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Prototype Green Energy System for Real Estate Housing Development Based Internet of Everything

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ABSTRACT

Climate change and the crisis of conventional energy resources are two interrelated global issues that severely impact environmental sustainability and economic development. Real estate development using renewable energy is carried out for various reasons involving environmental, economic, and social aspects. Internet of Everything (IoE) is a concept that expands the Internet of Things (IoT), including machine-to-machine, machine-to-person, and person-to-person communications with expanded digital features. The research method is quantitative, with numerical data that can be statistically measured in system performance. The research focuses on developing a prototype architecture of green energy for real estate development to maximize the efficiency of solar energy potential. The research's conclusion holds excellent promise for broader implementation. Solar energy's efficiency and potential can be maximized as a renewable energy source by utilizing the Internet of Everything (IoE) for real-time monitoring, control, and analysis. Additionally, this approach can offer valuable insights for decision-making in energy management going forward.

KEYWORDS *Internet of Everything, Green Energy, Sustainable Energy, MQTT Dashboard, Solar Energy, Real Estate*

INTRODUCTION

Climate change and the crisis of conventional energy resources are two interrelated global issues that seriously impact environmental sustainability and economic development (Hasid et al., 2022). In this study, the author will focus on a prototype for real estate housing development that requires the application of efficient and environmentally friendly energy sources. Real estate development using renewable energy is undertaken for environmental, economic, and social reasons. Based on this study's background and research findings, using solar energy

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in real estate development is the most feasible option. The potential for solar energy in Indonesia is enormous, approximately 4.8 KWh/m2 or equivalent to 112,000 GWp, but only about 10 MWp has been utilized so far. The Indonesian government has issued a roadmap for solar energy utilization, targeting an installed capacity of 0.87 GW or about 50 MWp per year by 2025.

The Internet of Everything (IoE) is a concept that expands the Internet of Things (IoT) by encompassing machine-to-machine (M2M) communication, machine-to-person (M2P) communication, and person-to-person (P2P) technology-assisted communication with expanded digital features. It includes various devices, equipment, and objects connected to the global internet. IoE consists of four components: people, processes, data, and things, to create more relevant and valuable connections. These components enable us to create new capabilities, broad experiences, and economic opportunities for individuals and businesses. IoE connects people in more relevant and valuable ways, delivers the correct information to the right person and machine at the right time, leverages data into more useful information for decision-making, and connects physical devices and objects through the Internet of Things (IoT) (Sivakumar & Kumar, 2021).

IoE enables devices and systems to interact and share data, allowing us to make better decisions and improve efficiency in various aspects of life. The application of IoE in the development of solar energy sources in real estate could not only increase energy efficiency but also create a more sustainable and cost-effective environment. Based on the theoretical review, IoE could maximize the potential of solar energy to enhance the efficiency and management of solar energy resources in the context of green energy development in real estate housing development.

The primary objective of the research is to create a model for sustainable energy infrastructure specifically designed for the construction of real estate developments. The research uses quantitative methodologies with the Rapid Application Development (RAD) system development methodology. The system development protocol is based on the Message Queuing Telemetry Transport (MQTT). MQTT is known for its diverse uses in the field of IoT, encompassing environmental monitoring, home automation, and renewable energy systems. The research utilized the open-source Thingsboard Community Edition (CE) as the MQTT solution, which is known for its dependable management of MQTT.

This research paper's organizational framework is presented in the subsequent sections. Section 2 comprehensively explains the related prior research in this field and delineates the various concepts employed in the current research. Section 3 provides a comprehensive explanation of the research methods used in this research. Section 4 provides a detailed explanation of the system development technique employed in the system's conception. Section 5 provides an in-depth analysis of the precise hardware and software specifications utilized during the system development process. Section 6 explains the structure and idea behind the residential property used in the system development concept. Section 7 delineates the specific electrical energy demands necessary for the architectural concept of solar energy generation to achieve self-sufficiency in electricity.

Research includes the development of concepts for the environment and dwelling. Section 8 comprehensively explains the specific device specifications necessary for generating solar power, which are determined through research on electrical power needs. Section 9 comprehensively explains the infrastructure and independent electrical network ideas related to solar energy generation and power utilization in electronic devices. Section 10 provides a graphical illustration that displays the tangible elements of the system and their interconnections. Section 11 explains the seamless collaboration between hardware and software through integrated processes and system procedures. Section 12 will explain the findings and suggest possible avenues for future research. Section 13 provides a comprehensive analysis of the findings and the significant impact of the research that has been implemented.

Information and computer technology improve the control, management, and optimization of wind power and photovoltaic solar energy technology, significantly impacting renewable energy sources (Kangas et al., 2021). By connecting various parts of the building with sensors and specialized devices that could interact with each other through the internet, we could make homes more intelligent and more connected. People could have a better living experience because they could gain more insights into the condition of their homes (Hildayanti & Machrizzandi, 2020). In the transition from smart homes to sustainable cities, smart cities must address obstacles such as better infrastructure and new strategies for energy requirements to manage energy more (Kim et al., 2021).

Energy management systems could help balance the supply and demand of electricity, reducing issues such as power outages by efficiently managing resources like solar panels and wind power. These systems are crucial for maintaining a stable and effective power grid (Khan et al., 2022). By using various combinations and methods of machine learning approaches, it is possible to identify and rectify different types of data issues, such as missing data and incomplete information, more effectively (Kasaraneni et al., 2022). Using specialized computer languages and tools could help various intelligent city components, such as traffic lights and buses, work together more efficiently. The Internet of Everything (IoE) is critical to creating an innovative, environmentally friendly, resilient city against natural disasters (Pliatsios et al., 2023). Developing energy-efficient techniques for Wireless Sensor Networks (WSNs) is crucial for enabling the Internet of Things (IoT) and reducing energy waste in IoT applications (Farhan et al., 2021).

