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Implementation of the Haversine Algorithm in the Development of a WebGis-Based Transmission Tower Disturbance Monitoring System

***1Agung Pambudi, 2Ahmad Fikri Hanif, and 3Syauqi Rahmat**

[1,2,3] Department of Computer Science, Faculty of Mathematics and Natural Sciences, Lampung University
Jl. Prof. Sumantri Brojonegoro No. 1, Gedong Meneng, Rajabasa, Bandar Lampung Province, Lampung, Indonesia
e-mail: [*1]**agungpambudi@fmipa.unila.ac.id**, [2]2317051061@students.unila.ac.id , [3]2317051084@students.unila.ac.id

Abstract - *Monitoring transmission tower disruptions require a system capable of presenting location information accurately and quickly to support the decision-making process. Limitations in the presentation of spatial data and the manual process of identifying disruption locations pose obstacles to improving the effectiveness of network infrastructure management. This study aims to develop a web-based transmission tower disruption monitoring system that integrates geospatial visualization and distance calculations to determine the nearest tower. The methodology used is the Waterfall development model, which includes the stages of needs analysis, system design, implementation, testing, and maintenance. The system is built using web technology with digital map support to display tower locations and disruption points interactively. Backend testing results using k6 show that all endpoints have a 100% success rate without failure, with response times ranging from 1.73 ms to 4430 ms, with the majority being below 1000 ms. All response values are still within the tolerance limit (<5000 ms), indicating stable system performance in handling various types of requests. In addition, the results of User Acceptance Testing (UAT) show that all system modules run according to user requirements. This system can improve monitoring efficiency and accelerate the process of identifying fault locations. The research's contribution lies in the integration of a web-based geospatial system with a distance calculation approach to support more effective and structured transmission infrastructure management.*

Keywords: *Geospatial; Monitoring System; Transmission Tower; WebGIS.*

1. INTRODUCTION

The development of information technology has brought changes in company management and operational systems [1]. Various information systems have emerged to support company operations, such as asset recording and monitoring to data analysis to provide recommendations [2]. However, there are still crucial activities in companies that often encounter obstacles because data is not fully managed digitally, one of which is asset management [3]. Asset monitoring that is still carried out manually can create operational risks, such as inaccuracies, redundancies, or errors in the asset management and monitoring process [4]. In addition, reliance on physical documents or conventional archives results in ineffective information monitoring and validation processes, which can hinder the smooth running of work and the strategic decision-making process in a public agency [5].

In supporting the decision-making process, data presentation is a very important indicator [6]. The use of geospatial systems is a strategic solution in transforming abstract tabular data into more informative and easy-to-understand information visualization[7]. Through geographic coordinate-based mapping, companies can analyze asset distribution and identify disruption points more intuitively in the context of geographic space [8]. In addition, accurate geospatial visualization plays an important role in helping technical teams map evacuation routes, monitor, and maintain assets spread across various regions, where the use of interactive maps in asset management has been proven to speed up the location identification process by up to two times compared to conventional methods [9].

In supporting accurate spatial analysis, the determination of distance between coordinates is carried out by applying the Haversine algorithm. This algorithm was chosen because of its ability to calculate the shortest distance between two points on the earth's surface precisely by utilizing a trigonometric approach [10]. Its application in monitoring systems has proven effective in validating disturbance locations based on latitude and longitude parameters [11]. In addition, the Haversine algorithm also provides computational efficiency on the data processing side, so it can process large amounts of coordinate data quickly [12]. Its ability to support radius-based search features also facilitates the identification of important objects around anomalous points [13]. Thus, the resulting level of accuracy makes this method a reliable standard in minimizing positioning errors in the field [14].

A web-based Geographic Information System (WebGIS) approach is used as the basis for developing solutions to support transmission tower infrastructure monitoring, supported by various previous studies that demonstrate the effectiveness of WebGIS in the context of asset monitoring [15]. Research [16] related to the maintenance and repair monitoring system for PT PLN Kota Metro facilities shows that a web-based system can improve the effectiveness of monitoring the performance of field officers and support more structured decision-making. In addition, research [17] shows that the use of WebGIS in mapping land and building assets can transform conventional recording into a more informative visual system, thereby accelerating the data search process and increasing the accuracy of real-time location identification.

