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Implementation design of energy trading monitoring application for blockchain technology-based wheeling cases

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ABSTRACT

One obstacle to the energy industry's tendency toward adopting renewable energy is the requirement for a monitoring system for energy transactions based on microgrids in the wheeling scheme (shared use of utility networks). The quantity of transaction expenses for each operational generator is not monitored in any case. In this project, a mobile phone application is developed and maintained to track the total amount of fees paid and received by all wheeling parties and the amount of electricity produced by the microgrid. In the wheeling case system research, the number of transaction costs, such as network rental fees, loss costs, and profit margins, must be pretty calculated for all wheeling participants. The approach created in this study uses a blockchain system to execute transactions, and transactions can only take place if the wheeling actor and the generator have an existing contract. The application of energy trading is the main contribution of this research. The created application may track energy transfers and track how many fees each wheeling actor is required to receive or pay. Using a security system to monitor wheeling transactions will make energy trades transparent.

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1. INTRODUCTION

Because of the growing concern about lowering greenhouse gas emissions, the usage of renewable energy has become a trend in the energy industry. Installing renewable energy based on microgrids is one of the issues associated with the Implementation of renewable energy. The microgrid system enables the trading of energy. Due to the variable nature of renewable energy, energy trading takes place. Backups from other sources, such as utilities or other microgrids with excess power, are required to meet the load requirements.

The utility's electrical power system network is now shared due to the high installation costs of microgrids. This led to the creation of a monitoring system to keep track of the expenditures incurred by each actor. The wheeling case is the name given to this idea. Owners of microgrids, utilities, and consumers make up the wheeling case. It is essential to keep track of the costs incurred by each wheeling actor while trading energy using the wheeling case idea. To ensure that all parties are at ease, the cost of electrical energy must be accurately and safely recorded [1].

Previously, communities or customers could only use electricity delivered to them. To generate power, consumers can employ solar energy or photovoltaic panels. On the other hand, because sunlight significantly impacts it and temperatures fluctuate constantly, consumer power generation is erratic and challenging to forecast. When the prosumer experiences a surplus of electrical energy, the prosumer has several choices: The energy can be kept for later use in storage devices, exported to the power grid, or sold to other energy consumers [2]. Energy trading, often known as peer-to-peer (P2P) energy trading, is direct energy trading between consumers and prosumers. The difference between prosumer and consumer is that prosumer generates and consumes electricity, whereas consumer only consumes electricity. Because of the greater variety of energy age, exchanging the P2P model will upgrade the neighborhood energy age and utilization equilibrium, as indicated by [3]. Other conventional power sources can also profit, such as lowering top power interest, lowering maintenance and operating expenses, and improving the consistency of the electrical system [4].

Andoni *et al*. [5] described the issues with peer-to-peer energy trading, specifically with the P2P trading platform. Data security for energy trading must be stored on energy P2P networks. A trustworthy and secure platform is necessary for customers and consumers. Modern technology, known as the blockchain, aims to decentralize and support exchange security. A distributed information base known as blockchain technology is used to securely store vital data such as agreements, information, occasions, and exchanges. Blocks of information are stored, and chains are used to connect them [6].

There are many technical and industrial applications for blockchain technology. However, there are currently no applications for blockchain technology that would make it simpler for business participants to transact. It is only used for computations. Pipattanasomporn *et al*. [7] and Malkawi *et al*. [8] studied the exchange of solar electric energy using a laboratory-scale application because blockchain technology is still in its infancy and is only available to a small number of users. Furthermore, Mengelkamp *et al*. [9] examined a blockchain-based smart grid: towards sustainable local energy markets, who, in this study, presented a comprehensive concept, market design, and simulation of local energy markets between 100 residential households with a personal blockchain approach-decentralized local energy market.

After investigating the potential of blockchain innovation, some new businesses seek to change how energy is produced and traded locally. Shared power exchange using blockchain technology developed by Powerledger, a localized microgrid powered by Brooklyn Microgrid, and a regional energy trading system [5] Recent compound industry exploration has been encouraged to work with machine-to-machine (M2M) relationships and develop an M2M power market. An analysis of the usage of blockchain technology to link consumers and manufacturers to perform energy [10], [11]. They depicted a scenario where two power producers and a power client trade power via a blockchain network [12]. Nobody has created a mobile application-based energy trading monitoring system, especially for trading in wheeling scenarios. Furthermore, Zhao *et al*. [13] explained how blockchain technology can be used to solve issues with data storage confidentiality, a crisis of confidence between vendors and purchasers, and transaction information transparency based on the research that was done.