The Data Analysis Task Autonomy Cycle highlights the importance of specific tasks such as monitoring, analysis, and decision-making to enhance energy efficiency in smart buildings (Aguilar et al., 2021). The Internet of Energy has the potential to revolutionize power systems by enabling advancements in renewable energy integration, large-scale energy storage, system operations and protection, demand response programs, microgrids, plug-in electric vehicles with vehicle-to-grid (V2G) capabilities, and residential energy management in smart buildings (Shahinzadeh et al., 2019). Practical and systemic changes in the real estate industry to adapt to the advancements brought by Real Estate 4.0 technology ensure improved user experience and preservation of investment value (Starr et al., 2021). Real estate developers implementing green building practices are likelier to use IoT technology to create intelligent and energy-efficient buildings, as they see it could help reduce various energy supply costs (Cuc et al., 2023).

IoT-based monitoring systems offer practical solutions to challenges such as inaccurate billing and high electricity costs in rental homes, empowering users to manage their energy consumption more efficiently (Msimbe et al., 2022). Integrating solar energy devices with buildings through IoT wireless sensor networks and Zigbee has been identified as an important step in enhancing the efficiency and effectiveness of distributed solar energy systems (Wu et al., 2022). Property market value increases with greater flexibility in energy management, highlighting the importance of Smart Grid in enhancing market value due to higher flexibility in production and consumption (D'Alpaos & Moretto, 2019). The research indicates that the IMCF+ framework effectively balanced the environmental benefits of reduced CO2 emissions with users' comfort requirements in intelligent buildings (Constantinou, 2021).

The metaheuristic algorithms notably increased the utilization of photovoltaic (PV) energy for self-consumption, leading to reduced power costs while maintaining a balance between client comfort satisfaction and economic expenses in the green building energy system (Wang et al., 2023). Existing IoT-based PV systems typically focus on monitoring or maintaining PV panels and specific parameters like temperature and voltage, needing more capability to automate utility control on-premises. In contrast, the proposed IoT system provides monitoring and maintenance and enables automatic control of utilities based on user-defined priorities, showcasing superior performance in load automation (Uzair et al., 2022). IoT-based energy management system for intelligent green buildings consists of three main phases: measuring power consumption, forecasting power consumption, and face recognition (Mahmoud et al., 2022). The necessity of advancing sustainable Internet of Things (IoT) devices by emphasizing eco-friendly manufacturing, sustainable energizing, and wireless connectivity for developing next-generation IoT systems (Rahmani et al., 2023). The application of fuzzy logic-based expert systems in several areas of solar energy has demonstrated their versatility and potential in this field (Sridharan, 2022).

RESEARCH METHOD

The research method used in this study is quantitative, involving the collection and statistical analysis of numerical data. It will utilize experiments and structured trials to measure the prototype's performance. An IoE electricity prototype in a residential real estate area will be used as the research object, harnessing solar energy potential as a renewable energy source. Data collection methods and research references include using literature study methods from several online journals indexed by Sinta or Scopus and collecting experimental data through analysis results from system development conducted through an experiment with controlled variables. Figure 1 shows the conceptual framework that delineates the step-by-step progression of this research, starting from topic selection and culminating in the journal's publication.