The development of a transmission tower disruption monitoring system is carried out through the integration of web-based geospatial visualization with distance calculations using the Haversine algorithm to automatically identify the nearest tower [18]. This system is designed to display tower location information spatially while processing location data in a structured manner, using data obtained from PT. PLN (Persero) UIP3B Sumatra UPT Tanjung karang as a representation of real conditions in the field. The application of the Haversine algorithm allows for precise and efficient distance calculations between points, so that the process of identifying the nearest location can be carried out quickly [19]. This integration between visual and computational components supports increased response speed to disruptions and provides more accurate support in the location-based decision-making process [20]. In the development process, this system was built using the Waterfall model, which applies sequential stages starting from needs analysis to testing. The selection of this method was based on well-defined system requirements, allowing the development process to be carried out in a structured and controlled manner [21].

2. RESEARCH METHODOLOGY

The Waterfall model is used as the development approach in this research. This model is included in the classic category of the Software Development Life Cycle (SDLC) which emphasizes a structured and gradual workflow. Each stage must be completed thoroughly before proceeding to the next stage, so that the development process can be carried out systematically and controlled. The stages in the Waterfall model include requirements analysis, system design, implementation, testing, and maintenance [22]. In general, the process flow is shown in Figure 1. The SDLC itself acts as a framework in software development that defines activities, procedures, and objectives at each stage of system development, so that the development process can take place in a structured, measurable, and comprehensively evaluated manner [23].

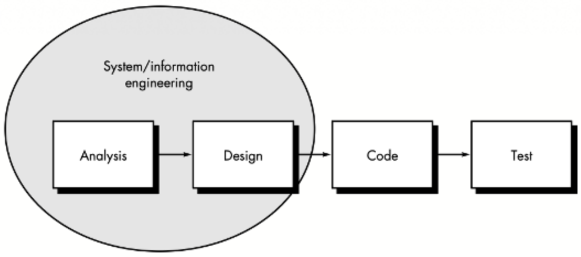

Figure 1. Waterfall method.

2.1. Analysis

In the system design process, requirements analysis is an important stage to identify operational conditions and specific user needs, so that system specifications can be formulated precisely and are able to provide effective solutions. System requirements are classified into functional and non-functional requirements [24]. Functional requirements include the main functions of the system related to user interaction, such as input, processing, and presentation of information [25]. Meanwhile, non-functional requirements focus on aspects of system quality, including reliability, usability, performance, accessibility, security, and hardware and software support used in system development [26].

2.1. Design

In the design phase, a technical system design is developed, including the design of a data storage structure to enable the management of large numbers of outage reports in a structured and consistent manner. This design includes database modeling that supports integrity and ease of data processing and retrieval. Furthermore, a data exchange mechanism is designed between the server and the user interface to ensure that information related to location and anomaly status can be delivered efficiently, responsively, and in real time without compromising system performance [27]. This phase also includes the design of an intuitive user interface to support ease of interaction and enhance the user experience in accessing information.

2.1. Code

In the coding phase, the system was developed using the Next.js framework with the TypeScript programming language to improve code reliability, consistency, and readability. The use of TypeScript also allows for the implementation of more structured data types, thus minimizing errors during the development process. On the interface side, Tailwind CSS is used as a display framework that supports the creation of responsive, flexible, and efficient designs [28]. For geospatial data visualization needs, the system integrates Leaflet as an interactive map library that allows for the dynamic display of tower locations and disruption points. The integration of these various technologies supports the development of a modular, scalable system that can present spatial information quickly and interactively [29].

2.1. Test

In the testing phase, a system evaluation is conducted to ensure reliability and functional suitability to user needs. Data processing reliability testing on backend services is conducted using k6 to measure system performance in handling access loads, including testing response time, stability, and the system's ability to process requests simultaneously [30]. In addition, functional testing is conducted through a User Acceptance Testing (UAT) approach to validate that all developed features are in accordance with user needs and expectations [31]. Through this combination of tests, the system can be evaluated both in terms of performance and functional suitability, resulting in a reliable and ready-to-use system.

