser than 720x1280. We recommend 1080x1920 for the best view.

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6.2 Authentication

In the authentication process, the user has to prove their identity to the server. This allows the server to grant the privilege to the user in case they are an analyzer who desires to manipulate the data or a field worker who wants to look into the data configuration.

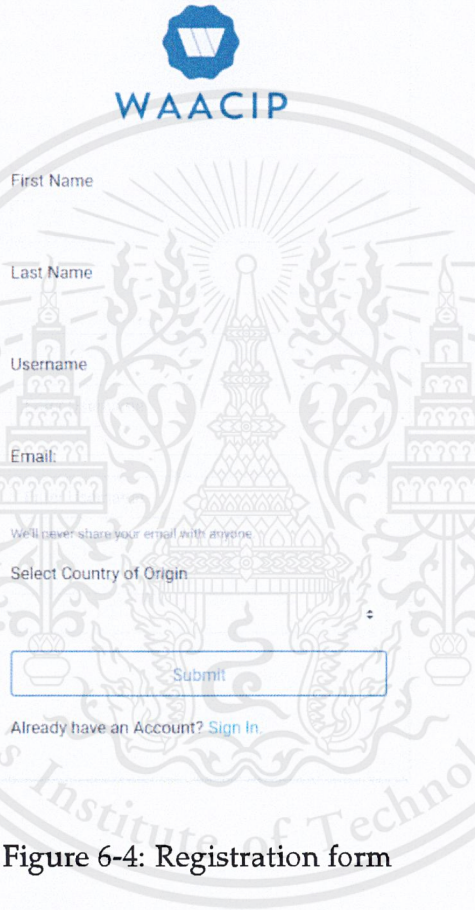


Figure 6-4: Registration form

Figures 6-4 shows what our registration form looks like. To use our application, the user is required to register their information though our page. Then, they will receive the generated password through their e-mail, and be acknowledged by a notice as shown on Figure 6-5 when successfully registered. The user profile will be reviewed by the administrator who will assign a proper privilege to the user. Until then the user has only the read-only privilege.

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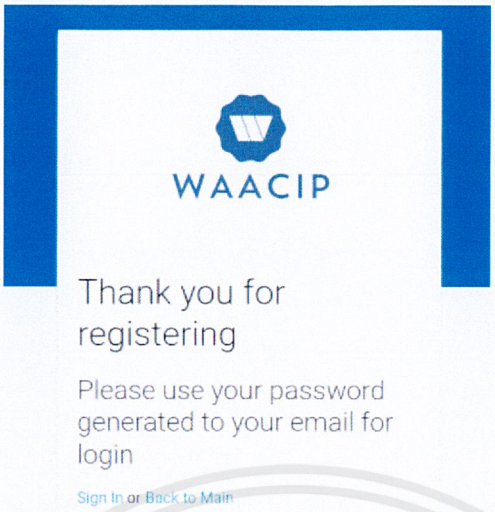


Figure 6-5: A notice confirming that the user has successfully registered

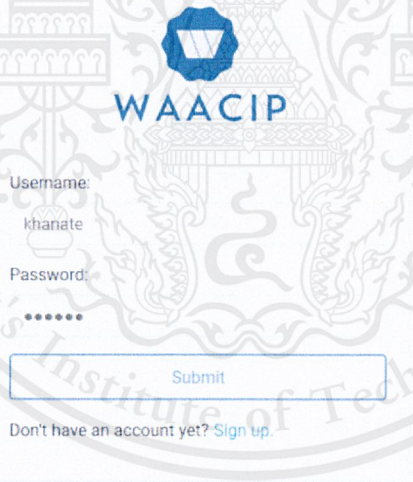


Figure 6-6: Login form

Figure 6-6 portrays what our login form looks like. The user is required to login using their registered user name and generated password in order to use the system.