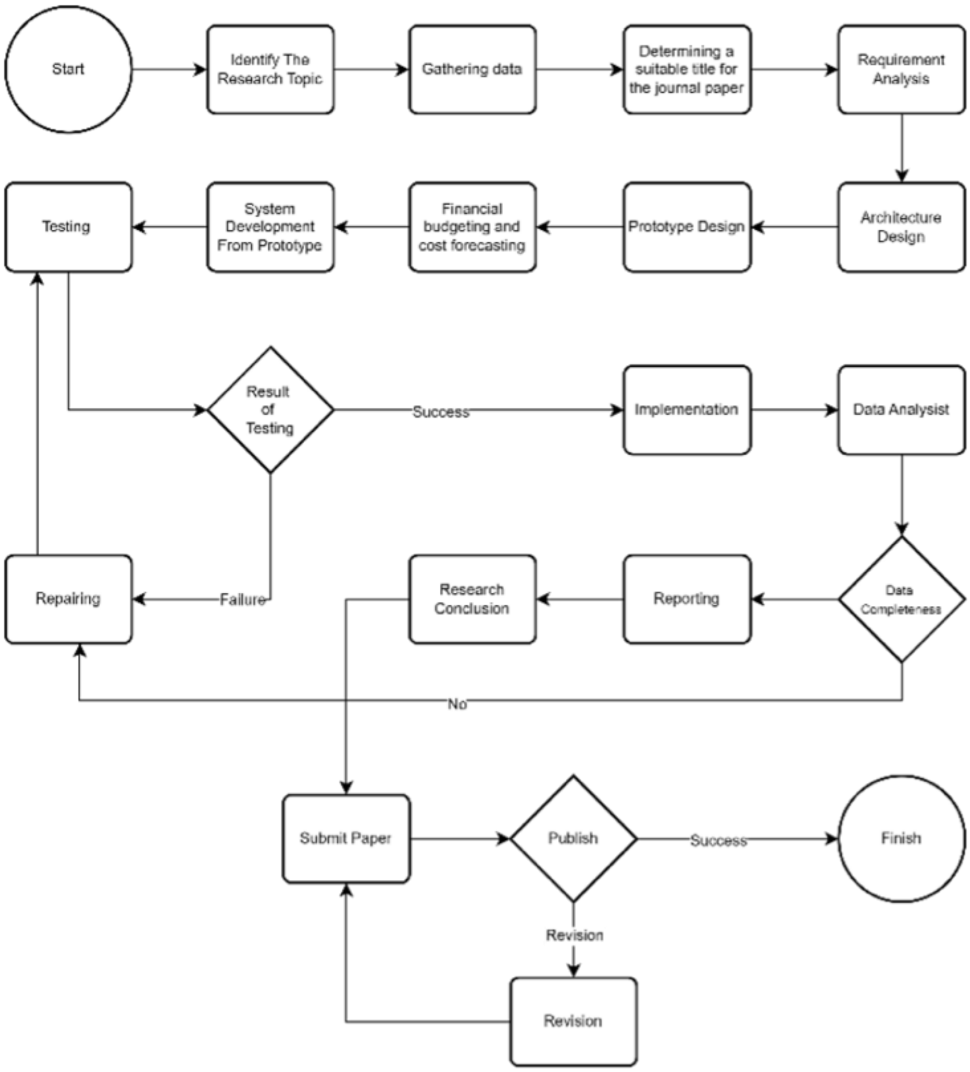

Figure 1. Conceptual Framework

RESULT AND DISCUSSION

Hardware and Software Requirements

Examining hardware and software requirements guarantees that the chosen hardware and software fulfill functional and non-functional criteria while preventing the acquisition of overly costly or inappropriate equipment. From Table 1, Hardware and from Table 2, software requirements will be divided into photovoltaic systems, microcontrollers, MQTT platform servers, and client devices requirements.

Table 1. Hardware Requirements

No	Photovoltaic	Microcontrollers
1	Mono Solar Panel	Nodemcu ESP8266

2	Solar Controller Charge	INA219
3	Photovolatic Cable	BH1750
4	DC to AC Inverter 220 Volt	DHT22
5	LifePo4 Battery	Relay 3.3 VDC
6	MC4 Cable Connector Socket	ZMPT101B
7	Automatic Transfer Switch (ATS)	Real Time Clock (RTC)

Table 2. Software Requirements

No	MQTT Server	Software Development
1	VPS 2 VCPU 1,8 Ghz	Arduino IDE 1.8
2	VRAM 3GB	Visual Studio Code
3	Virtual SSD 40 GB	Thingsboard CE Web 2.6.4
4	Bandwidths 1TB per Month	Thingsboard CE Mobile 1.1.0
5		Flutter Framework
6		Gitlab

Analysis of property and residential architecture

This concept entails the construction of 43 exemplary residences, which will be organized into three distinct clusters labelled A, B, and C. The land area measures 4,752 square meters, with a width of 66 meters and a length of 72 meters. The housing type is a one-gate cluster structure characterized by a solitary front gate and a road row width of 6 meters. The dwellings to be constructed have a land area of 72 square meters and a construction space of 48 square meters. Solar photovoltaics will ultimately meet the electricity demand of the residential area. The household electricity will be provided by solar photovoltaic, with the assistance of a 1300-watt conventional electricity source of the off-grid kind. Figure 3 shows the site architecture of the residential land based on the analysis provided earlier.

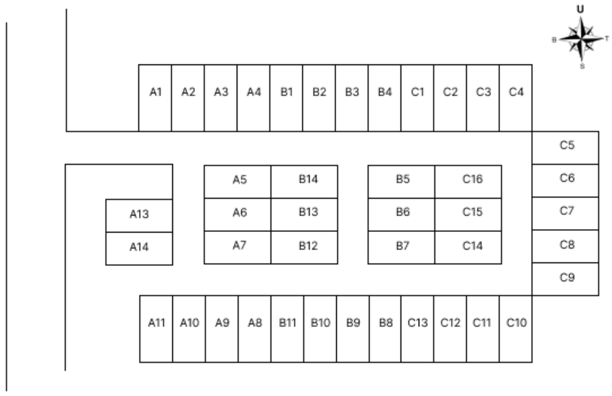

Figure 2. Site Plan for Residential Clusters

Analysis of electric energy requirements

The architecture will be categorized into two segments: power demands for the environment or residential clusters and electricity demands for individual dwellings. Accurately determining the electricity requirements is essential for specifying the appropriate amount and power rating of devices necessary for designing the system.

Analysis of electric energy requirements for residential clusters

Table 3 shows the analysis of the electric energy requirements for residential clusters.

Table 3. Analysis of Electric Requirements for Residential Clusters

No	Device	Power	Quantity	Total Power (w)	Hour	Total Power in Hour (w)
1	Street Light	15	27	405	12	4,860
2	CCTV IP	5	27	135	24	3,240
3	IoE Device	5	30	150	24	3,600
4	Wifi Router	10	7	70	24	1,680
5	Electronic Security Guard Room	240	1	240	24	5,760
	Total Power Consumption (watt)			1,000		16,224

From Table 3, the total power requirement for residential clusters amounts to 1,000 watts, and the total power consumption of the devices operating 24 hours a day is 16,224 watts.

Analysis of electric energy requirements for residential homes

Table 4 shows the examination of the electrical energy needs for residential homes.