3. RESULTS AND DISCUSSION

The implementation results of a webGIS-based transmission tower disruption monitoring system are described through a display of features and a user interface, including a geospatial map visualization that displays the distribution of tower locations and disruption points. The tower point information displayed is the result of spatial data processing that supports the identification of the nearest location. Next, a discussion of the system's performance is conducted based on the test results, covering aspects of reliability and suitability of functions to user needs. This description provides an overview of the system's ability to support the monitoring process and location-based decision-making more effectively.

3.1. Analysis

The analysis phase resulted in the identification of system requirements that included functional and non-functional requirements as the basis for developing a transmission tower disturbance monitoring system. Functional requirements included user authentication features, asset data management such as substations, segments, and transmission towers, user data management, system activity monitoring, and the ability to detect disturbance locations and display statistical data in an integrated manner. Meanwhile, non-functional

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requirements focused on system quality aspects, such as reliability and performance in processing data quickly and stably, ease of use through an intuitive interface, flexible web-based system accessibility, and security through user authentication and authorization mechanisms. The results of this analysis ensured that the developed system was able to meet operational needs effectively and provide an optimal user experience.

3.2. Use Case Diagram (Design)

The use case diagram in Figure 2 illustrates the interaction between actors and the developed transmission tower disturbance monitoring system. This diagram demonstrates that the system has several key functions accessible to users according to their roles. Generally, users can authenticate through the login feature before accessing the system. Once successfully logged in, users can view transmission network maps, monitor disturbance data, and access information related to tower, segment, and substation data. The system also provides a user profile management feature.

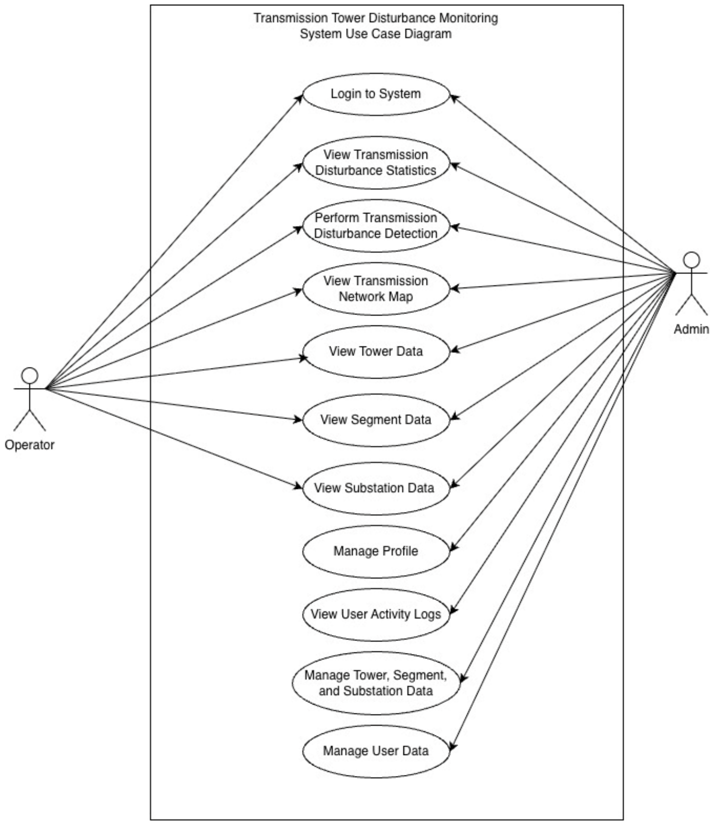

Figure 2. Use case diagram.

On the data management side, additional functions allow users with specific access rights to manage tower, segment, substation, and user data. The system also supports user activity monitoring as part of operational control. This use case allows for a comprehensive understanding of the interaction flow between users and the system, facilitating system development and evaluation.

