# Cost Analysis of using IoT-Based Power Breakers in Smart Building Lighting Systems

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Publication Date: 2025/06/3

**Abstract: This innovative research delves into the cost analysis of using Internet of Things-based power breakers in smart building lighting systems. The method employed for cost analysis is a meticulous process of planning, comparing, and implementing an Internet of Things-based smart building system using power breakers in building objects. The results of the tests conducted revealed that the cost of IoT-based power breaker equipment for the lighting system was Rp. 14,542,000 and the efficiency of the IoT-based power breaker was 75.33% when compared to Smart Building equipment that uses Direct Digital Control in the building where it is applied.**

***Keywords*: *Cost Analysis, Power Breakers, Internet of Things, Smart Building.***

**How To Site:** Bontor Panjaitan; Eka Nuryanto BS; Bustanul Arifin (2025). Cost Analysis of using IoT-Based Power Breakers in Smart Building Lighting Systems. *International Journal of Innovative Science and Research Technology,* 9(6), 3289-3308. https://doi.org/10.38124/ijisrt/24june266

## I. INTRODUCTION

This research is a response to the pressing need for a control system that is not only cost-effective but also tailored for a system in a smart building. The current development of an IoT system in Indonesia and its affordability serve as the driving force behind this research, underlining its practical implications.

This research aims to analyze costs and find the effectiveness of applying IoT-based power-cutting equipment to smart building lighting systems.[1] [2] [3]

➢ *Theoretical Basis*

The theoretical basis for this research includes:

- Internet of Things
- Building Automation Systems
- Lighting system
- IoT-based power breaker.
- IoT Platforms.

Several outlines can be drawn from the theoretical basis of this research, including:

- *Internet of Things*

It can be seen in a simple IoT picture, where IoT consists of the Internet, Data, and Equipment. It can be seen in the image. 2.1. It can be defined as the Internet of Things, which is any equipment connected to the Internet with some address or data to communicate with other devices via the Internet.[4]

- *Building Automation Systems.*

Automation is the use of mechanical equipment, control systems, and information technology to obtain optimal production results from goods and services. It can be applied if the results are faster or better in quantity than those obtained using human labour.

A building automation system can be interpreted as instrumentation, mechanization, and data aggregation from various building systems to make monitoring and control of building equipment more efficient and automatic to meet the environmental conditions targeted in a building and optimize all equipment use. You can see a simple picture of the building automation system in Figure 1 [2] [5] [6] [7]

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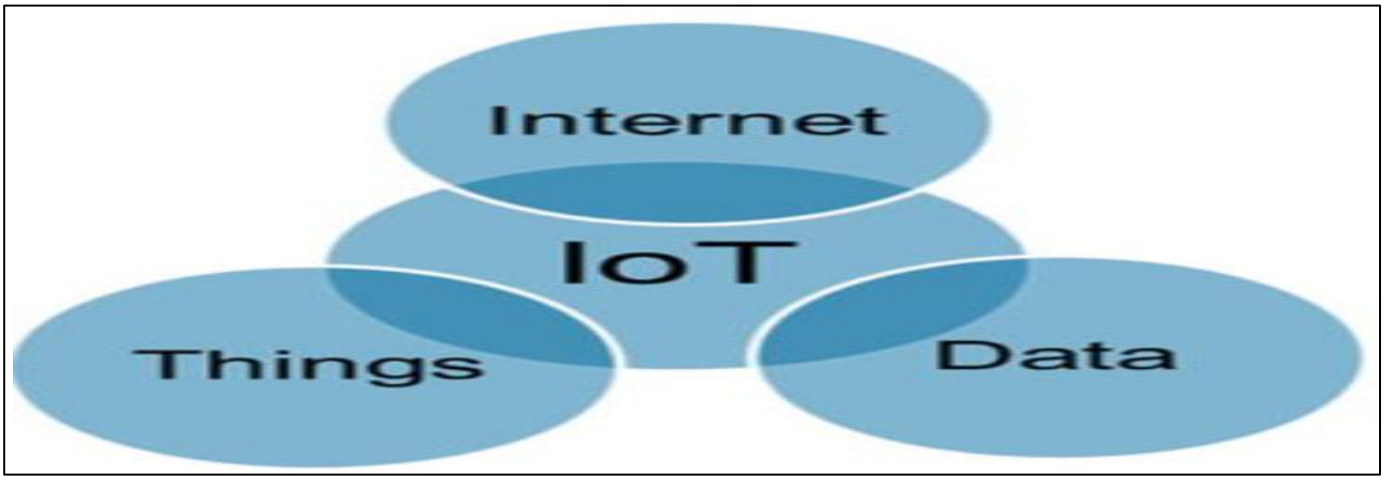


Fig 1 Simple IoT Framework.


Fig 2 Simple Overview of a Building Automation System

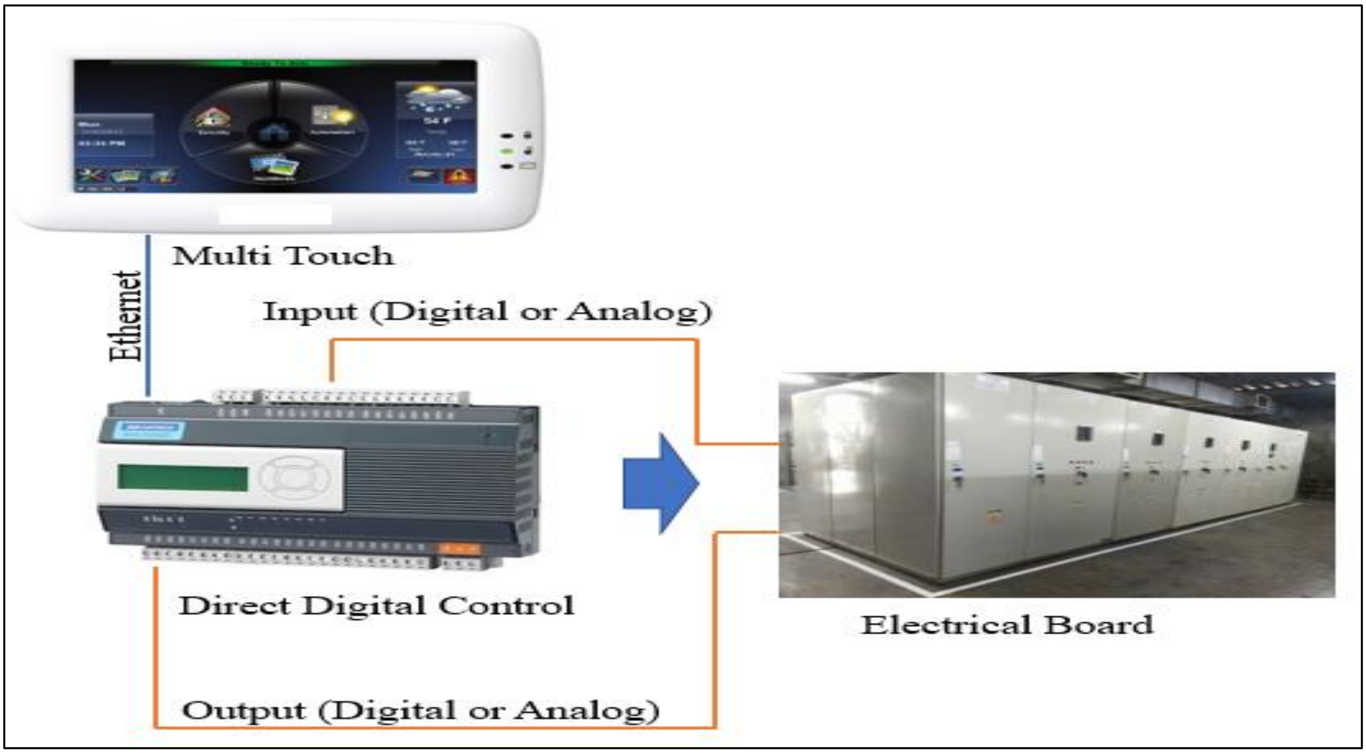


Fig 3 Simple Example of a Building Automation System.

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- *Lighting System.*

A lighting system is an installation assembled for lighting/lighting equipment. Where the lighting system is generally assembled with several parts, as follows:

- ✓ Power source.
- ✓ Distribution Panel.
- ✓ Switch.
- ✓ Light.

When building a lighting system, several measurements are taken first. This is to be able to adjust the specifications of each part of the lighting system, both from the connecting contacts, connection panels, and sources.

The unit of illumination is expressed in Lux (symbol lx). In measuring lighting, the function of each room in a building must be known to determine how much lighting is needed for each room's function. The lux constant for each room can be used in units from SNI 6197:2011. Steps for determining each piece of equipment:

Step 1: Determine the required Lux.

Step 2: Determine the total power, then divide each lighting group according to the position or capability of the connecting contact. Total power is obtained from the measured Lux (1 watt = 75 Lumens).

Step 3: Design the Connecting Panel according to the total power.

Step 4: Request for source power from the electricity source provider in the amount required.

The formula for determining the number of lights can be used as follows:

$$\text{Luminaries} = \frac{\text{Illumination Level (lx)x Area (m2)}}{\text{Output lumens from luminaries (lm)x UF x LLF}}$$

Were, the level of immunization can be see in Table 2.2

The lumen output from each luminary is following factory specifications, which can be seen in Table 2.4

UF is a utilization factor with a value of 0.9.