Table 4. Analysis of Electric Requirements for Residential Homes

No	Device	Power	Quantity	Total Power (w)	Hour	Total Power in Hour (w)
1	Garage Lamp	15	1	15	12	180
2	Living Room Lamp	15	1	15	7	105
3	Kitchen Lamp	15	1	15	12	180
4	Main Bedroom Lamp	15	1	15	7	105
5	Child Bedroom Lamp	10	1	10	7	70
6	Back Outdoor Lamp	10	1	10	12	120
7	Toilet Lamp	5	1	5	5	25
8	Television	50	1	50	6	300
9	Router Access Point	10	1	10	24	240
10	AC Main Bedroom	330	1	330	10	3,300
11	AC Child Bedroom	330	1	330	10	3,300
12	Dispenser	200	1	200	24	4,800
13	Blender	180	1	180	1	180
14	Microwave	450	1	450	1	450
15	Refrigerator	170	1	170	24	4,080

16	Rice Cooker	350	1	350	2	700
17	Washing Machine	400	1	400	1	400
18	Electric Iron	200	1	200	1	200
19	IoE Device	5	17	85	24	2,040
20	Others	10	1	10	24	240
	Total Power Consumption (watt)			2,850		21,015

From Table 4, the total power requirement for a residential home amount to 1,000 watts, and the total power consumption of the devices operating 24 hours a day is 21,015 watts.

Analysis of Photovoltaic Components Requirements

The next step is determining the electrical power and how much power and devices are needed. This research will use an electrical circuit with a parallel type because if one component fails, the other components will still function as they are connected in parallel and have separate paths for electrical flow.

Analysis of Solar Panel Requirements

The electrical energy generated by solar panels cannot be fully utilized, as there is approximately a 40% loss of electrical energy during transmission from the solar panels to the load. Therefore, the power generated is only 60% of the total power absorbed by the solar panels [25]. (Yen & Davis, 2019)

$$Wd \times 60\% = Wb \qquad (1)$$

Where:
Wd is Total require power (watt)
60% is Total of result of loss electrical energy
Wb is Total load power (watt)

During this research, the solar panel with the highest power and competitive price is a 540-watt peak solar panel with a power of 40 watts and a voltage of 13.27 amperes. The optimal photovoltaic process only occurs for 5 hours [25]. Therefore, the following calculation could be used to calculate the number of solar panels used. (Utami & Wijayanti, 2022).

$$Ps = \frac{Wd}{5 \times Ws} \qquad (2)$$

Where:
Ps is Total unit for required solar
Wd is Total power for required solar panel (watt)
Ws is Solar panel power (watt)

Based on the calculation above, 10.01 or 10 units of solar panels are needed for the residential clusters and for 12,97 or 13 unit of solar panels for the residential homes.

Analysis of Solar Control Charge (SCC) Requirements

SCC for residential clusters based on the solar panel requirement calculations, 10 panels will be used, and a parallel circuit configuration will be employed for the electrical installation. Therefore, 40 volts and a current of 132.7 amperes (13.27 amperes per panel x 10 panels) will be needed. During this research, the available solar charge controllers in the market are 10 amperes, 30 amperes, 60 amperes, 80 amperes, and 100 amperes. Therefore, the researcher will divide the electrical circuit into two paths, splitting the 132.7 amperes into two, each carrying 66.35 amperes. As a result, two 80-ampere SCC units will be used. Figure 4 shows the scc relation with solar panel for residential clusters.

SCC for residential homes based on the solar panel requirement calculations above, 13 panels will be used, and a parallel circuit configuration will be employed for the electrical installation. Therefore, a voltage of 40 volts and a current of 172.51 amperes (13.27 amperes per panel x 13 panels) will be needed. During this research, the available solar charge controllers in the market are 10 amperes, 30 amperes, 60 amperes, 80 amperes, and 100 amperes. Therefore, the researcher will divide the electrical circuit into two paths, splitting the 172.51 amperes into two, each carrying 86.25 amperes. As a result, two 100-ampere SCC units will be used. Figure 5 shows the scc relation with solar panel for residential homes.

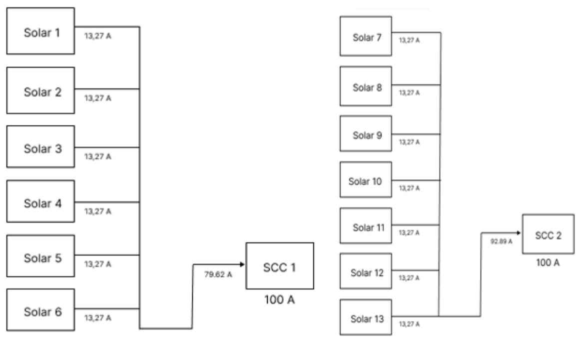

Figure 3. SCC Relation With Solar Panel for Residential Clusters

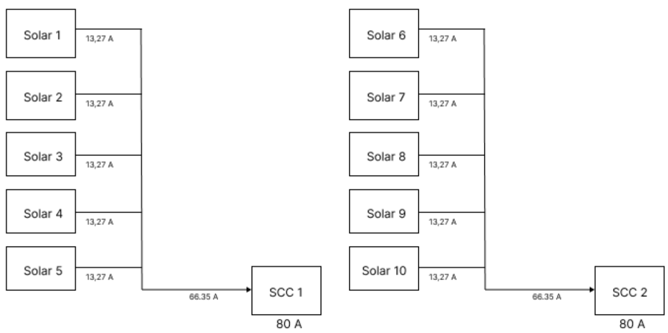

Figure 4. SCC Relation With Solar Panel for Residential Homes

Analysis of Solar Cable Requirements

Cables are essential elements in the installation of Photovoltaic systems. They connect solar panels, inverters, and batteries. Optimal cables and appropriate connectors guarantee seamless and effective electrical conductivity throughout the Photovoltaic system. Table 5 shows the suitable cable diameter sizes correlating to the discharge electrical currents. Following the rules, it is imperative to ensure that the cable sizes and electrical currents are compatible to avoid electrical resistance and short circuits.