3.3. User Interface (Implementation)

The implementation of the transmission tower disruption monitoring system is demonstrated through an interface display that represents the main functions that have been developed. This interface displays various system features, such as geospatial map visualizations to show tower locations and disruption points, asset data presentation, and detailed information that can be accessed directly by users. Each display reflects the integration between data processing and information presentation that has been built into the system. Through this interface, users can access, monitor, and manage information in a structured manner according to operational needs.

a. Login Page

The login page in Figure 3 represents the initial gateway users use to access the transmission tower disruption monitoring system. On this page, users are asked to enter their registered username and password. The authentication process ensures that only authorized users can access the system. After successful verification, users are redirected to the system's main page, appropriate for their role. Conversely, if an error occurs while entering data, the system displays a notification as feedback to the user. The implementation of this login page plays a crucial role in maintaining data security and controlling access to system features.

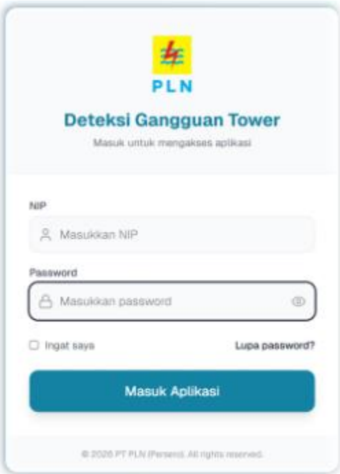

Figure 3. Login page.

b. Statistics Dashboard Page

The statistics dashboard page in Figure 4 presents a visual and integrated summary of key information related to transmission network conditions. This information is displayed as an indicator of the total number of assets, such as the total number of towers, segments, and substations, as well as the number of critical conditions detected in the system. Furthermore, the dashboard features data visualization in the form of a pie chart showing the distribution of network statuses, such as safe, alert, and critical, making it easier for users to understand the proportion of overall network conditions. A bar chart is also presented to display the distribution of tower statuses by region or service unit, allowing users to perform rapid comparative analysis. This visual presentation of information supports real-time monitoring and helps users identify network conditions more effectively and efficiently.

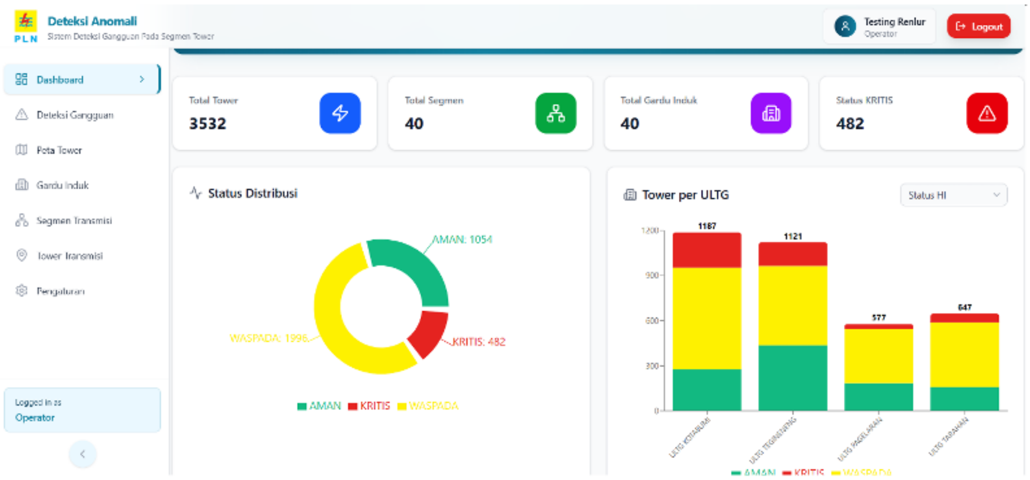

Figure 4. Statistics dashboard page.

c. Transmission Interference Detection Page

The fault detection page in Figure 5 serves to identify fault locations on the transmission tower network based on user-entered parameters. On this page, users can specify the start and end points of a tower segment and enter a fault distance value as the basis for the analysis. The system then processes this data to generate fault location information, which is displayed in the analysis results section. These results include a list of towers indicated as affected and their condition status, making it easier for users to determine fault points more accurately. Furthermore, this page also displays detailed segment information, such as segment name, conductor type, network length, and other technical data that support the identification process. This integration between parameter input and analysis results enables the fault detection process to be carried out systematically and efficiently.