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6.3 Import/Drawing

To utilize the full functionalities of the GIS application, there must be a tool bar for the functional usage in the map and a function for importing data and visualizing it on the map.



Figure 6-7: Load the data and draw the geodata

The Figure 6-7 shows what happens when the user clicks on the load data drop down button. The program loads all the GIS data from the database at the server and modifies it which allows the map to display the data properly. There are three types of data that are loaded into the program : pipelines, overhead power lines, and segment lines. All of the objects contain properties. Some of the properties can be manipulated and used for plotting the graph.

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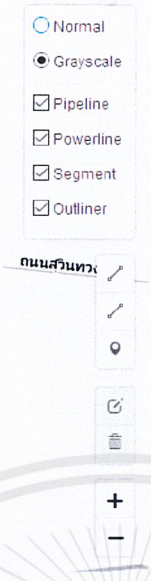


Figure 6-8: Load the data and draw the geodata

The GIS application needs tools to create and manipulate objects. Leaflet provides a drawing module called *Leaflet.draw* which creates a blank tool bar for the developer to include other drawing functions by themselves. We create a tool bar that contains layers control. It allows the user to turn each layer on/off. The draw module provides the functionality for drawing pipelines, overhead power lines, and segment lines. These GIS objects can be edited by the editing tool or deleted by the deleting tool. Lastly the zoom control is used for zoom in/out of the map for viewing at a certain level. Figure 6-8 illustrates the tool bar in details.

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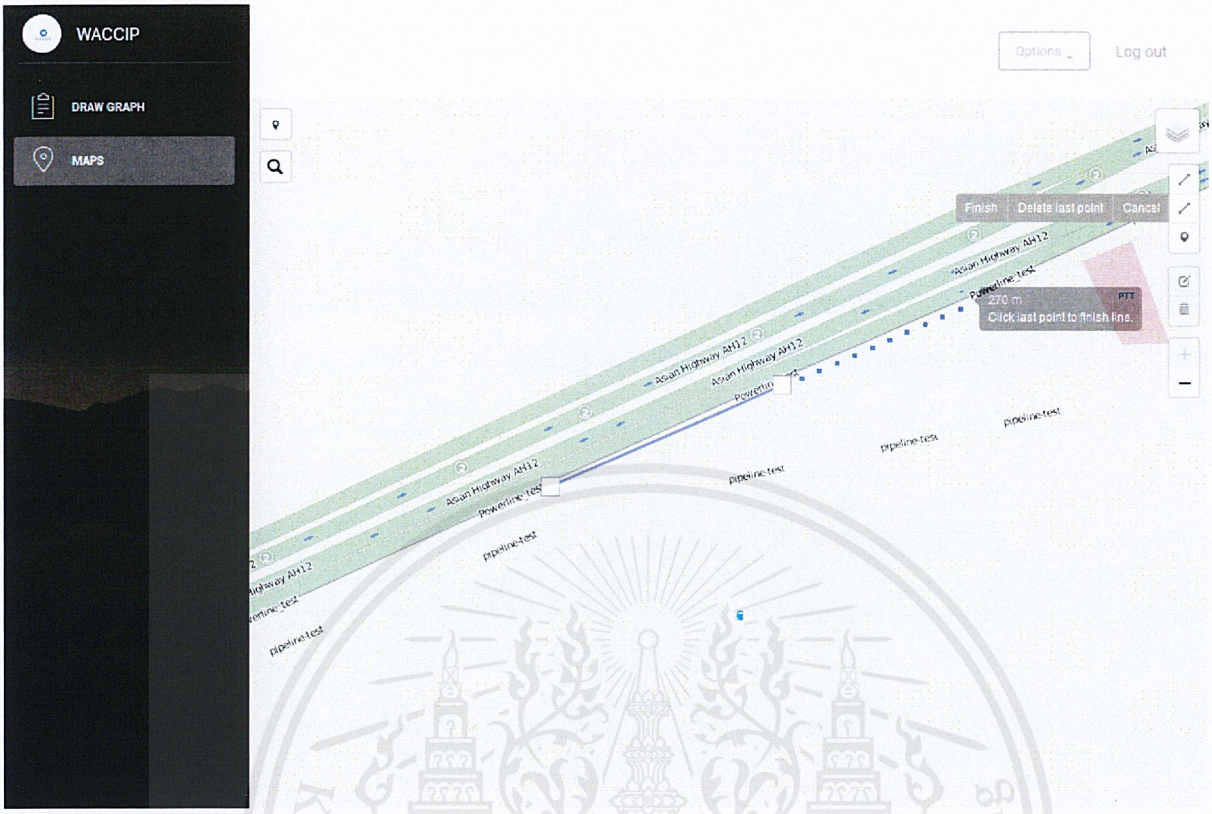