Table 5. Solar Cable Diameter Size for Maximum Current

No	Cable Diameter (mm^2)	Maximum Current (A)
1	0.75	12
2	1.00	15
3	1.5	18
4	2.5	26
5	4.0	34
6	6.0	44
7	10	61
8	16	82
9	25	108
10	35	135
11	50	168

Source : (Utami & Wijayanti, 2022) *[26]*

Solar Cable required for residential clusters based on the research on SCC requirements, the total current flowing to the SCC is 66.35 amperes. According to the cable size reference in Table 5, a cable with a diameter of 16 mm^2 will be used.

Solar Cable required for residential homes based on the research on SCC requirements, the total current flowing to the SCC is 86.25 amperes. According to the cable size reference in Table 5, a cable with a diameter of 35 mm^2 will be used.

Analysis of Battery Requirements

Solar panels will charge the battery during the day, so it will fully utilize the battery's energy at night. This research will use a LifePO4 battery with a voltage of 48 volts and a current of 100 Ah. The battery energy cannot be fully utilized, as the inverter potentially loses 20% of the energy. Therefore, an additional 20% reserve is needed, making the usable battery capacity 80% [25].

$$Tb = \frac{Wd}{(Wb \times Ab) \times 80\%} \tag{3}$$

Where

Tb is Total unit for required battery
Wd is Total power electricity in residential clusters or homes (watt)
Wb is Battery voltage capacity (48 volts)
Ab is Battery current capacity (100 ampere)

Battery required for residential clusters based the calculation above shows that 4.2 units round up to 5 units of 48-volt 100 Ah.

Battery required for residential homes based the calculation above shows that 5.4 units round up to 6 units of 48-volt 100 Ah.

Analysis of DC to AC Inverter

The devices' total power for residential clusters is 1,000 watts, based on the total power from Table 3 Analysis of Electric Requirements for Residential Clusters. Therefore, the inverter to be used will be a 1,000-watt inverter with a voltage of 48 volts. The devices' total power for residential homes is 2,850 watts, based on the total power from Table 4 Analysis of Electric Requirements for Residential Homes. Therefore, the inverter to be used will be a 3,000 watts inverter with a voltage of 48 volts.

Electric Power Grid Infrastructure

The system's architecture design refers to the process of planning the structure and components of an information system. This research divides the architecture design into two parts, residential clusters and homes.

Electric Power Grid Infrastructure for Residential Clusters

Figure 6 shows the electric power grid infrastructure implemented in this research, where solar energy will cover the electricity for the entire environmental area. Below is the site plan for the environmental area:

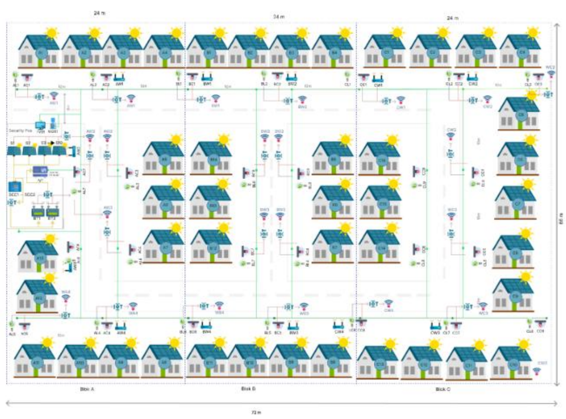

Figure 5. Electric Power Grid Infrastructure for Residential Clusters

Including notations on the solar power generator blueprints is crucial for conveying precise and organized instructions regarding installing and configuring solar power generation systems. Table 6 shows the blueprint, and the symbol notations for the residential clusters site plan concept are included.

Table 6. Symbol Notation for Electrical Power Grid for Residential Clusters

No	Notation	Description
1	(A1, A2, A3 …, Ay)	Home Block A number 1 and so on
2	(B1, B2, B3 …, By)	Home Block B number 1 and so on
3	(C1, C2, C3 ..., Cy)	Home Block C number 1 and so on

4	(SP1, SP2, SP 3 ..., SPy)	Environmental Solar Panel number 1 and so on
5	(SCC1, SCC2)	Environmental SCC (Solar Charge Controller) number 1 and 2
6	(BT1, BT2, BT3 …, BTy)	Environmental LifePo4 Batteries number 1 and so forth
7	(IV1)	DC to AC Inverter for the Environment
8	(AL1, AL2, AL3 …, ALy)	Street lighting in Block A, starting from number 1 onwards
9	(BL1, BL2, BL3 …, BLy)	Street lighting in Block B, starting from number 1 onwards
10	(CL1, CL2, CL3 …, CLy)	Street lighting in Block C, starting from number 1 onwards
11	(AC1, AC2, AC3 …, ACy)	IP CCTV cameras in Block A, starting from number 1 onwards
12	(BC1, BC2, BC3 …, BCy)	IP CCTV cameras in Block B, starting from number 1 onwards
13	(CC1, CC2, CC3 …, CCy)	IP CCTV cameras in Block C, starting from number 1 onwards
14	(AW1, AW2, AW3 …, AWy)	Access Point in Block A, starting from number 1 onwards
15	(BW1, BW2, BW3 …, BWy)	Access Point in Block B, starting from number 1 onwards
16	(CW1, CW2, CW3 …, CWy)	Access Point in Block C, starting from number 1 onwards

Electric Power Grid Infrastructure for Residential Clusters

This prototype utilizes middle to lower-class residences as the fundamental concept, featuring building proportions of 48 m² and a land area of 72 m². The residence is separated into multiple sections, including a garage, a garden, a living room, a kitchen, a main bedroom, a children's bedroom, a backyard garden, and a restroom. Figure 7 shows the electric power grid infrastructure implemented in this research, where solar energy will back up conventional electricity for the house area. Below is the site plan for the house area.