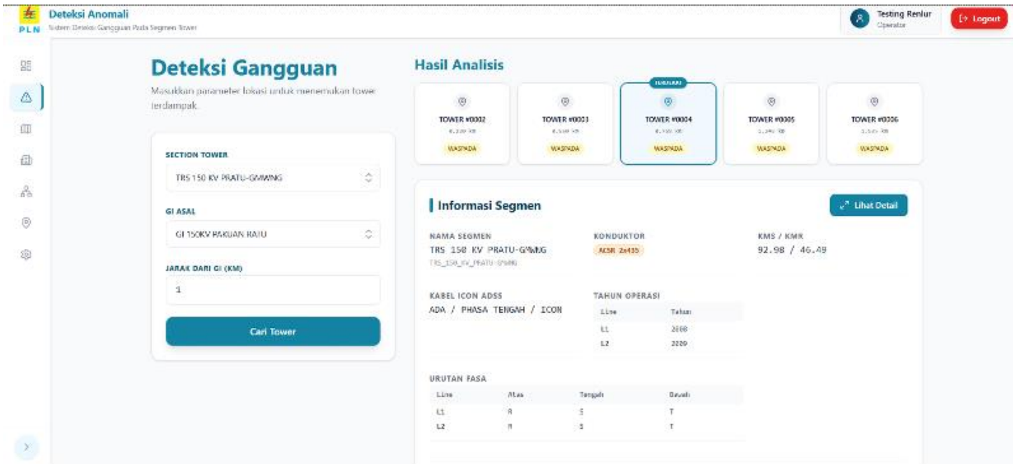

Figure 5. Transmission interference detection page.

a. Transmission Interference Detection Detail Page

The fault detection details page in Figure 6 presents a spatial visualization of the fault location based on the analysis of the input from the previous stage. In this stage, the Haversine algorithm is used to accurately calculate and determine the position of the nearest tower to the fault point. The calculation results are then visualized through an interactive map component that displays the geographic location of the fault within the context of the transmission line. Through this interface, users can identify the fault point marked with a special visual indicator and trace the path of the affected conductor segment from the substation to the faulted asset. This spatial presentation of information provides a more intuitive understanding of the fault location and supports more effective analysis and response processes.

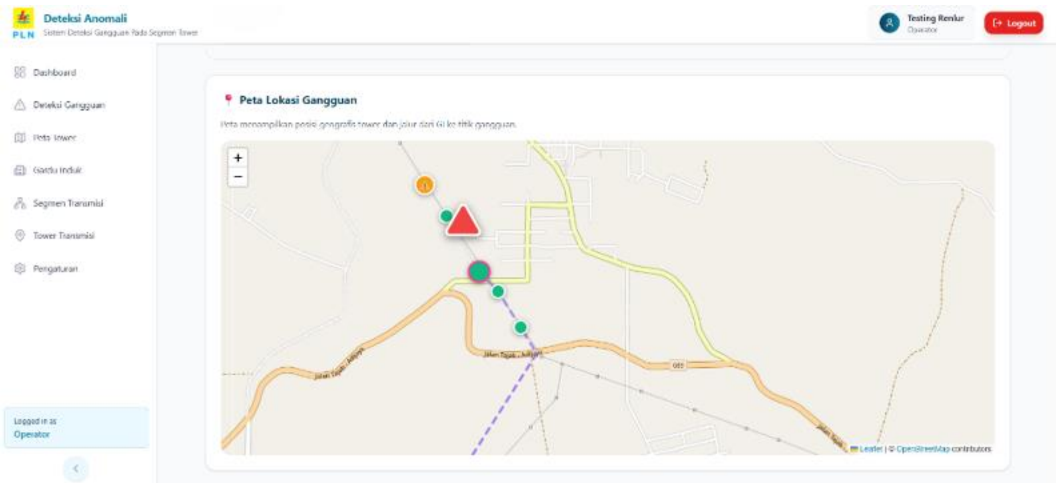

Figure 6. Transmission interference detection detail page.