LLF is a light loss factor with a value of 0.8

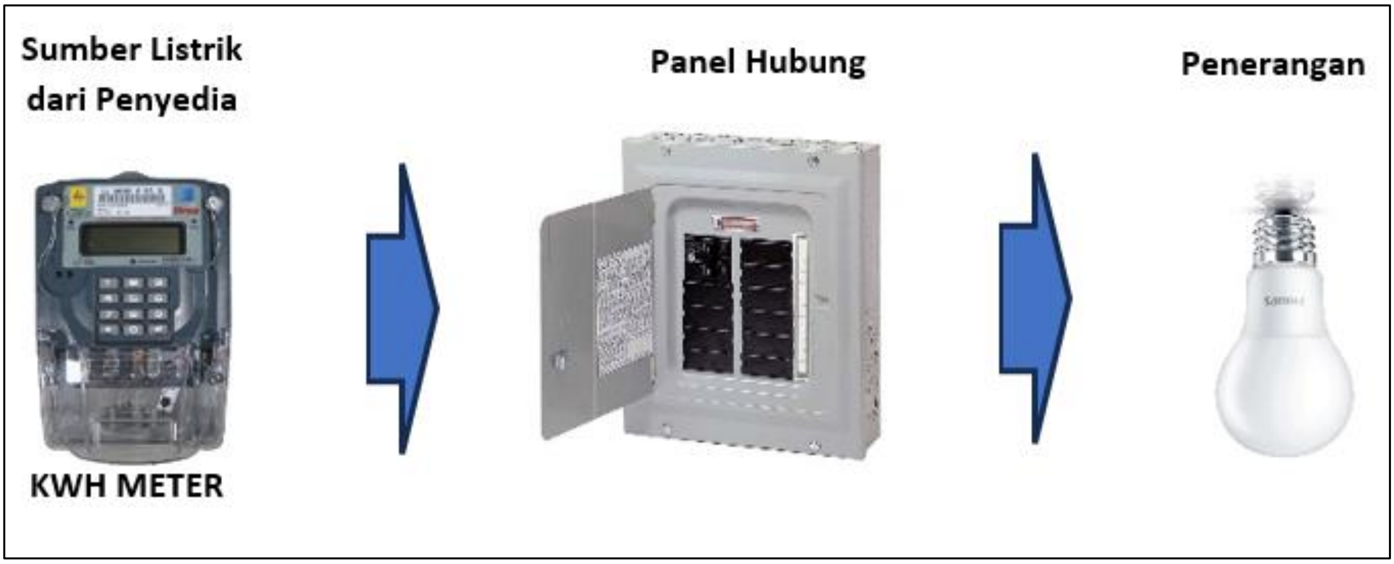


Fig 4 Simple Example of a Lighting System.

- *Iot-Based Power Breaker.*

An IoT-based power breaker is a connecting and disconnecting piece of equipment that works magnetically based on IoT. Where the Smart Breaker contains a magnetic coil contact to work by attracting and breaking the contact points on the breaker component. In this equipment, a microcontroller is embedded. Which works as a controller for the coil contacts. Which can be connected wirelessly. As described in Figure 5.

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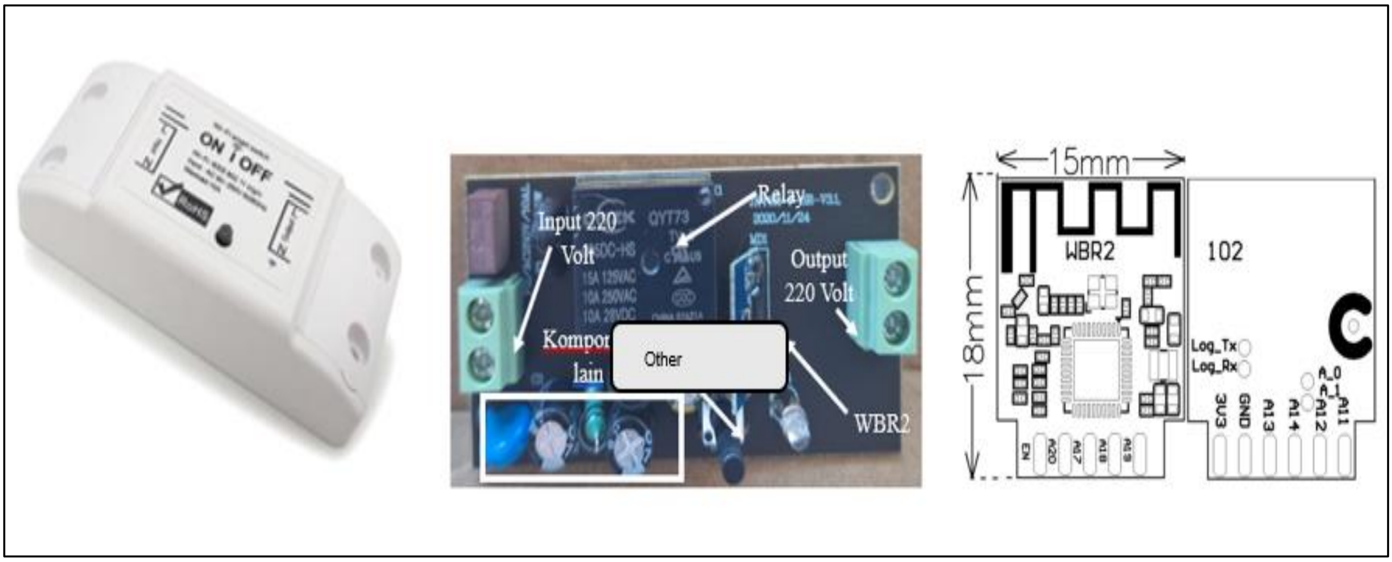


Fig 5 Physical form, Component Details and Processing of an IoT-Based Power Breaker.

The processing used is called WBR2. Which is a low-power embedded Wi-Fi and Bluetooth module that has been developed by Tuya. It consists of a highly integrated RF chip (RTL8720CF) with an embedded Wi-Fi network protocol stack, and a powerful library of functions.

The WBR2 also contains a KM4 low-power microcontroller unit (MCU), a WLAN MAC, a 1T1R-capable WLAN baseband, 256 KB of static random-access memory (SRAM), 2 MB of flash memory, and extensive peripherals. WBR2 is an RTOS platform that integrates all the function libraries of Wi-Fi MAC, and TCP/IP protocols. You can develop embedded Wi-Fi and Bluetooth products as needed. The WBR2 architecture can be see in Figure 6.

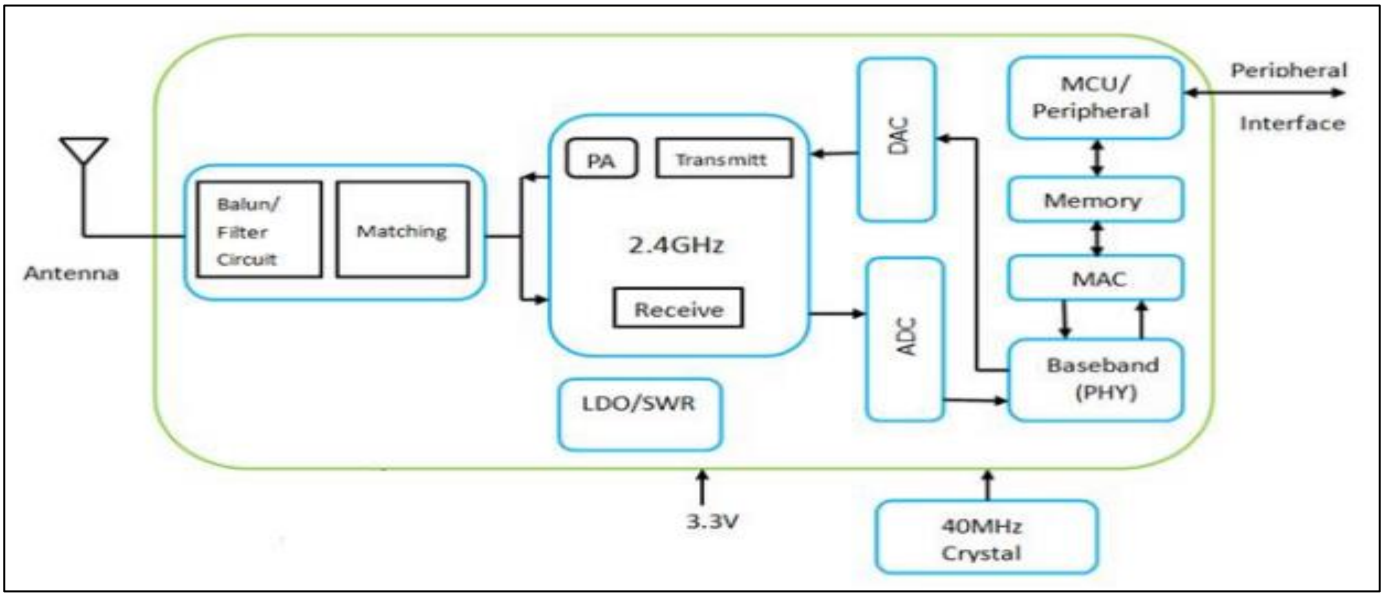


Fig 6 WBR 2 Architecture

Table 1 Function of Each Terminal on WBR2

| Pin | Tipe IO | Description |
|---|---|---|
| **3V3** | NA | Current Source Pin (3.3 Volts). |
| **A19** | IO | Hardware PWM pin. |
| **GND** | NA | Current source reference ground pin. |
| **A18** | IO | GPIOA 18 Hardware PWM pin. |
| **A13** | IO | GPIOA 13 User-side serial interface pin (UARTO_RXD). |
| **A17** | IO | GPIO17 Hardware PWM pin is connected to pin 38 on the internal IC. |
| **A14** | IO | GPIOA 14 User-side serial interface pin (UARTO_TXD). |
| **A20** | IO | GPIO A20 Common GPIO is connected to pin 1 on the internal IC. |