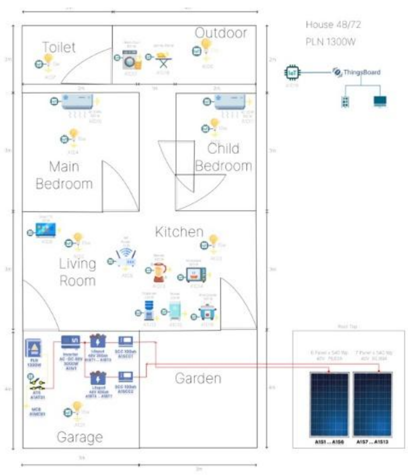

Figure 6. Electric Power Grid Infrastructure for Residential Homes

Including notations on the solar power generator blueprints is crucial for conveying precise and organized instructions regarding installing and configuring solar power generation systems. Table 7 shows the blueprint, and the symbol notations for the site plan concept are included with A_n (Notation for **n** is a number of homes with numbers 1 to 43).

Table 7. Symbol Notation for Electrical Power Grid for Residential Homes

No	Notation	Description
1	(A_nS_1, A_1S_2, A_1S_3, ... A_1Sy)	Solar Panel
2	(A_nSCC_1, A_1SCC_2)	Solar Controller Charge
3	(A_nBT_1, A_1BT_2, A_nBT_3, ... A_1BTy)	Battery LifePO4
4	(A_nIV_1)	Inverter DC to AC
5	(A_nATS_1)	Automatic Transfer Switch (ATS)
6	(A_nMCB_1)	MCB
7	(A_nD_1)	Garage Lamp
8	(A_nD_2)	Living Room Lamp
9	(A_nD_3)	Kitchen Lamp
10	(A_nD_4)	Main Bedroom Lamp
11	(A_nD_5)	Child Bedroom Lamp
12	(A_nD_6)	Back Outdoor Lamp
13	(A_nD_7)	Toilet Lamp
14	(A_nD_8)	Television
15	(A_nD_9)	Access Point Router
16	(A_nD_{10})	AC Main Bedroom
17	(A_nD_{11})	AC Child Bedroom
18	(A_nD_{12})	Dispenser
19	(A_nD_{13})	Blender
20	(A_nD_{14})	Microware
21	(A_nD_{15})	Refrigerator
22	(A_nD_{16})	Rice Cooker
23	(A_nD_{17})	Washing Machine
24	(A_nD_{18})	Electric Iron
25	(A_nD_{19})	IoE Device
26	(A_nD_{20})	Others

Physical Diagram Of The Electric Power Grid

The diagram is a visual representation that shows the physical components of a system and how these components are interconnected. This diagram will depict the hardware used in the system, including solar panels, inverters, batteries, and other elements that contribute to the overall system operation.

Physical Diagram for Residential Clusters

Figure 8 and 9 shows a diagram illustrating the hardware used in the system installed in the environment. Here is the diagram for residential areas.

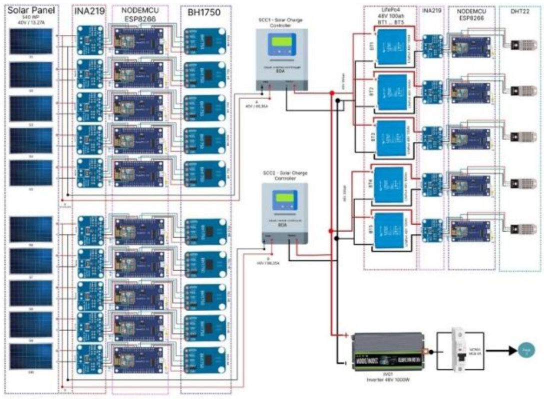

Figure 7. Physical Diagram for Residential Clusters Part 1

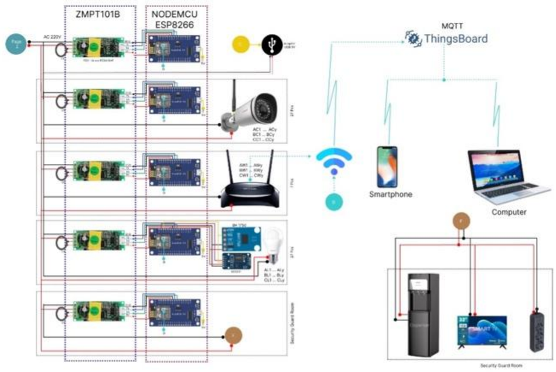

Figure 8. Physical Diagram for Residential Clusters Part 2

Physical Diagram for Residential Homes

Figure 10 to 12 shows the diagram that will illustrate the system installed in the residential home area. For example, it will be used in-house with the notation A1 (A_n) as follows:

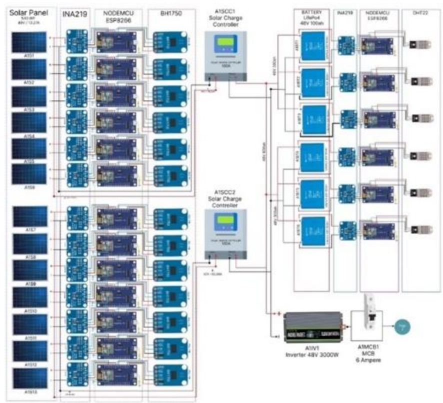

Figure 9. Physical Diagram for Residential Homes Part 1

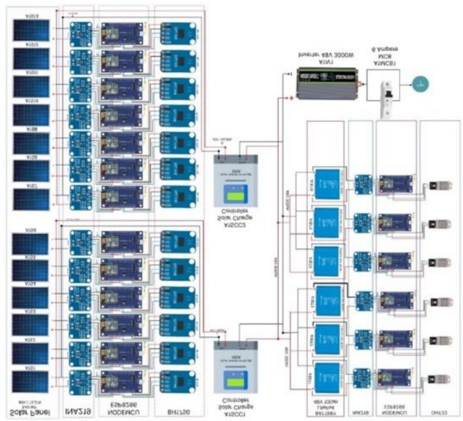

Figure 10. Physical Diagram for Residential Homes Part 2

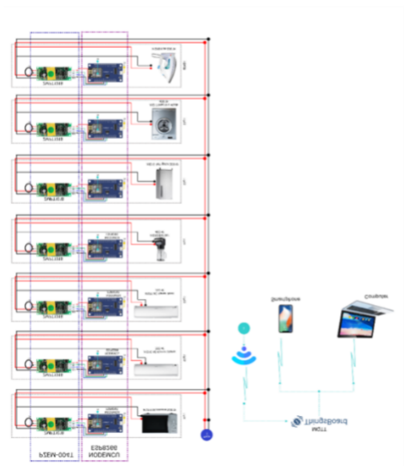

Figure 11. Physical Diagram for Residential Homes Part 3

Identification of Connected Sensor

Table 8 shows the integrated system between device components and MQTT Dashboard platform, the required sensors, and data.

Table 8. Identification of Connected Sensor

No	Sensor	Function
1	BH1750	• Identifying the optimal times for solar energy absorption • Efficiency of the light through the intensity of light
2	INA219	• We identify solar panel quality through the voltage generated from solar energy absorption. • Knowing the power (P) and current (A) output during usage • Identifying light quality through voltage. • Total electrical power usage of lamps during operation • Determining the total electrical power consumption of the cctv during the usage of the system. • Determining the total electrical power consumption of the router during the usage of the system.
3	DHT22	• Monitoring battery temperature performance

4	Relay	• Controlling the device on/off

Integrating with IoE using the MQTT Dashboard

Figure 12. MQTT Publish / Subscribe Architecture

Integrating the electric power grid with the IoE through an MQTT dashboard entails establishing a system where data from the electrical grid can be collected, communicated, and displayed in real time. MQTT is a messaging protocol for the IoT standardized by OASIS. This message transport's design is optimized for linking remote devices with limited code size and network capacity, making it highly suitable for lightweight publish/subscribe communication. MQTT is currently employed in several industries, including automotive, manufacturing, telecommunications, oil and gas, and more [27]. Figure 13 shows the process of the MQTT platform to publish or subscribe architecture. (Idris, 2019)

Thingsboard Community Edition (CE) for MQTT Dashboard

Thingsboard is an open-source IoT platform that enables rapid development, management, and scaling of IoT projects. Our goal is to provide the out-of-the-box IoT cloud or on-premises solution that will enable server-side infrastructure for your IoT applications [28]. At this research's time, the latest version is version for web application version is 3.6.4 and the mobile app version is 1.1.0. For the installation and configuration process, please refer directly to its documentation at https://thingsboard.io/docs/installation. Some advantages gained when using the CE version include:

- **Open-Source**: Thingsboard CE is an open-source IoT platform, allowing users to access its source code, modify it as needed, and contribute to community development.
- **Active Community**: Thingsboard CE has an active community that provides technical support, shares knowledge, and collaborates on developing new features and improvements.

While some drawbacks of using the CE version include:

- **Feature Limitations:** Some features and functions may not be as comprehensive or robust as those in the Enterprise version. Limitations could be problematic, especially for large projects requiring deeper integration or greater scalability.
- **Integration Limitations:** The ability to integrate with specific systems or technologies may not be as extensive as the Enterprise version, which could be a deciding factor in choosing an IoT platform for specific solutions.

Identification of User Role Login

Table 9 shows the MQTT Dashboard platform's three main roles: system administrator, tenant, and customer. The integration between residents and managers is based on mapping into the MQTT Dashboard platform.

Table 9. Identification of User Role of MQTT Platform

No	Role	Function
1	System Administrator	• Tenant Management • Customer and User Management • Dashboard Summary • Setting and Security Application
2	Tenant	• Integration and, Control of device. • Customer and User Management • Device information • Dashboard Summary • Setting Application
3	Customer	• Controlling Home Devices Independently • Device information • Dashboard Summary

Integration Process into MQTT Dashboard

A token from the MQTT Dashboard is required to link the devices and sensors to the system and establish a connection to MQTT. This token is a unique key for connecting devices and sensors to MQTT. Figure 14 shows the integration process flow between devices and the MQTT Dashboard platform. MQTT Dashboards are extensively utilized in IoT applications for effective communication and data presentation. Figure 14 shows the following the processes and system interactions of the MQTT Publish and Subscribe, allowing the user to control and analyze data and information from devices connected to the MQTT Dashboard.