Figure 6-9: Load the data and draw the geodata

The user can draw two types of lines: pipelines and overhead power lines. This allows the user to place additional pipelines or power lines onto the map. Figure 6-9 shows how drawing a line (here we are drawing a pipeline) looks like with the distance tool tips providing the length of the line. Line distance is accurate up to 500 meters. From 501 to 1,500 meters, the error increases to 0.5 to 0.6 percent and from 1,501 to 3,000 meters, the error increases to 1.5 to 1.9 percent. The reason for this inaccuracy has to do with the Spherical Law of Cosine formula and the Earth's surface elevation.

6.4 Property Editor

The property editor is an essential tool in our application. It allows the user to manipulate the GIS data and use the saved data for later calculation and drawing graph.

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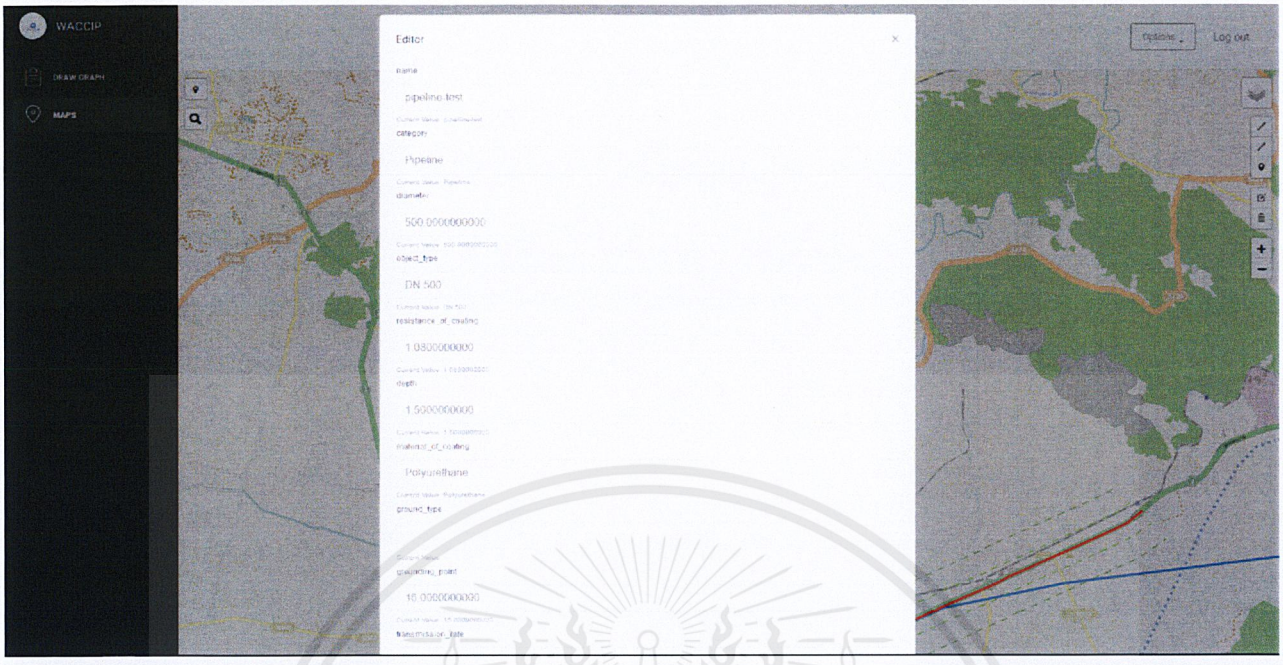