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| | | |
|---|---|---|
| **A12** | IO | GPIOA 12 Hardware PWM pin is connected to pin 2 6 on the internal IC. |
| **EN** | NA | Enable pin is active at high level (pin has been pulled and can be controlled externally). |
| **A11** | IO | GPIOA 11 Hardware PWM pin is connected to pin 25 on the internal IC. |

- *IoT Platforms*

Many IoT platforms can be used on smartphones today. In Indonesia, there are currently several IoT platforms that provide smart home and building applications, including Bardi, Wiz, Acome, and many more. You can see Figure 2.7, which shows the appearance of one of the IoT platforms.

## II. METHODOLOGY

- *Research Flow.*

The flow chart in this research can be see in Figure 7 below.

Fig 7 Application View from one of the IoT Platforms.

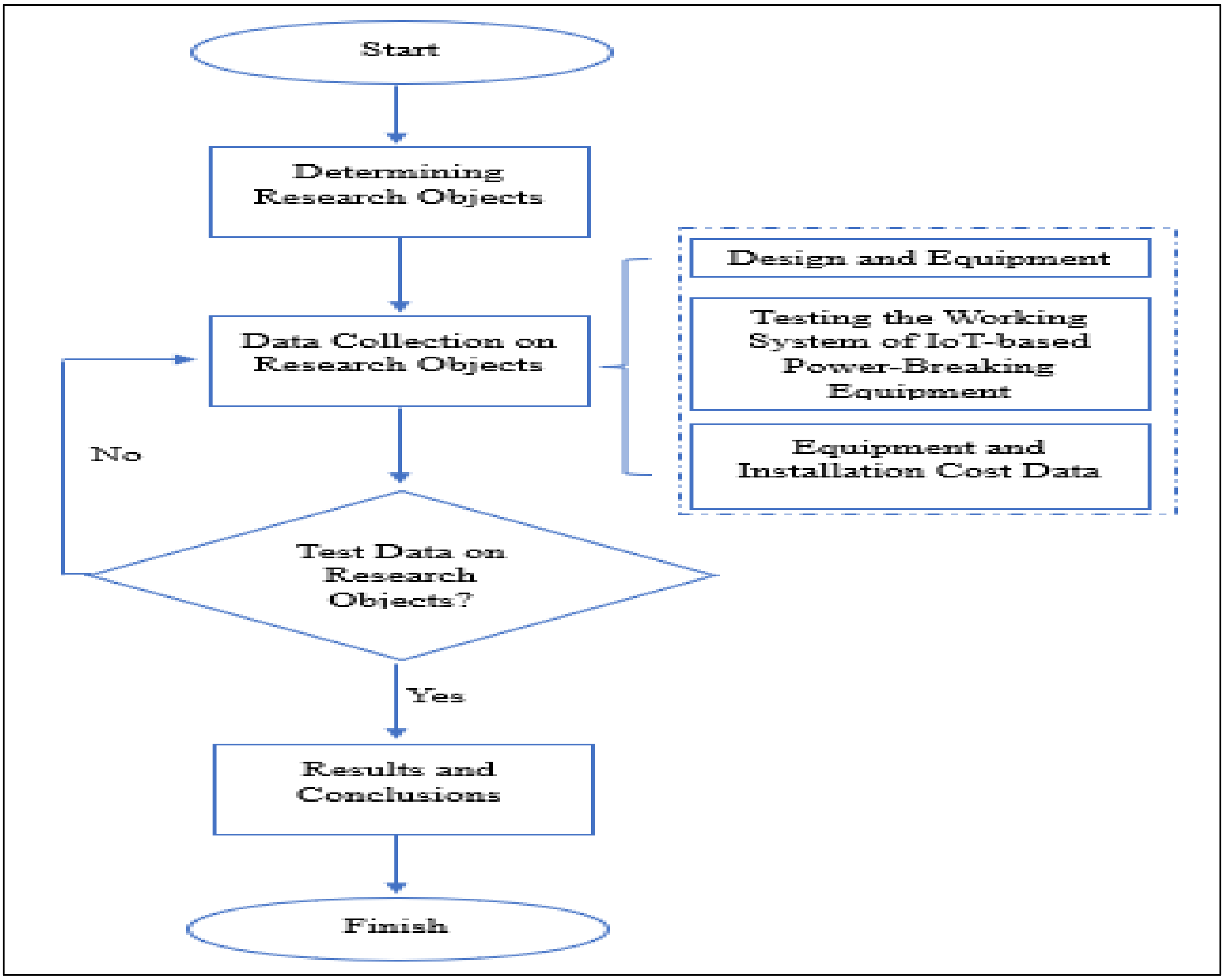

Fig 8 Research Flow Chart for Cost Analysis

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➢ *Research Location.*

The location for the application of the Smart Breaker System is at the new PT office. Benih Parsada, located at Jalan Perjuangan Raya No.1 Tugu Selatan Koja, North Jakarta 14260.

- *The Parsada Seed Building stands on a land area of 48 m² and a building area of 144 m². This Building Consists of 3 (three) Floors, Including:*

✓ Floor 1 has a parking area, toilets, stairs, and a lobby.
✓ Floor 2 consists of a work area, stairs, and a toilet.
✓ The 3rd floor consists of a canteen or smoking area.

It can be see in Figure 9

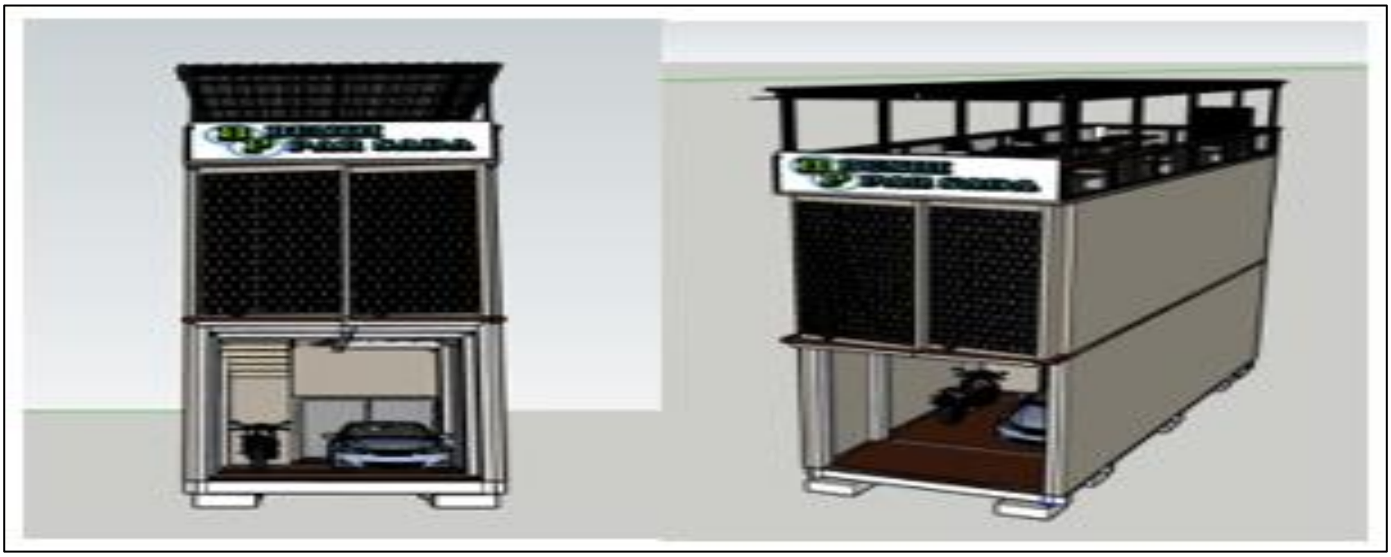

Fig 9 Parsada Seeds Office Plan.

➢ *Grouping of Lighting Sources and Control Distance.*

The grouping of lighting sources is divided into several room and floor functions. The data obtained at the Parsada seed office can be grouped as follows:

Table 2 Distance of Control

| Floor | Function room | Lighting grup | Control distance |
|---|---|---|---|
| 1 | Parking, toilets, stairs and lobby | 4 | 8,6 Meter |
| 2 | Work area, toilet and stairs. | 3 | 11,38 Meter |
| 3 | Canteen or smoking area | 1 | 9,35 Meter |


Fig 10 Control Points and Operators.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/24june266

➢ *Equipment Work Process.*

In the work process of IoT-based power breaker equipment, every command on the power breaker is received from the smartphone, and the push button is embedded in the power breaker.