Given these problems, it is imperative to adapt by giving a transaction security system top priority when developing an application that can capture all transaction data. Monitoring is necessary for a solar energy trading system based on a microgrid [14], the condition of the load value, the number of losses, the amount of solar energy produced, the power factor, the length of the power exchange, and the microgrid owner’s profit margin are among the variables. This monitoring can be the foundation for calculating the transaction costs for all wheeling actors-a blockchain transaction security mechanism. The transaction would only happen if the generator already had a prior contract. Contracts have a transaction code on them. If both generators have the same code, energy sharing will take place. If the transaction code is different, the transaction will not go through. Hence this code can be viewed as a representation of a security mechanism in transactions.

Mobile phone applications have increased in the digital era, such as today [15], [16]. Especially in the event of a pandemic that forces everyone to do all their business online, smartphones are becoming an essential element of daily life. The electrical energy sector must adapt to and contribute as the installation of microgrid systems increases. One example is creating a mobile phone application-based system for tracking energy trade, focusing on transaction security.

One of the security frameworks for energy exchanges uses blockchain technology. Blockchain innovation takes into account direct power trade between environmentally friendly power providers and customers to contemplate energy decentralization [4], [17], [18]. The use of blockchain technology has aided the entire transaction process indirectly. In revolution 4.0, blockchain-based services such as public ledgers and distributed databases will be used in real-time. Integrity verification is a relatively new profession in the blockchain industry. Data and transactions related to the creation and lifespan of products or services are saved by blockchain integrity verification programs [19].

This research uses a mobile phone application to create an energy trading monitoring system for a wheeling case scheme on a microgrid. A photovoltaic microgrid is used in Surabaya, Indonesia. The system is comprised of 24 buses and 14 microgrids. The application of the blockchain system is used as a parameter in maintaining transaction security.

This research contributes to developing a wheeling case system-based mobile application for energy trading, providing an approach to capturing energy transfers for actors on all fours (microgrid owners, utilities, and consumers). The developed application can collect data from both the generating and consuming sides. This research also provides a safe and efficient environment for trading in energy.

With the help of intermediaries-free double-spending elimination provided by the blockchain, new opportunities are made possible [20]. Data is stored in a blockchain in blockchain, and a proof-of-work system (security algorithm) is used to secure the blockchain [21], [22]. Blockchain can address several issues in a centralized system, including transactions without mediators, transaction processing times, and blockchain data updating [23], [24]. Blockchain is a network of interconnected nodes serving as a decentralized data storage system. A blockchain is made up of blocks or records of data exchanges. Blockchain acts as a distributed database or global ledger, recording every transaction on the blockchain network. A timestamped cryptographic hash is used to distinguish blocks of transactions. A blockchain is a series of blocks that are organized in a linear order, with each block referencing the hash of the one before it. Each node in the network that controls blockchain conducts and records duplicate transactions. The nodes of the blockchain network duplicate the blockchain. The network's nodes all have the ability to read transactions [25].

The usage of blockchain technology is possible in several technical and industrial domains. Khan *et al*. [26] studied the selling of solar electricity using blockchain technology with laboratory-scale Implementation. This is because blockchain technology is currently in its early phases, and only a small number of parties can use it. Additionally, Khan *et al*. [27] examined the study including a thorough conceptualization of decentralized local energy, as well as a market design and simulation of local energy markets between 100 residential families utilizing a customized blockchain market approach.

Following the realization of the potential of blockchain innovation, a few new enterprises are attempting to revolutionize the production and trading of local energy. Powerledger's decentralized energy exchange is powered by blockchains, Brooklyn Microgrid's neighborhood-powered microgrid, and Powerpeers' platform for group energy exchange [5]. In the chemical sector, research is still being done to improve machine-to-machine (M2M) connections and create an M2M power market. On a blockchain network, they described a scenario in which a power buyer and two power producers trade electricity [28].