Figure 6-10: Property panel editor

Figure 6-10 shows a pop up of the property window when the user clicks on a pipeline on the map. The GIS object has its own properties distinguishable by the category type. Almost all data fields are manipulatable and when the user finishes editing the data and press the OK button at the bottom of the editor, the edited properties will automatically be saved to the database. However, this only applies to the user with a proper privilege.

6.5 Segmentation

Our web application requires the user to manually create sections by first choosing a pipeline, a transmission line, the type of segmentation, and the name of the critical area, as shown in Figure 6-11.

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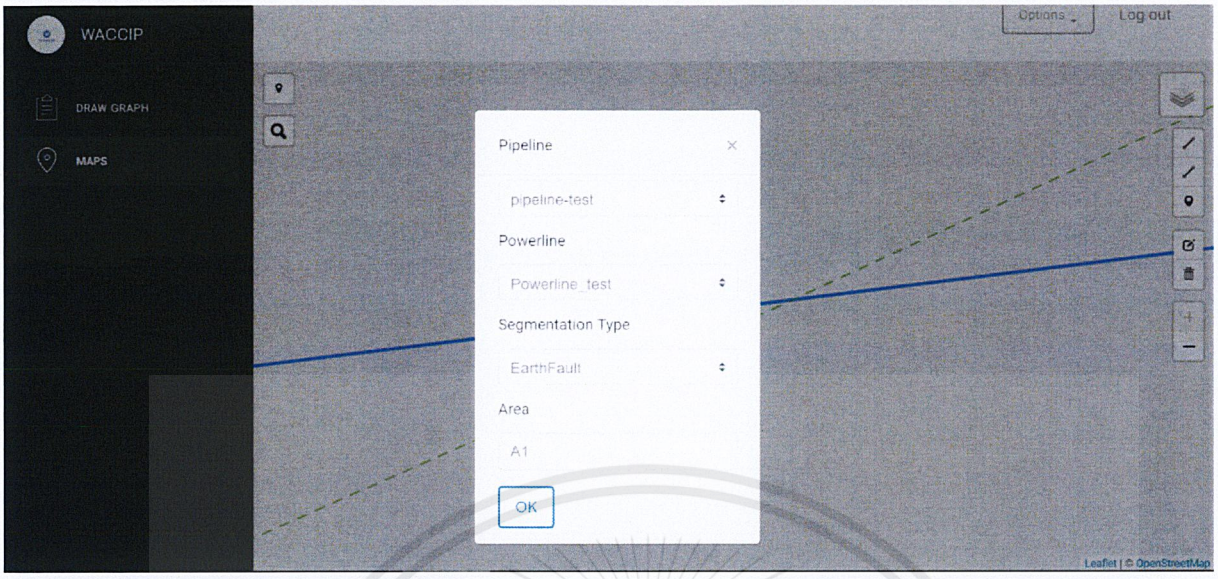


Figure 6-11: Making segments option

In Figure 6-12, after the user clicks on a pipeline, the program will automatically create a dashed line that perpendicular to the transmission line. By doing this, segments of the pipeline and transmission line will be created from the endpoint of dashed lines. This process, the user can select any lines to work with whether a pipeline or a transmission line. The limitation of this is the freedom of choice where the user can freely choose any line which means the user must choose only one type of line for the segmentation.



Figure 6-12: Result after sectioning

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6.6 Graph and Table

In Figure 6-13, the user can view the analyzed graph and result table by choosing a pipeline and a critical area.