So, if the Power Breaker gets the on input from the smartphone/push button, then the relay contacts embedded in the Power Breaker work and produce a 220-volt electricity source at the output, and the load gets the electricity source and works. Vice versa, if the Power Breaker gets an Off input from a smartphone/push button, then the relay contacts embedded in the Power Breaker do not work and do not produce a 220-volt electricity source at the output. The load does not get an electricity source and does not work. As outlined in Figure 10.

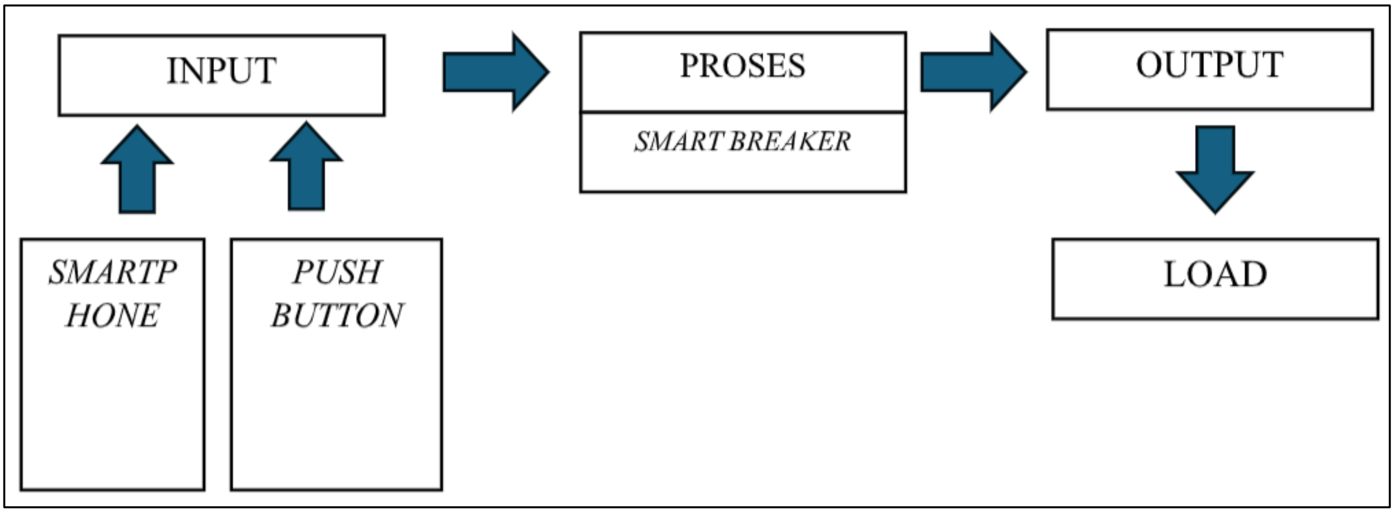


Fig 11 Equipment Work Process.

➢ *Design*

- *Internet Network Schematic of Smart Breaker.*

The network scheme for the Smart Breaker is as shown in Figure 12. where the network on the Smart Breaker is networked with a router connected to the internet network. (internet providers such as Telkom and others). And the smartphone is connected to an external internet connection which can be interconnected with equipment on the Smart Breaker internet network.

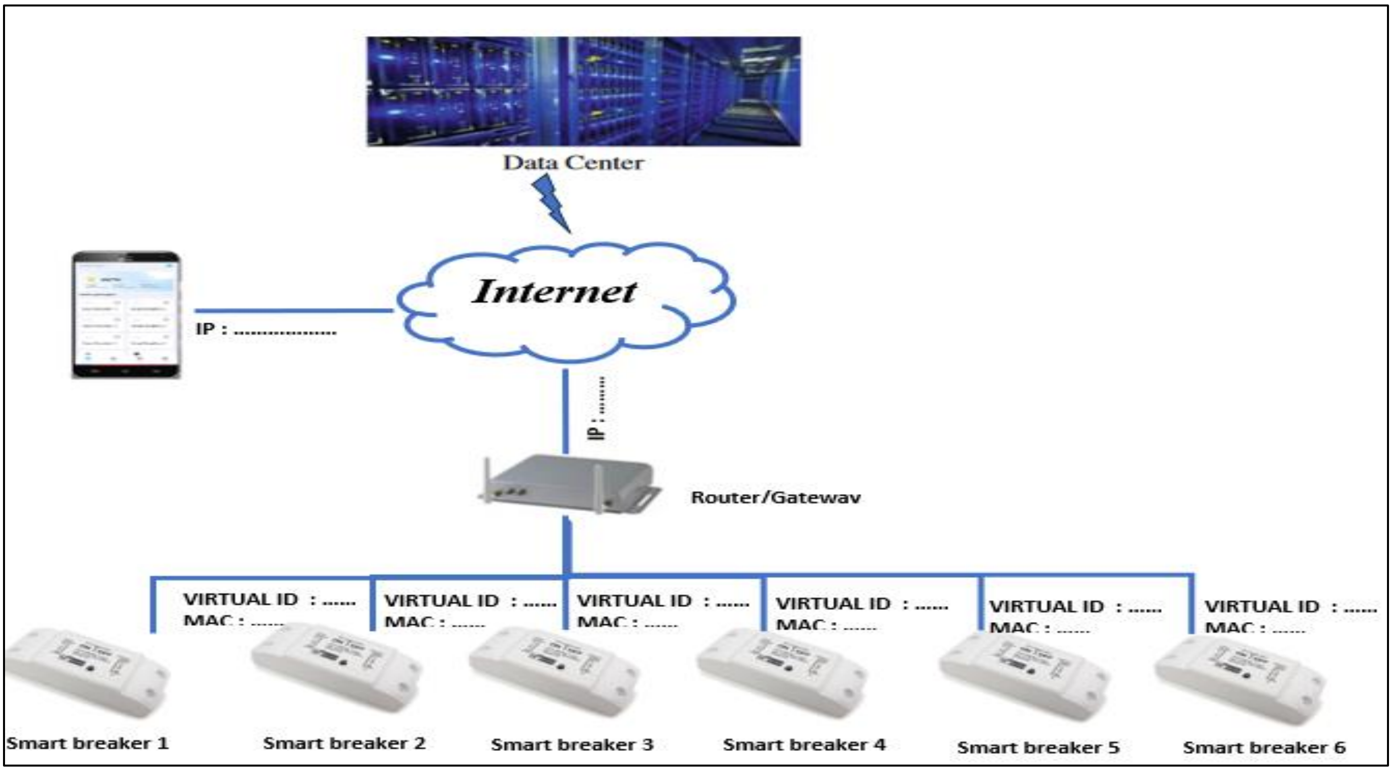


Fig 12 Scheme of Internet of Thinks-Based Power Breaker Network.

Volume 9, Issue 6, June – 2024 International Journal of Innovative Science and Research Technology
ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/24june266

- *Electrical Installation of IoT-based Power Breakers.*

Electrical installation on an IoT-based Power Breaker is quite simple. It only consists of protection, connection, control (IoT-based Power Breaker), and load. Line and wiring diagrams of IoT-based Power Breaker are described in Figures 13 and 14.

However, when planning an electrical installation system, it must still be based on the characteristics of the load used, especially in the connection, because the IoT-based Power Breaker only acts as a command control or pilot in the control system. This application is still only in minimal capacity because it is only a test material for later application to large loads.

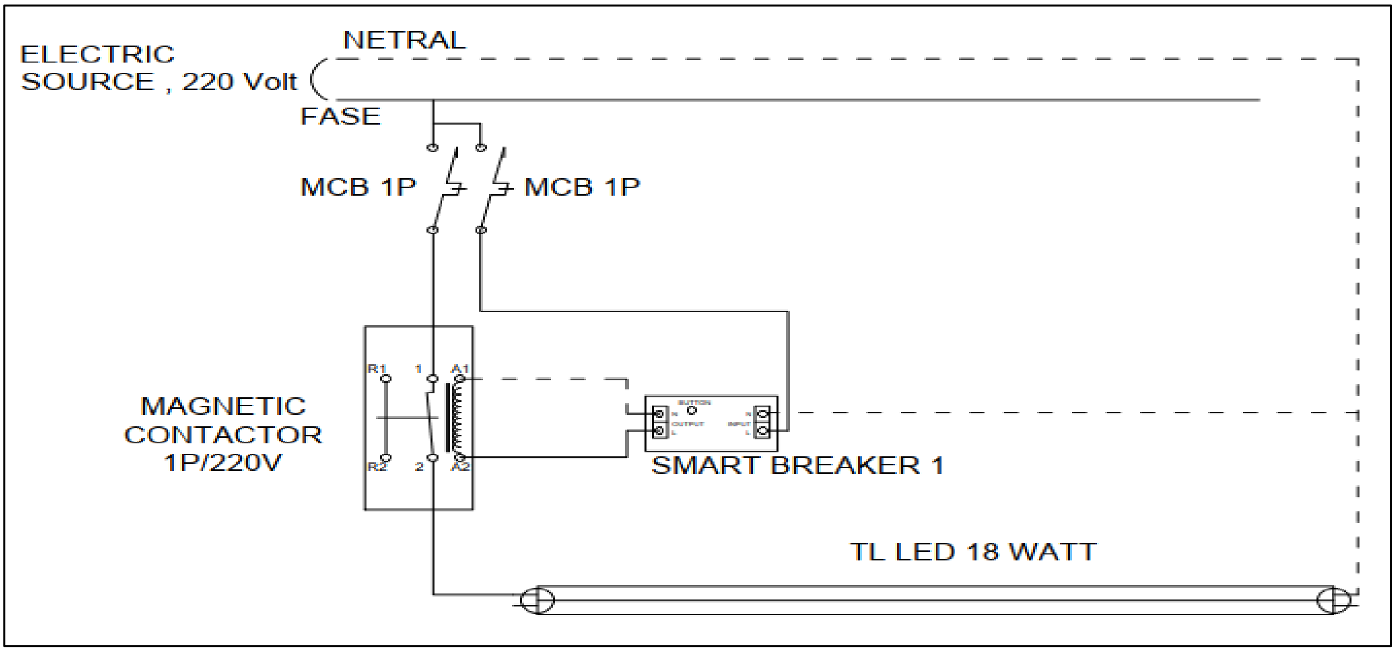


Fig 13 Simple Line Diagram of IoT-Based Power Breaker Electricity.