Khan *et al*. [29] examined the application of blockchain technology to facilitate the exchange of energy between consumers and producers. The research claims that no one has yet tracked electrical energy transactions using the development of blockchain technology. Furthermore, Zhao *et al*. [13] demonstrated how difficulties with data storage secrecy, a crisis of confidence between vendors and customers, and transaction information transparency can be resolved using blockchain technology.

In this study, we will solve concerns with energy transactions by building an application model for tracking electrical energy transactions using a blockchain system based on a mobile phone application. The power generated by the photovoltaics (PV) system, the power factor value, the amount of load, and the total revenue, profit, and loss for each transaction actor region could all be displayed by this application in real time. The electricity factor gauges the quality of the power generated. This program allows for monitoring the battery's condition in both the charge and discharge positions.

2. METHOD

The software development life cycle (SDLC) originally had four main stages: planning, analysis, design, and implementation. Using a blockchain security framework, a monitoring application for electrical energy transactions is developed through several stages. Due to the sequential nature of each stage's execution and the fact that each stage is executed just once at a given moment, the SDLC phases are collectively referred to as the "SDLC Waterfall" in Figure 1.

a) Planning focuses on resolving issues or determining the system's objectives. Due to the issue with the system's lack of transparency, ReSmartTrading was developed. The fundamental objective of it is to safely synchronize transaction data across different places and the blockchain system.
b) In the analysis, all relevant sources are looked up, and the proposed system is assessed as a whole. References to the Cloud Firestore database and the Flutter application framework are obtained during the analysis phase. Flutter is a brand-new cross-platform programming language (it can be used to develop applications or software on different platforms). Google invented a NoSQL Cloud Hosted Database called Cloud Firestore.

c) The process and information used to construct the system are determined by the design. The method's design makes use of Adobe XD, a program created especially for designing user interfaces. The following will materialize as a mobile application.
d) Application preparation, data structure creation, hardware assembly, and system use are all parts of Implementation. The results of the design implementation result in a responsive mobile application that is linked to the database.

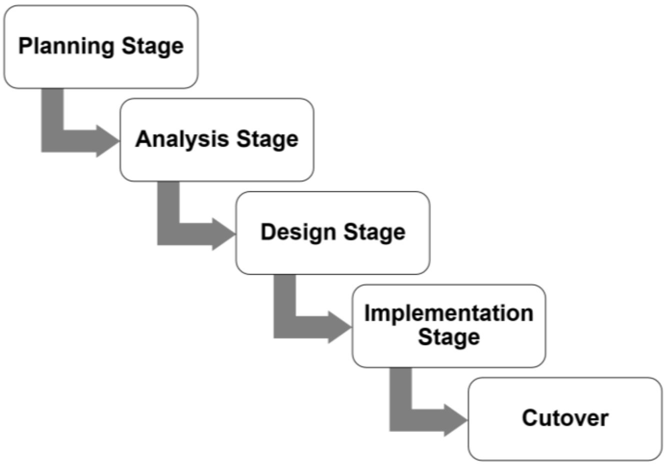

Figure 1. Model development of application

3. RESULTS AND DISCUSSION
3.1. Planning
The planning stage focuses on finding a solution to the issues at hand or figuring out the system's objectives. Due to the issue with the system's lack of transparency, ReSmartTrading was developed. Its primary purpose is to synchronize transaction data across locations and the blockchain system securely.

3.1.1. Analysis
The analysis stage is broken down into three categories: application users, non-functional users, and functional users. Both functional requirements analysis and an overview of the system's reaction process to the input given and performed by the system are critical functions that must be provided in the application.
a. The app can give details on the data on power transactions at each generator.
b. Every time a new transaction takes place, the program can carry out calculations and deliver blockchain code.
c. The application can also show a graph representing the benefits and drawbacks of each site.
d. The following are some non-functional requirements analysis as a tool in application development.
- Software: Google Chrome, Android Studio, Flutter, and Visual Studio Code.
- Computer Hardware With a minimum system of Microsoft Windows 7/8/10 (32-bit or 64-bit), 8 GB RAM, 4 GB Storage, and 1280×800 screen resolution.
- Smartphone with the minimum system of 1 GHz processor, 1 GB RAM, 8 GB internal storage, Android OS version 5.0 (Lollipop), and internet connection.