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b. Tower Data Management Page

The transmission tower data management page as in Figure 7 displays information related to tower assets, accessible according to user role. Operator users only have access to view data, while super admins have full access to manage data, such as adding, modifying, and deleting data individually. Furthermore, the system provides a mechanism for bulk data management through data import using Excel files and the deletion of all data through the delete all function. To facilitate data management, this page is equipped with search, filter, and pagination features that allow data to be displayed dynamically and in a structured manner. These features enable more efficient and organized transmission tower data management.

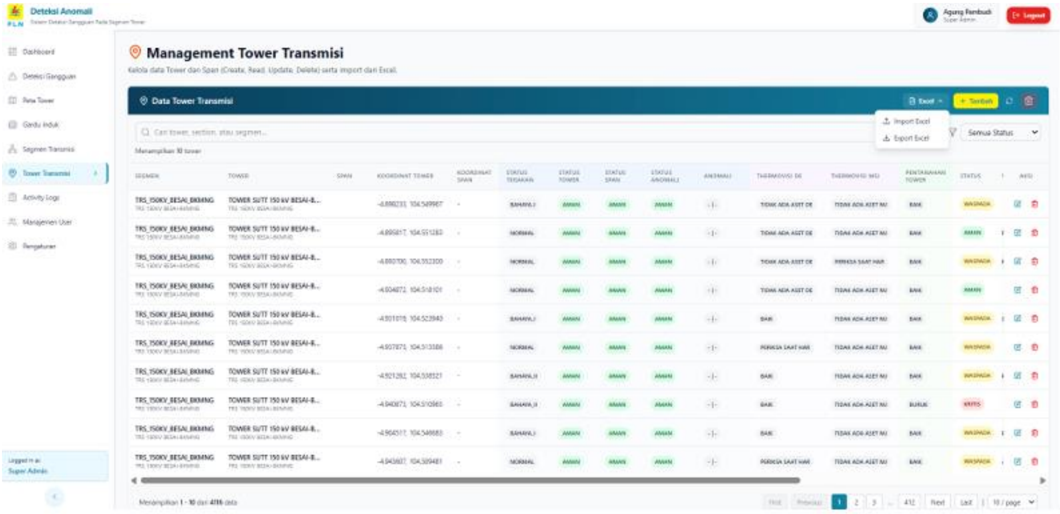

Figure 7. Tower data management page.

3.4. System Evaluation (Test)

System testing was conducted to evaluate the performance and reliability of the developed application, both in terms of functionality and service performance. This testing process aims to ensure that the system can operate according to user requirements and maintains a high level of stability in handling access loads. Backend service performance testing was carried out using the k6 tool to measure the system's ability to handle data requests, as can be seen in Table 1. Based on the test results, all endpoints demonstrated a 100% success rate with no failures (failed requests = 0%), indicating the system's stability in processing each request. Response times varied, ranging from 1,73 ms to 4.430 ms, with most endpoints having response times below 1.000 ms.

The highest response value of 4.430 ms occurred in the data deletion process, which involves deleting many data rows at once, thus requiring a longer execution time than other endpoints. All response times remained within the established tolerance limit of less than 5.000 ms, indicating that the system was able to respond effectively to requests. Some endpoints with higher processing complexity exhibited longer response times, but these were still within acceptable limits and did not impact overall system performance. In general, the results of this test show that the backend service has a good level of reliability and performance in handling various types of requests, including in concurrent access conditions.

Table 1. Backend service performance testing.