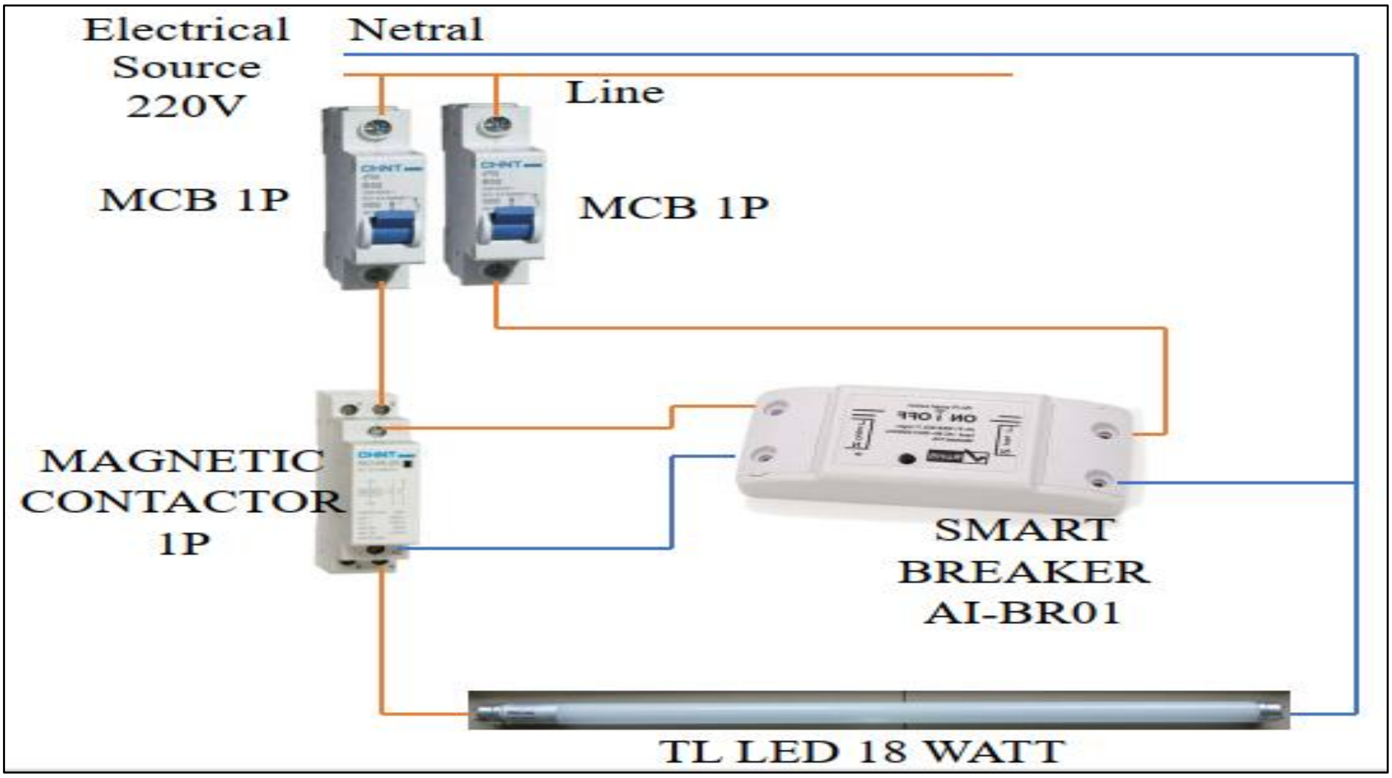


Fig 14 Actual Simple Wiring for IoT-Based Power Breaker Electricity.

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- *Implemented Building Automation System Development Scheme.*

The scheme implemented in this automation system replaces the general equipment scheme in the building automation system using DDC with Smart Breaker equipment, as described in Figure 15.

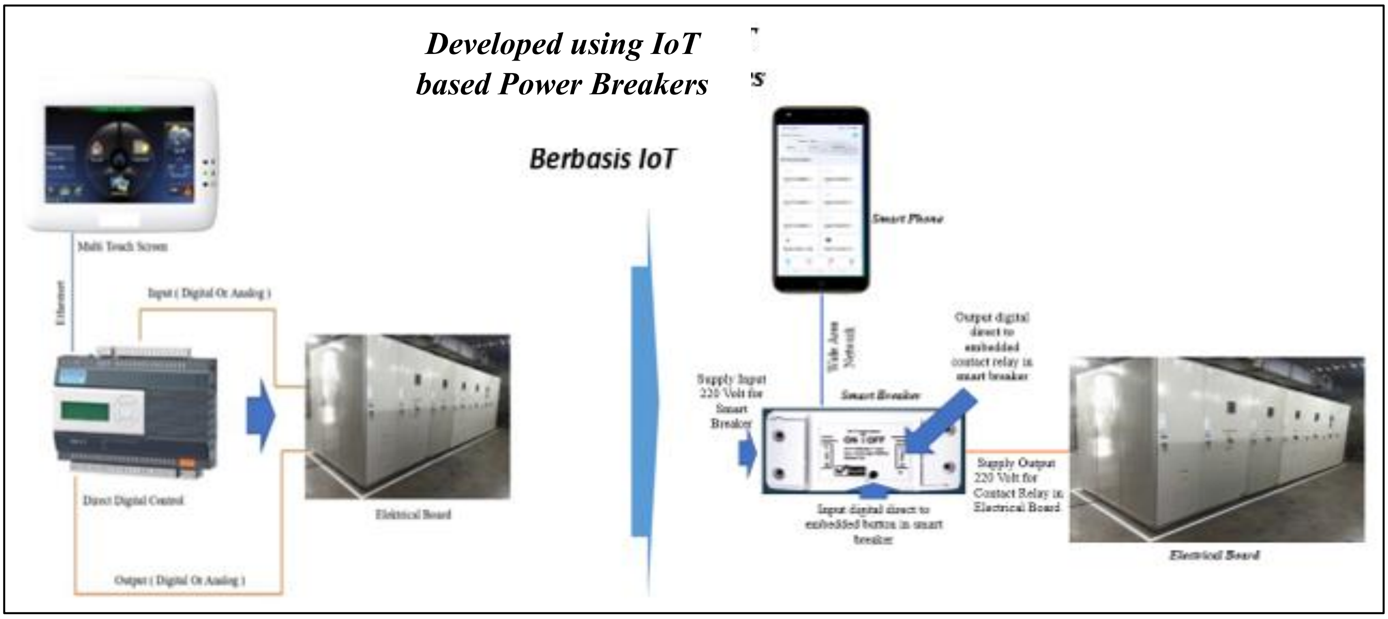


Fig 15 Building Automation System Development Scheme using IoT-Based Power Breakers.

- *Parsada Seed Building Automation System Scheme.*

The building automation system scheme in the Benih Parsada building is planned with two comparison schemes and two building automation system schemes used with Direct Digital Control and IoT-based Power Breakers.

The scheme with Direct Digital Control is used as a comparison to get the difference in costs for building automation systems using IoT-based Power Breakers. It also places significant emphasis on analysing similarities or similarities in work characteristics when IoT-based Power Breakers are used for building automation, providing a comprehensive understanding of the system's operational aspects.