3.1.2. Design
Flowchart is a diagram that describes the process flow of a program. In create a program, flowcharts play an important role in translating the running process of a program so that it is easier to understand. Flowcharts play an important role in deciding a step or functionality of a programming project that involves many people at once. Flowcharts of the application design are displayed in Figures 2 to 5.

3.1.3. User interface in blueprint
Blueprint is a detailed framework (architecture) as the basis for policy making which includes setting goals and targets, formulating strategies, implementing programs, and focusing activities as well as steps or implementation that must be carried out by each unit in the work environment. The preliminary design of user interfaces prior to their incorporation into the application, as in Figure 6.

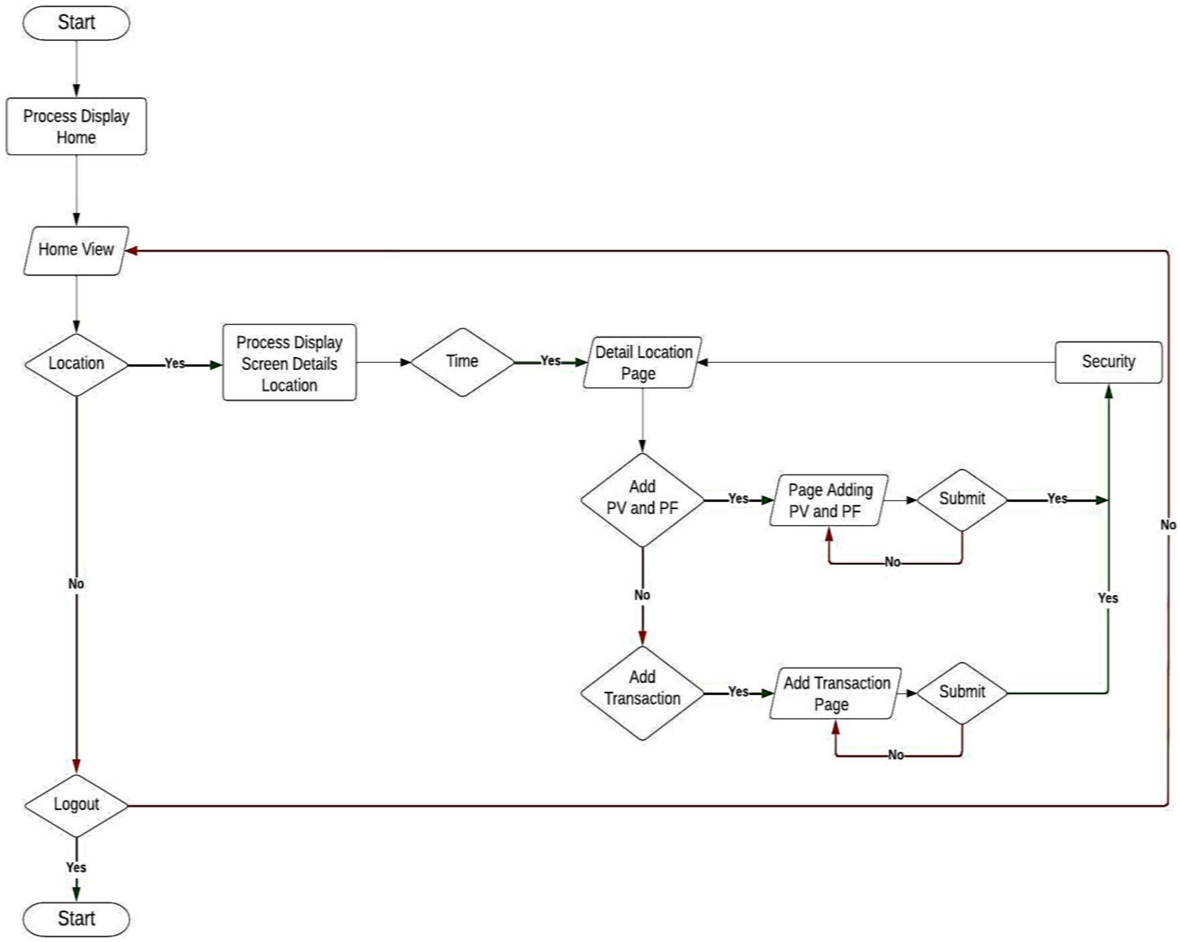

Figure 1. Flowchart application works

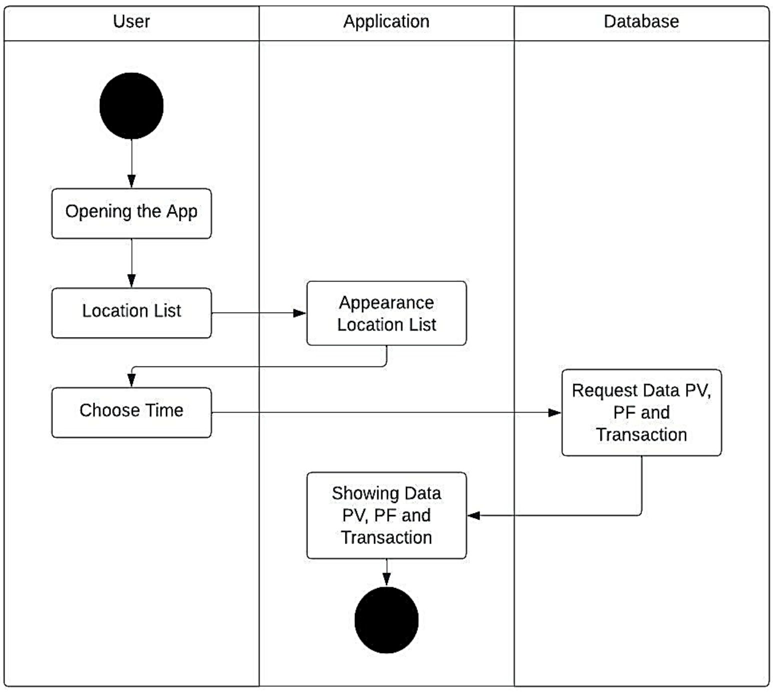

Figure 3. Diagram activity menu locations

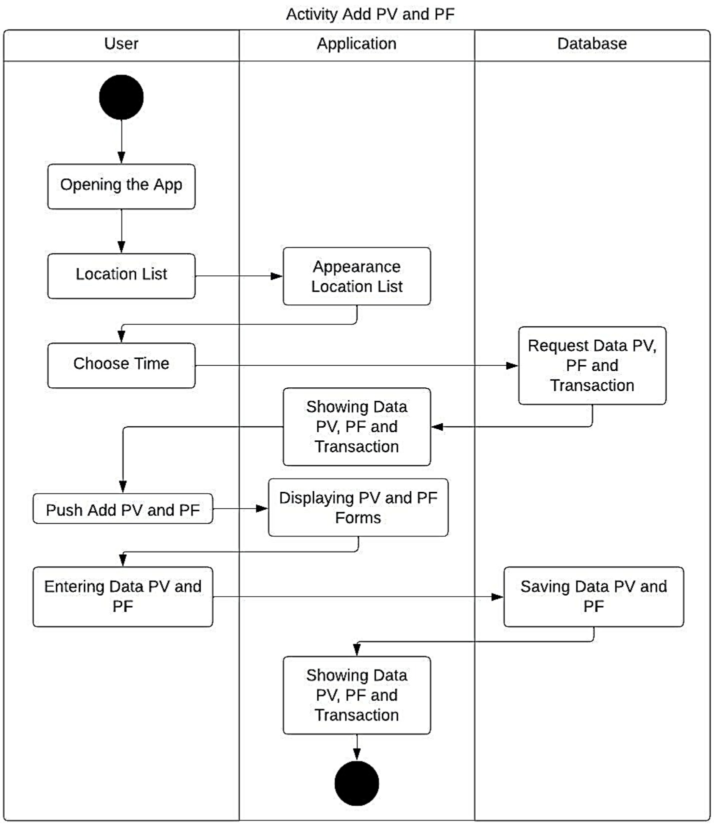

Figure 4. Diagram activity add PV and PF

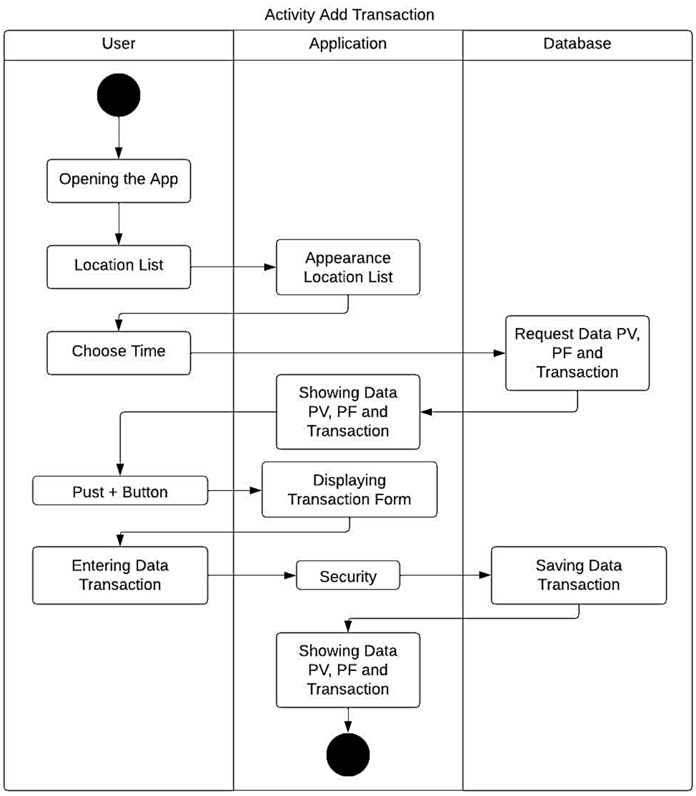

Figure 5. Diagram activity add transaction

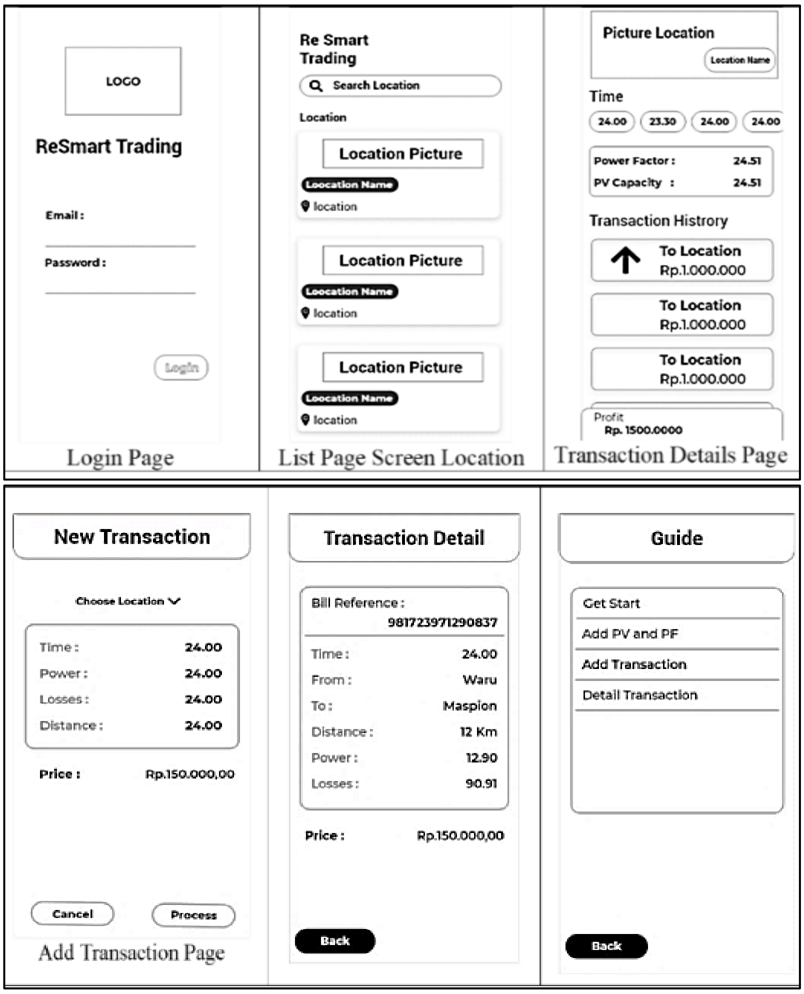

Figure 2. The initial application design

3.1.4. Implementation

Application preparation, data structure creation, hardware assembly, and system use are all parts of Implementation-the Implementation of the design results in a responsive mobile application that is linked to the database. The structure of the Cloud Firestore Database is shown in Figure 7. Collection, Document, Field, and Data are the components of the NoSQL database Cloud Firestore. Various documents with the same use or purpose make up the collection. The field represents data or the contents of documents that may be accessible in letters, numbers, maps, and lists, whereas the document represents a set of information.