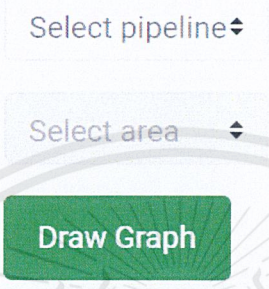


Figure 6-13: Graph selection

After the user has selected the pipeline and critical area, the graph and result table will be displayed. There are two types of graphs: operation fault and Earth fault, which are respectively long-term and short-term electrical influence. Figure 6-14 is an example of an interactive graph where the user can toggle between the *induced longitudinal field strength* and *longitudinal stress*.

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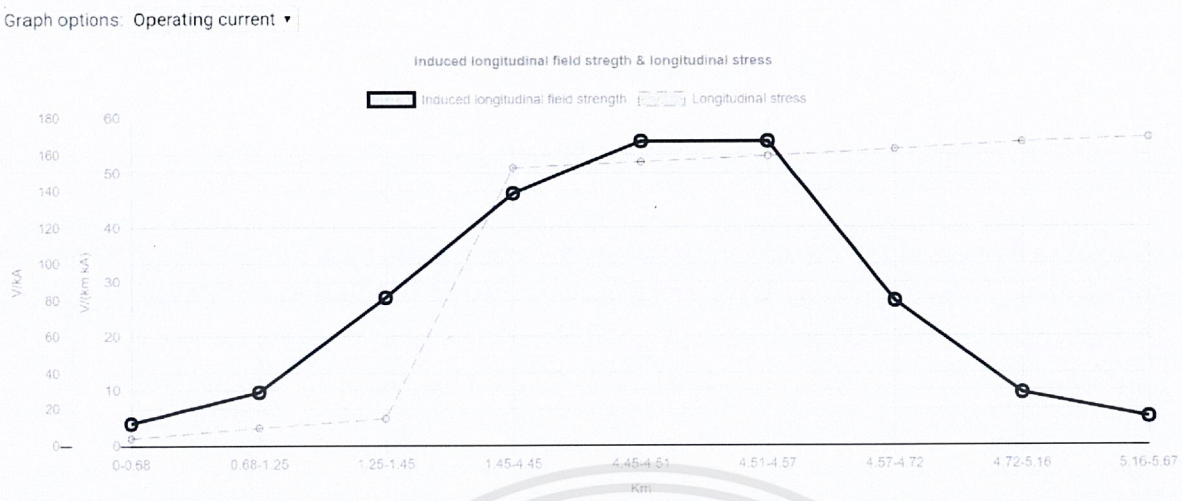


Figure 6-14: Sample graph showing induced longitudinal field strength and longitudinal stress

Induced longitudinal field stregth & longitudinal stress

SECTION	A1	A2	A	|EK|R/|IK|	|UR|/|IK|	|UX|/|IK|	SUM(|UR|)	|EK|R/|IK|	|UR|/|IK|	3(|UR|/|IK|)
0-1	400	219	300	5.2	0.653	0.676	0.68	4	3.4	3.4
1-2	219	65	130	10	0.56	0.58	1.25	9.7	5.6	9
2-3	65	25	43	28	0.187	0.193	1.45	27.1	5.2	14.2
3-4	25	25	25	46	3	3	4.45	46	138	152.2
4-5	25	7	12	60	0.052	0.056	4.51	55.7	3.1	155.3
5-6	7	25	12	60	0.052	0.056	4.57	55.7	3.1	158.4
6-7	25	72	43	28	0.137	0.146	4.72	26.3	3.8	162.2
7-8	72	236	130	10	0.412	0.439	5.16	9.4	4.1	166.3
8-9	236	400	300	5.2	0.481	0.512	5.67	4.9	2.5	168.8

Figure 6-15: Sample table showing induced longitudinal field strength and longitudinal stress

In Figure 6-14, *induced longitudinal field strength* and *longitudinal stress* come from column 9 and column 11 (denoted as $|EK|R/|IK|$ and $3(|UR|/|IK|)$) respectively in the result table in Figure 6-15. This is the table that we obtain after the calculation from the server. Both the graph and the result table can be used for further analysis of the high-voltage

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AC influence on pipelines by a cathodic protection specialist.