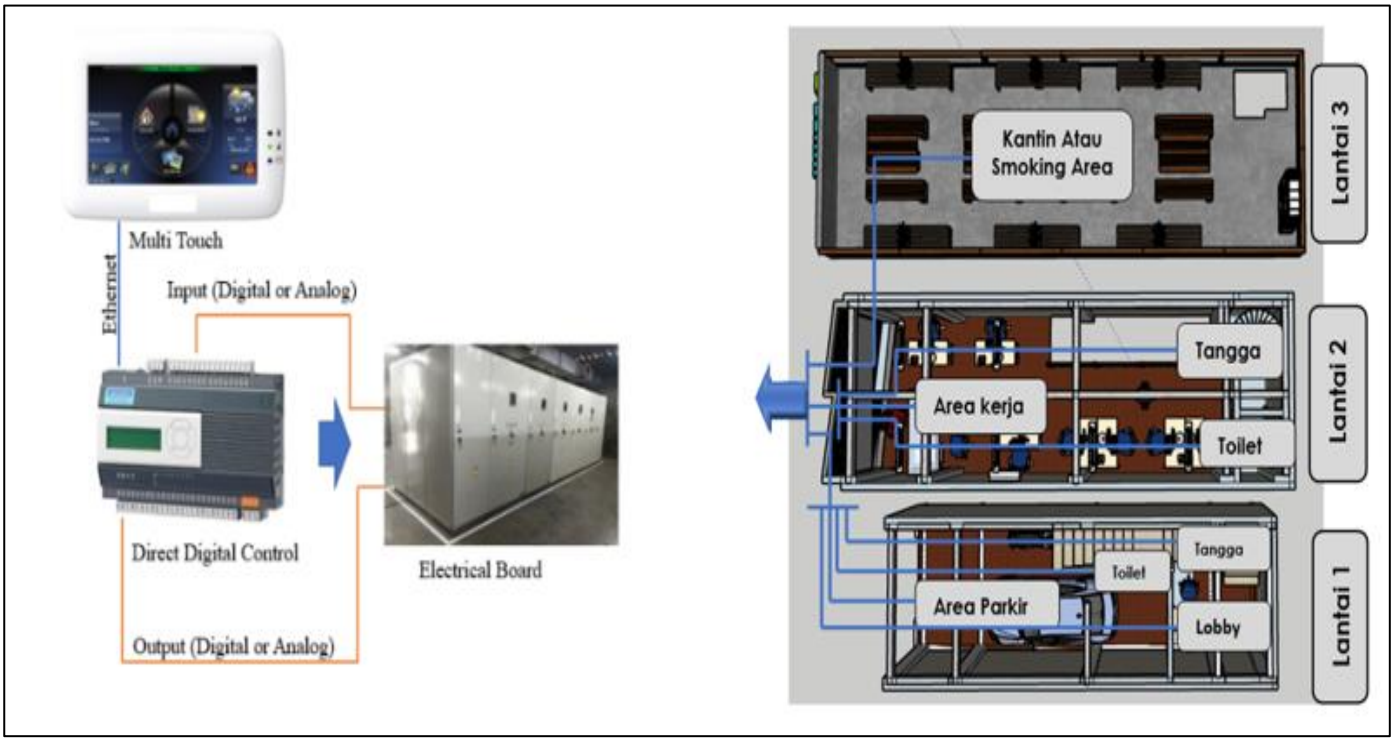


Fig 16 Schematic Plan for Building Automation System with Direct Digital Control.

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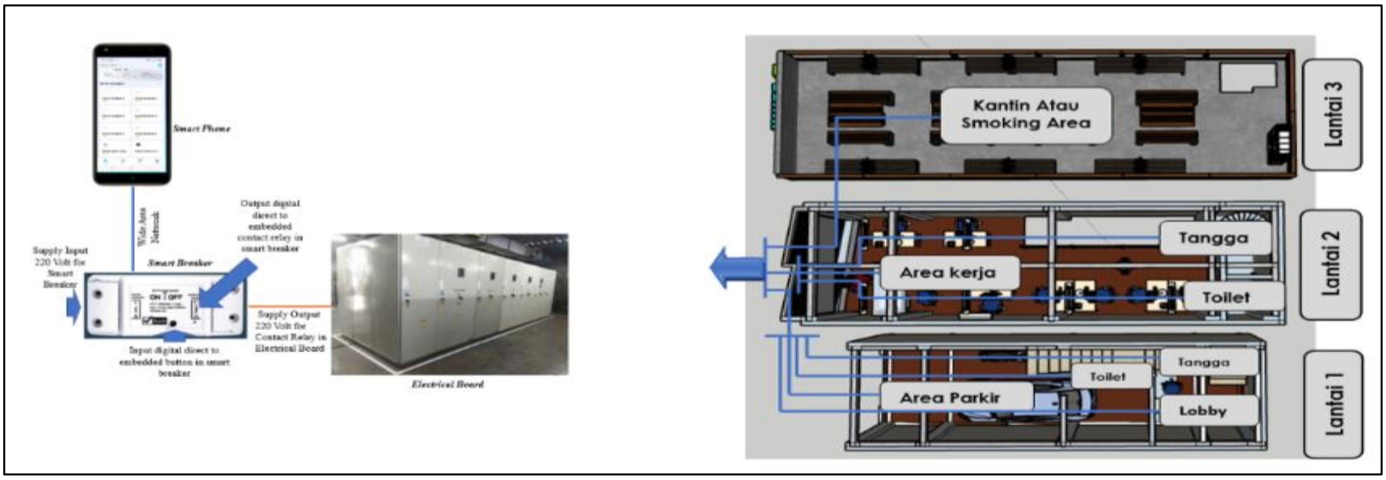


Fig 17 Schematic Plan for Building Automation System with IoT-Based Power Breaker.

- *Lay Out IoT-based Power Breaker Control Panel.*
  The layout of the IoT-based Power Breaker can be see in Figure. 18.

➢ *Equipment Prices.*

The comprehensive data on equipment prices includes the cost of lighting panels, prices of Direct Digital Control equipment, and IoT-based Power Breakers. The prices are as follows, providing a reliable basis for decision-making:

Table 3 Price of Equipment.

| Device | Price |
|---|---|
| Lighting Panel | Rp. 7.360.000 |
| Digital Direct Control ( Opsi 1 ) | Rp. 51.255.000 |
| IoT-based Power Breaker | Rp. 68.000 |
| Smartphone | Rp. 2.099.000 |
| Internet Installation | Rp. 341.000 |

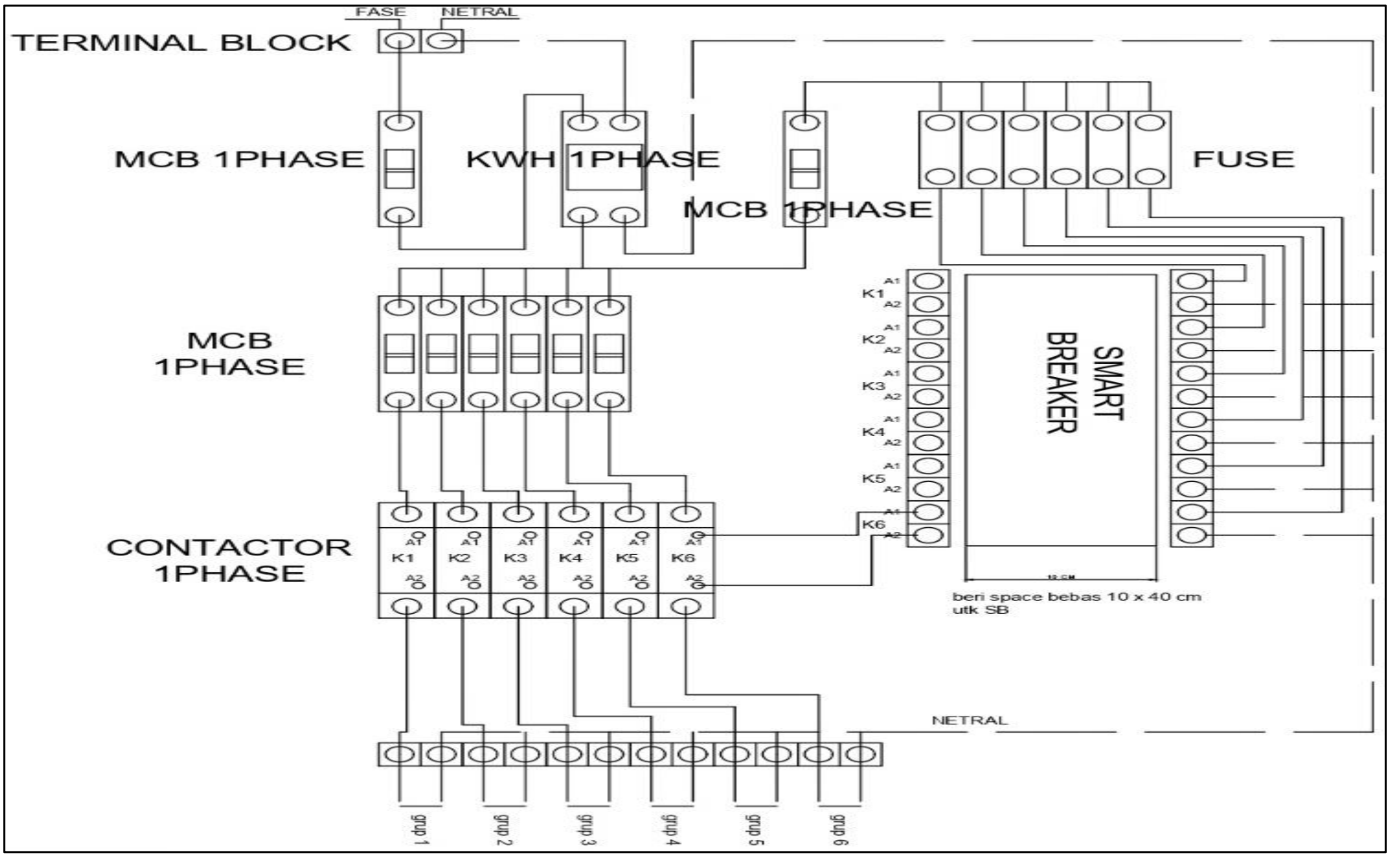


Fig 18 Lay out IoT Based Power Breaker Panel.