3.1.5. User interface application

The user interface is the process of creating a display or display on a computer device or software that focuses on design. The user interface is important to meet user expectations and support site functionality effectively. A well-executed UI can also facilitate effective interaction between the user and the program through contrasting visuals and a clean design. Users can see, add, and delete data delivered in real-time, according to the user interface, as in Figures 8-13.

Figure 8 shows the image of the login screen. The applications that are integrated with Cloud Firestore (Authentication) use this interface for authentication to check if a user has an account or not. Figure 9 shows the image of a location list. Users can access the location they want using this interface and the homepage on this page. Figure 10 shows the image of the search location; finding the location is simple thanks to the Search Location UI. Figure 11 shows the add image transaction pop-up. Users add transactions using an interface at a particular place and time. Figure 12 shows the location specifics, which is a location and time detail entered into the database and shown through the interface. Figure 13 shows the transaction details, where the transaction code is shown. Only when both areas involved in a transaction have the same code are transactions possible. In order to prevent duplicate transactions, it is crucial to complete this form.

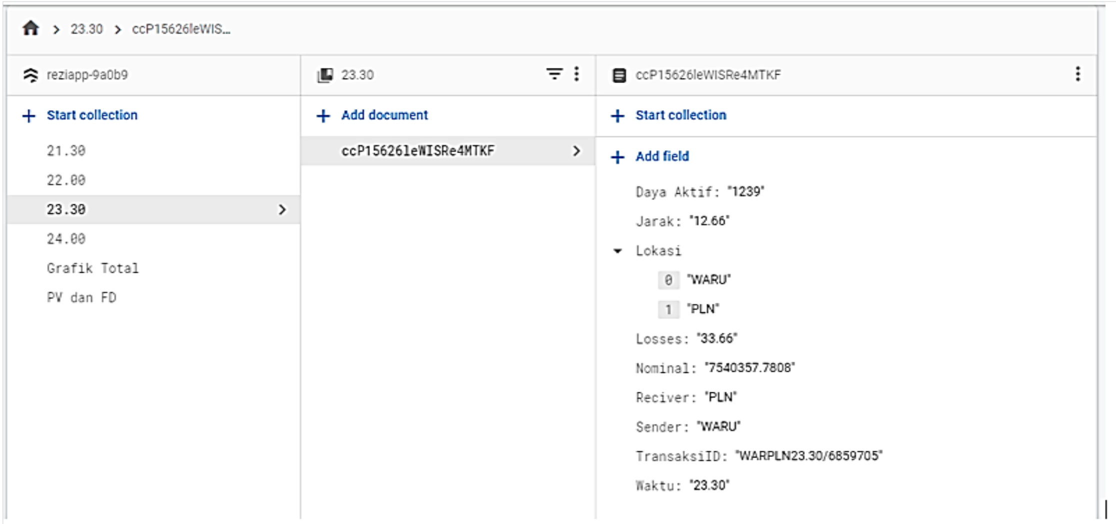

Figure 3. Cloud Firestore database structure

Figure 8. Login screen

Figure 9. Location list

Figure 10. Search location

Figure 11. Transaction popup

Figure 12. Location specifics

Figure 13. Transaction details

A distributed database is created using blockchain technology using blocks and chains to securely store essential data, including contracts, transaction history, production, energy consumption, and consumer data. The public, businesses, and government organizations can more easily track the exchange of electrical energy thanks to the energy trading application. According to the generated energy transaction scenario, the study's findings show that the designed application can record and store grid-to-grid transactions and display profit results as charts. However, as the features still mainly concentrate on tracking profits and losses, there is still room for improvement.

4. CONCLUSION

This study creates a microgrid energy transaction monitoring application. This application will be helpful, mainly if Indonesia introduces free energy trading. Application for tracking energy transactions is crucial to the energy trading process. Therefore, there must be no data leakage during any application use, and the program must be completely safe. Blockchain systems require faster data transfer rates in addition to security in order to provide real-time verification. Future development and research will create applications that will expand the scope of the energy trade or be utilized by all Indonesian power plants, making the user interface more appealing and the application simpler to use.

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