Endpoint	Method	Tolerance	Response	Status
api/activity-logs	GET	<5000 ms	1.190 ms	Success
api/dashboard/stats/segmen	GET	<5000 ms	504 ms	Success
api/dashboard/stats/ultg	GET	<5000 ms	558 ms	Success
api/dashboard/stats/ultg-distribution	GET	<5000 ms	1.540 ms	Success

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Endpoint	Method	Tolerance	Response	Status
api/gi	GET	<5000 ms	1.540 ms	Success
api/segmen	GET	<5000 ms	3.050 ms	Success
api/towers	GET	<5000 ms	2.790 ms	Success
api/towers/nearby	GET	<5000 ms	2.190 ms	Success
api/towers/search	GET	<5000 ms	1.330 ms	Success
api/towers/ultgs	GET	<5000 ms	584 ms	Success
api/gi	POST	<5000 ms	61.33 ms	Success
api/segmen	POST	<5000 ms	788 ms	Success
api/towers/create	POST	<5000 ms	492.28 ms	Success
api/users	POST	<5000 ms	952.45 ms	Success
api/gi/[id]	PUT	<5000 ms	172.08 ms	Success
api/segmen/[id]	PUT	<5000 ms	75.05 ms	Success
api/towers/[id]	PUT	<5000 ms	48228 ms	Success
api/users	PUT	<5000 ms	1.73 ms	Success
api/gi/[id]	DELETE	<5000 ms	72.95 ms	Success
api/segmen/[id]	DELETE	<5000 ms	961 ms	Success
api/towers/[id]	DELETE	<5000 ms	4.430 ms	Success
api/users/[id]	DELETE	<5000 ms	378 ms	Success

System functionality testing was carried out using the User Acceptance Testing (UAT) method to ensure that each module was running according to user needs, the test results can be seen in Table 2. Based on the test results, all tested modules demonstrated valid performance, with each main system function operating according to the specified scenario. This demonstrates that the system meets user requirements and is ready for implementation in an operational environment.

Table 2. User Acceptance Testing (UAT) results.

No	Use Case	Test Scenario	Expected Result	Test Result	Status
1	Login to System	User logs in using valid credentials	System authenticates user and redirects to dashboard	Success	Valid
2	View Transmission Disturbance Statistics	Display disturbance statistics data	Statistical data is displayed correctly	Success	Valid
3	Perform Transmission Disturbance Detection	Input disturbance detection parameters	System displays accurate disturbance detection results	Success	Valid
4	View Transmission Network Map	Display transmission network map	Map shows tower locations and disturbances accurately	Success	Valid
5	View Tower Data	Access tower data	Tower data is displayed correctly	Success	Valid
6	View Segment Data	Access segment data	Segment data is displayed correctly	Success	Valid

No	Use Case	Test Scenario	Expected Result	Test Result	Status
7	View Substation Data	Access substation data	Substation data is displayed correctly	Success	Valid
8	Manage Profile	Update user profile	Profile changes are saved successfully	Success	Valid
9	View User Activity Logs	Admin views user activity logs	System displays user activity logs	Success	Valid
10	Manage Tower, Segment, and Substation Data	Admin manages asset data (create, update, delete)	Data is processed according to user actions	Success	Valid
11	Manage User Data	Admin manages user accounts	User data can be added, updated, and deleted	Success	Valid

4. CONCLUSIONS

Based on the design, implementation, and testing results, the web-based transmission tower disruption monitoring system can run according to the specified requirements. The integration of geospatial visualization allows for a more intuitive presentation of tower location information and disruption points, thus facilitating the monitoring process. In addition, the application of distance calculations to identify the nearest tower supports increased speed and accuracy in handling disruptions. Test results indicate that the system has a good level of reliability in terms of backend service performance and has met the functional aspects based on User Acceptance Testing (UAT). Thus, the developed system can be used as a solution to support the monitoring process and location-based decision-making more effectively and efficiently.

Further system development can be directed at enhancing more sophisticated analytical features, such as integration with real-time data from sensors or IoT devices to support automatic disturbance detection. Mobile-based application development can also be considered to improve accessibility for field officers. From a spatial analysis perspective, distance calculation methods can be combined with other approaches to improve accuracy in more complex geographic conditions. Furthermore, adding a notification feature as an early warning mechanism for detected disturbances is also important. Implementing real-time notifications via web applications, email, or text messaging can expedite officer response in handling disturbances. Furthermore, integration with other information systems owned by relevant agencies can be implemented to support more centralized and integrated data management.

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