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## III. ANALYSIS, TEST & RESULTS

➢ *From the Data Obtained in Chapter 3 and the Formulation from Chapter 2, Analysis can be Carried out Based on Several Criteria, Namely:*

- Analysis of electrical loads on building lighting.
- Analysis of the need for the number of controls used.
- Cost loss analysis on conventional systems.
- Cost analysis of IoT-based power breaker systems.
- Analysis of the difference in costs of 2 automation systems being compared.

➢ *Electrical Load Analysis.*

From the formulation in discussion 2, the electrical load on lighting can be calculated. Based on the distribution of types of lights in each room and the amount of lighting in the room according to factory specifications and established standards. Table 4 shows the types of lights used in buildings.

Table 4 Room, Type and Lumen of Lamps.

| Floor/Room | Type Of Lamp | Square (M2) | Watt | Lumen | Lux |
|---|---|---|---|---|---|
| **1st Floor** | | | | | |
| - Parking Area | T8 | 30 | 16 | 1600 | 60 |
| - Toilet | Downligt slim | 1,8 | 12 | 900 | 250 |
| - Lobby | Downligt slim | 7,5 | 12 | 900 | 100 |
| - Stair | Downligt DN027C | 8,4 | 15 | 1200 | 100 |
| **2nd Floor** | | | | | |
| - Work Area | T8 | 38,7 | 16 | 1600 | 350 |
| - Toilet | Downligt slim | 2,1 | 12 | 900 | 250 |
| - Stair | T8 | 3,4 | 16 | 1600 | 100 |
| **3rd Floor** | | | | | |
| - Canteen / Smoking | T8 | 47,8 | 16 | 1600 | 200 |

From the data above, the number of lamps and the load on the lighting in the Benih Parsada building can be determined with the following formula:

$$Luminaries = \frac{Illumination\ Level\ (lx)x\ Area\ (m2)}{Output\ lumens\ from\ luminaries\ (lm)x\ UF\ x\ LLF}$$

So the number of lights and load per room can be see in Table 5 below:

Table 5 Number of Lamps and Loads

| Floor/Room | Type of lamp | Watt | Qty | Load (Watt) |
|---|---|---|---|---|
| **1st Floor** | | | | |
| - Parking Area | T8 | 16 | 2 | 32 |
| - Toilet | Downligt slim | 12 | 1 | 12 |
| - Lobby | Downligt slim | 12 | 1 | 12 |
| - Stair | Downligt DN027C | 15 | 1 | 15 |
| **2nd Floor** | | | | |
| - Work Area | T8 | 16 | 12 | 192 |
| - Toilet | Downligt slim | 12 | 1 | 12 |
| - Stair | T8 | 16 | 1 | 16 |
| **3rd Floor** | | | | |
| - Canteen / Smoking | T8 | 16 | 6 | 96 |

| | |
|---|---|
| Total load | 387 |

The data in Table 5 above show that the total load on the lighting system for the Seed Parsada building is 387 watts.

- *Analysis of Power Losses in Conventional Systems.*

Power losses in conventional systems can be calculated from each control distance on the building floor and the electrical power per floor. In chapters 3 and 4, the control distance and floor power were known.

Table 6 Floor Power and Control Distance.

| Floor | Function room | Electrical load ( Watt ) | control distance |
|---|---|---|---|
| 1 | Parking, toilets, stairs and lobby | 71 | 8,6 Meter |
| 2 | Work area, toilet and stairs. | 220 | 11,38 Meter |
| 3 | Canteen or smoking area | 96 | 9,35 Meter |

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From Table 6 above, it can be predicted that the time when control is carried out manually, where standard human steps have variations in speed based on general age. This can be see in table 7 [8]

Table 7 Step Speed [8]

| Age | Gender | Footstep speed (m/s) |
|---|---|---|
| 20 to 29 Years | Man | 1.36 |
| | Woman | 1.34 |
| 30 to 39 Years | Man | 1.43 |
| | Woman | 1.34 |
| 40 to 49 Years | Man | 1.43 |
| | Woman | 1.39 |

Suppose the sample is taken from male gender and age between 20 and 29 years. Then, the time required for each control on each floor can be determined. The time lost for each lighting control can be see in Table 8.

Table 8 Control Time.

| Floor | Function room | Control distance | Control time *(t = S/V)* | 2 x Control time *(On/Off)* |
|---|---|---|---|---|
| 1 | Parking, toilets, stairs and lobby | 8,6 Meter | 6,6 s | 13,2 s |
| 2 | Work area, toilet and stairs. | 11,38 Meter | 8,36 s | 16,72 s |
| 3 | Canteen or smoking area | 9,35 Meter | 6,875 s | 13,75 s |

Power losses in conventional control can be determined from the control time and floor power obtained. Can be see in Table 9.

Table 9 Power Loss.

| Floor | Function room | Electrical load ( Watt ) | 2 x Control time *(On/Off)* | Control time In 30 days | Time with hour / 30 days | Power loss in 30 days |
|---|---|---|---|---|---|---|
| 1 | Parking, toilets, stairs and lobby | 71 | 13,2 s | 369 s | 0,1025 hour | 7,275 watt |
| 2 | Work area, toilet and stairs. | 220 | 16,72 s | 501,6 s | 0,1393 hour | 30,646 watt |
| 3 | Canteen or smoking area | 96 | 13,75 s | 412,5 s | 0,114 hour | 10,944 watt |

- *Control Requirements Analysis*

If you follow the guidelines in Table 9, you can determine the need for an IoT-based power breaker for the lighting system in the Benih Parsada building. The control requirements for the lighting of the Benih Parsada building consist of 8 controls, adapting to 8 room functions on each floor of the building. Can be see in Table 10.

Table 10 IoT-based Power Breaker Control Requirements.

| Floor | Function room | Kelompok penerangan | Output Kontrol | Pemutus Daya Berbasis IoT | Keterangan |
|---|---|---|---|---|---|
| 1 | Parking, toilets, stairs and lobby | 4 | 4 | ***4*** | From the room function data, there will be 4 groups and 4 installed controls. |
| 2 | Work area, toilet and stairs. | 3 | 3 | ***3*** | From the room function data, there will be 3 groups and 3 installed controls. |
| 3 | Canteen or smoking area | 1 | 1 | ***1*** | From the room function data, there will be 1 group and 1 installed control. |
| **Number of controls** | | | | **8** | **IoT - Based Power Breaker** |

- *Cost Analysis of IoT-Based Power Breakers.*

From the price data in Chapter 3, and the number of controls obtained. The amount of costs required can be determined.

in this design. Some of the equipment needed to develop this control system consists of panels, IoT-based power breakers, smartphones, and internet networks. The number of each piece of equipment and the cost can be see in Table 11.

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Table 11 Number of Equipment and Cost of IoT-Based Power Breakers.

| Equipment | Qty | Unit | Price | Total |
|---|---|---|---|---|
| Lighting Panel | 1 | Pc | Rp. 7.360.000 | Rp. 7.360.000 |
| *IoT-Based Power Breakers* | 8 | Pcs | Rp. 68.000 | Rp. 544.000 |
| *Smartphone* | 3 | Pcs | Rp.2.099.000 | Rp.6.297.000 |
| Internet ( From Provider ) | 1 | Pc | Rp. 341.000 | Rp. 341.000 |
| **Total** | | | | **Rp. 14.542.000** |

The data above show that. The cost of designing, and building an IoT-based power breaker in the Parsada seed building is IDR. 14,542,000 (Fourteen et al. Thousand Rupiah).

- *Analysis of the Difference in Costs of 2 Compared Automation Systems.*

In buildings that implement smart buildings, they generally call the automation system a building automation system (BAS). This BAS system uses equipment called Digital Direct Control which was explained previously in chapter 2 and chapter 3. And to see the difference in costs compared to the two automation systems implemented as smart buildings, namely the costs of designing Digital Direct Control and IoT-based Power Breakers.

The design cost for the IoT-based power breaker in sub-chapter 4.1.3 has been obtained at IDR. 14,542,000 (Fourteen et al. Thousand Rupiah). The amount of digital direct control costs must be determined to find the difference in costs between an automation system and digital direct control.

An automation system with digital direct control requires equipment like an IoT-based power breaker, namely lighting panels, digital direct control-multi touch, and an internet network. This equipment can calculate the costs for an automation system with digital direct control. It can be see in Table 12.

Table 12 Cost of Automation System with Direct Digital Control.

| Equipment | Qty | Unit | Price | Total |
|---|---|---|---|---|
| Lighting Panel | 1 | Pc | Rp. 7.360.000 | Rp. 7.360.000 |
| *Digital Direct Control dan Multi touch* | 1 | Pc | Rp. 51.255.000 | Rp. 51.255.000 |
| Internet ( From Provider ) | 1 | Pc | Rp. 341.000 | Rp. 341.000 |
| **Total** | | | | **Rp. 58.956.000** |

From the data above, the cost for designing and building an automation system with digital direct control in the Parsada seed building is IDR 58,956,000 (Fifty-Eight Million Nine Hundred Fifty-Six Thousand Rupiah). So, the difference in cost of the automation system using breakers

IoT-based power with digital direct control in the Parsada seed building can be determined.