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Chapter 7

Conclusion

7.1 Project Summary

Developing a GIS application is challenging. Doing it as a website is even more complicated. However our work effort has paid off as we have learned many new tools and development skills. We have developed a client-side *Workbench for Analysis on AC Interference on Pipelines* GIS web application which serves to analyze the electrical interference across all the obtained data in pipelines system running along the overhead power lines.

All of our components have been developed using JavaScript web programming language under the framework of *Vue.js*. *Vue.js* is a JavaScript framework that is mainly used to build the user interface in our project. It helps us organize our programming structure. *Leaflet* library gives us a quick and easy way to develop a platform based on a map system and GIS information.

As a result, we have completed all the major requirements, delivering a quality web application with a user friendly interface for the user who has sufficient technical knowledge. The application offers good user experiences and reliable data accuracy and control.

7.2 Problems and Obstacles

There are three main problems that we faced during the project development: our limited electrical engineering knowledge, the language barrier, and the unavailability of the

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data. As our web application is intended to be used by an expert in the field of electrical engineering, we must have an expert who is already familiar with the work to guide us the calculation process and the project requirements. Due to our limited knowledge of electrical engineering, we had to spend some amount of time trying to understand how to use the formulas. Another issue is the language barrier. The documents that we followed, namely, *DVGW GW 22 (A)* and *TE-7 SfB 2014*, are in written in German language. The English translation was not clear and sometimes inaccurate. For this reason, we had to consult our supervisor who is a German electrical engineer to assist us in the translation of the documents. Lastly, our biggest problem is the availability of the data. We initially planned to use the pipelines data from Petroleum Authority of Thailand (PTT), but they only have the data in paper form. Also we only obtained the paper-based data of the high-voltage overhead power lines from Provincial Electricity Authority (PEA) because the process to obtain the soft data would take many days. Even if we had obtained the soft data from PEA, we could not be guaranteed the quality of the data.

Our technical issue involves Leaflet's wrapper called *Vue2Leaflet*. Because one of the *Vue2Leaflet* features was still under development. That is why we could not use feature groups in *Vue2Leaflet*. Feature groups provide a higher functional layers control such as draw layers and edit layers.

7.3 Future work

The web application can be extended easily due to the flexibility of *Leaflet*. We can add a plug-in to *Leaflet* for a new feature. The following list is the possible future work that can be added to the project:

- The pipeline segmentation can be automated. Normally, the application requires user with experiences to manually divide the lines for sectioning but for future work where the condition for sectioning pattern is well defined, the application can do pipeline sectioning automatically.
- Improve UI of the website to be more user friendly especially the map. Also, make

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the application support on all mobile platforms.

- The web application should be able to automatically detect the high interference areas on the map. It should indicate the potentially dangerous areas on the map by glowing colors on critical areas.

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Input	Output
-	Geographic objects
Data type: -	**Data type:** Geographic object

4.2.6 Create Geographic Object Service

After a geographic object is created, the application will pass the request to the server-side and get the newly created object back.

Request Method: POST

Input	Output
Zoom level, x coordinate, y coordinate, current map boundary	Geographic object
Data type: Integer, Float, Float	**Data type:** Geographic object

4.2.7 Edit Geographic Object Service

After a geographic object is being edited, the application will pass the request to the server-side and get the updated object back.

Request Method: POST

Input	Output
Zoom level, x coordinate, y coordinate, current map boundary	Geographic object
Data type: Integer, Float, Float	**Data type:** Geographic object

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