In this research, the result of the prototype is implementation and testing will be conducted through a model of the residential clusters in Block A and residential home for number A1, each using 2 electronic devices simulation tools. Implementing an MQTT platform entails establishing the essential framework for communication between IoT devices and a central server. MQTT platform could enable data collection, processing, and visualization. The following is the implementation of the MQTT Dashboard based on Table 8 User Role Identification.

MQTT Dashboard has extensive user management capabilities, enabling administrators to regulate access and permissions for different users and roles in the platform. Table 10 shows the following is the implementation for all users for example to MQTT Dashboard Management Users.

Table 10. Users Management MQTT Dashboard

No	User	Role

1	sysadmin@bioenergi.xyz	System Administrator
2	tenant@bioenergi.xyz	Tenant
3	a1@bioenergi.xyz	Customer (for Residential Homes A1)
4	cluster@bioenergi.xyz	Customer (for Residential Clusters)

Implementation of Customers Management

Using the MQTT Dashboard, renters may effectively manage clients, enabling them to arrange and regulate resource access for various user groups. Table 11 shows the implementation for customers management for MQTT Dashboard.

Table 10. Customers Management MQTT Dashboard

No	Customer	Description
1	A1	Customer for Block A No.1
2	Cluster	All the residents of the house

Implementation of Devices Management

Devices encompass tangible and intangible interconnected entities inside a network, including monitoring sensors, intelligent devices, machinery, and additional sensors. These devices could gather data such as temperature, humidity, and GPS coordinates and transmit it to the MQTT platform. Table 12 shows the implementation for connected devices to the MQTT platform.

Table 11. Devices Management MQTT Dashboard

No	Label	Customer	Description
1	AL1	Cluster	Light Street Blok A Number 1
2	AL2	Cluster	Light Street Blok A Number 2
3	S1	Cluster	Solar Panel for Clusters Number 1
4	BT1	Cluster	Battery for Clusters Number 1
5	A1S1	A1	Solar Panel for Home Blok A Number 1
6	A1BT1	A1	Battery for Home Blok A Number 1
7	A1D2	A1	Living Room Lamp Blok A Number 1
8	A1D10	A1	AC Main Bedroom Blok A Number 1

Implementation of Summary Dashboard

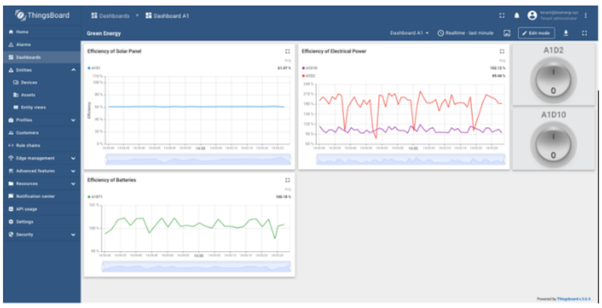

Figure 14. Dashboard User Interface MQTT Dashboard

MQTT Dashboard's user interface, which allows users to control devices and view summarized efficiency information in the chart or summary table. Figure 14 shows the following is the implementation for the MQTT dashboard.

Implementing a summary dashboard to monitor the electric power grid using MQTT requires establishing a system that collects, transmits, and shows real-time data from the power grid on a dashboard. The implementation of a summary dashboard with MQTT could efficiently monitor the electric power grid, allowing for real-time visualization and management of power grid characteristics. Figures 14 show the MQTT Dashboard's concept from MQTT Dashboard for sample to residential clusters and residential home A1, which allows user for customer A1 to control devices and view summarized efficiency information. Table 13 shows example widget from MQTT Dashboard of the capabilities from the user interface of Dashboard Home A1.

Table 12. Capabilities of All Widgets From Dashboard

No	Widget	Function
1	Efficieny of Solar Panel	Monitoring and analyzing many characteristics and metrics to evaluate its capacity to convert sunlight into useful electrical energy.
2	Efficieny of Electrical Device Power	Monitoring ensures the efficient operation of the equipment, reduces energy wastage, and aids in maintaining optimal performance.
3	Efficieny of Batteries	Monitoring the efficiency of batteries involves evaluating their performance in terms of energy storage and conversion efficiency.
4	Control Button A1D2	Widgets that communicate with device with notation A1D2 (Living Room Light) attributes or initiate activities in response to user input.
5	Control Button A1D10	Widgets that communicate with device with notation A1D10 (AC Bedroom) attributes or initiate activities in response to user input.

CONCLUSION

Implementing Internet of Everything (IoE) technology makes monitoring and regulating solar panels in real-time possible, enhancing energy conversion efficiency. The technology could optimize the placement of solar panels to achieve optimal sunlight absorption, even in diverse weather situations. The prototype showcases a dependable Internet of Everything (IoE) system performance with little data transmission delay and a high percentage of operational time. Real-time monitoring and control systems provide rapid reactions to dynamic conditions, ensuring the system operates at its peak performance. The system has been demonstrated to endure severe environmental conditions, such as harsh temperatures, precipitation, and dust. Using IP67 protection standards guarantees that the hardware is adequately safeguarded, ensuring consistent and uninterrupted functionality.

Integrating the Internet of Everything (IoE) offers substantial benefits in enhancing operating efficiency, streamlining maintenance processes, and achieving long-term cost reductions. The utilization of real-time data collecting enables the application of predictive analysis and preventative maintenance, hence improving the dependability and durability of the system. The analysis results indicate that the renewable energy prototype, which harnesses the solar energy potential using the Internet of Everything (IoE) concept, has significant potential for broader application. By implementing real-time monitoring, control, and data analysis through the Internet of Everything (IoE) technology, we could significantly enhance the efficiency and potential of solar energy as a renewable source. This technology also assists in making informed decisions for future energy management.

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