When referring to the cost of an automation system with digital direct control, the percentage obtained by an automation system with an IoT-based power breaker can be calculated.

$$Difference\ (\%) = \frac{Starting\ cost - Final\ cost}{Final\ cost} x\ 100$$

$$Difference\ (\%) = \frac{(\text{ Digital Direct Control Costs }) - (\text{Cost of IoT Based Power Breakers})}{(\text{ Digital Direct Control Costs })} x\ 100$$

$$Difference\ (\%) = \frac{\text{Rp. } 58.956.000\ - \text{Rp. } 14.542.000}{\text{Rp. } 58.956.000} x\ 100$$

$$Difference\ (\%) = \frac{\text{Rp. } 44.414.000}{\text{Rp. } 58.956.000} x\ 100$$

$$Difference\ (\%) = 75{,}33$$

$$Difference\ (\%) = 75{,}33\ \%$$

The calculation above shows a 75.33% cost difference if the IoT-based power breaker is applied to the automation system in the Parsada seed building as a smart building compared to general automation systems in buildings using digital direct control.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/24june266

Figure 19 of the bar diagram below shows an automation system with digital direct control and an IoT-based power breaker. The costs are minimal when designing IoT-based power breakers as smart buildings.

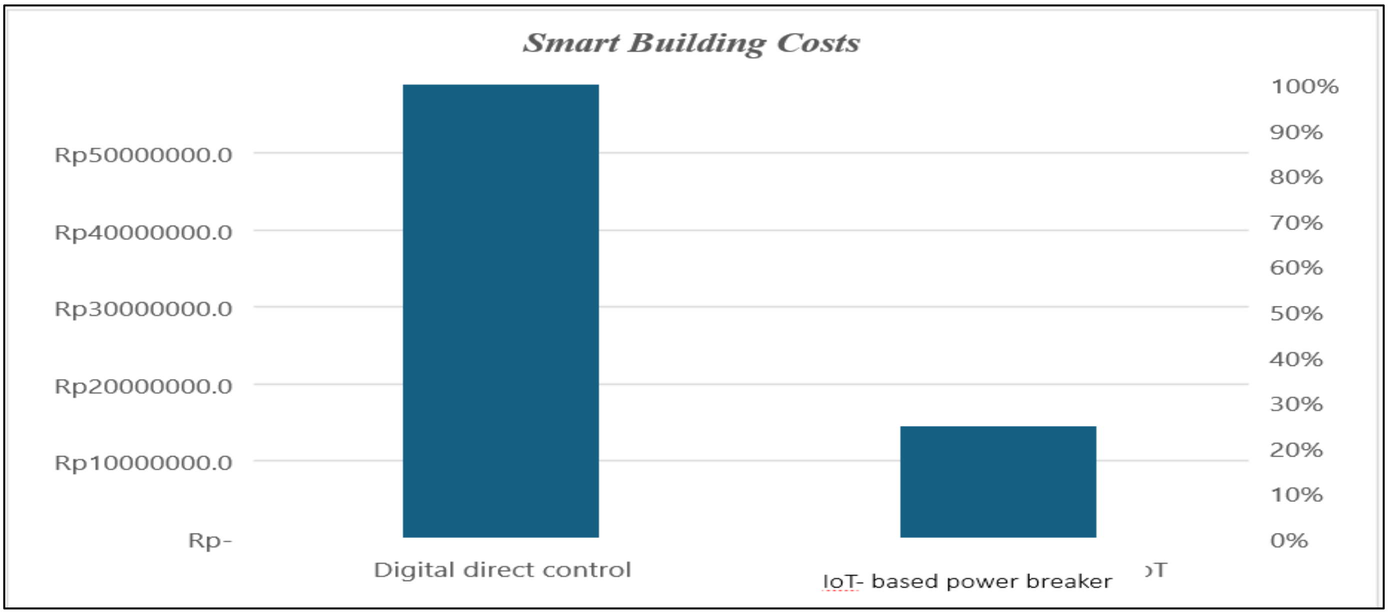



Fig 19 Bar Chart of Smart Building Costs

➢ *System Testing.*

System testing is a trial of the system that will be applied to the Parsada seed building; to test how effective the smart building is with an IoT-based power breaker and to see the power loss in a smart building with an IoT-based power breaker compared to an automation system with Direct Digital Control. And the physical application of the system test can be see in Figure 20.


Fig 20 IoT-based Power Breaker Simulation.

In the test, a control simulation was carried out by scheduling the lighting conditions for each room and floor. Where 2 (two) settings are scheduled, the light conditions can be see in Table 13.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/24june266

Table 13 Light Control Schedule

| Conditions | Time settings (Schedule) |
|---|---|
| Lights on | 18:00 s/d 22:00 |
| Lights off | 22:00 s/d 18:00 |

In the testing process, several data were obtained, including notifications in the application indicating that equipment or lighting was on or off, measurement data and work results from IoT-based power breaker equipment used as a smart building.

And notifications indicating that equipment or lighting is on or off can be seen in the image below:

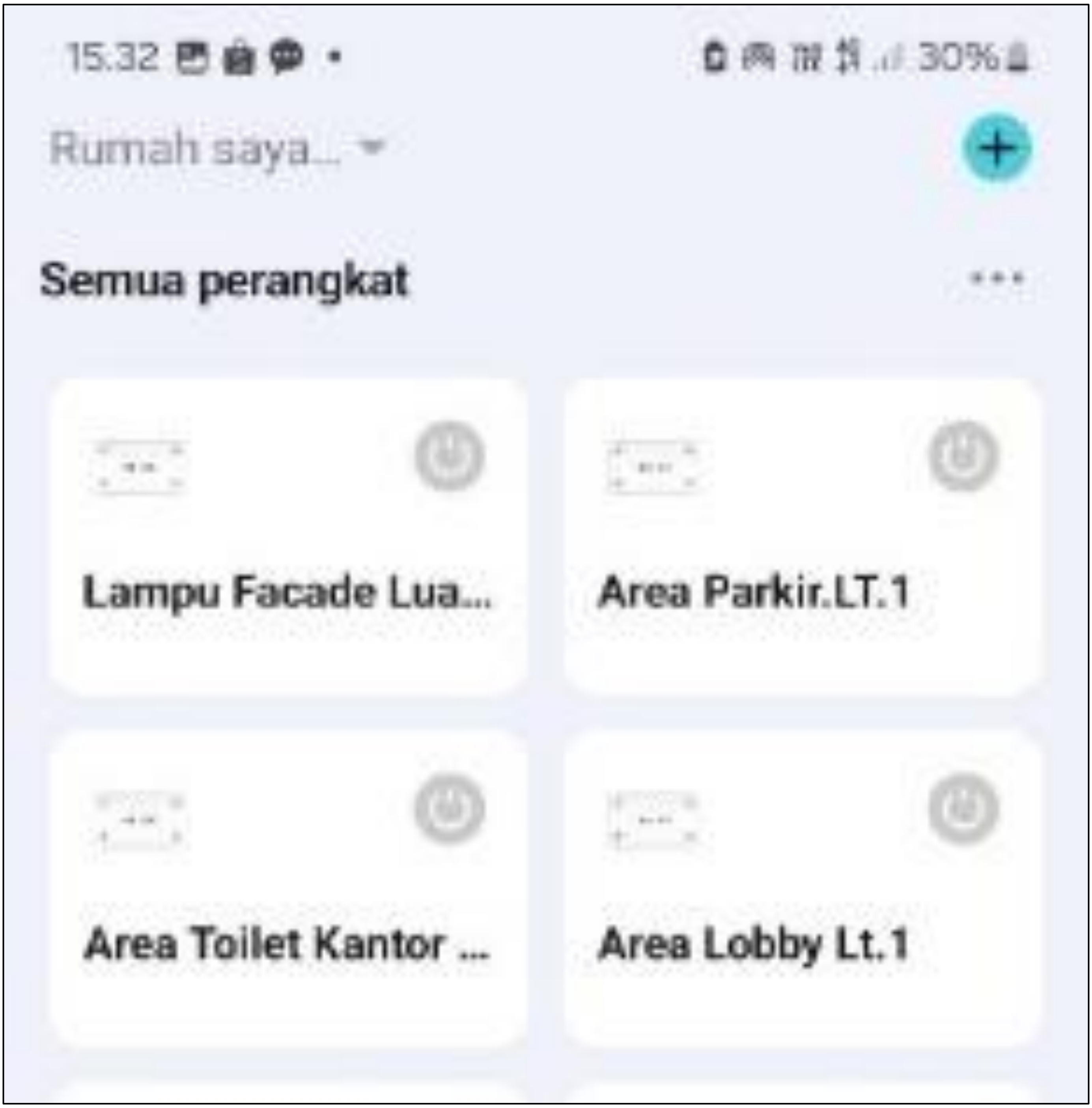



Fig 21 The Display from the Application Shows the Condition of the Equipment Being Off.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/24june266

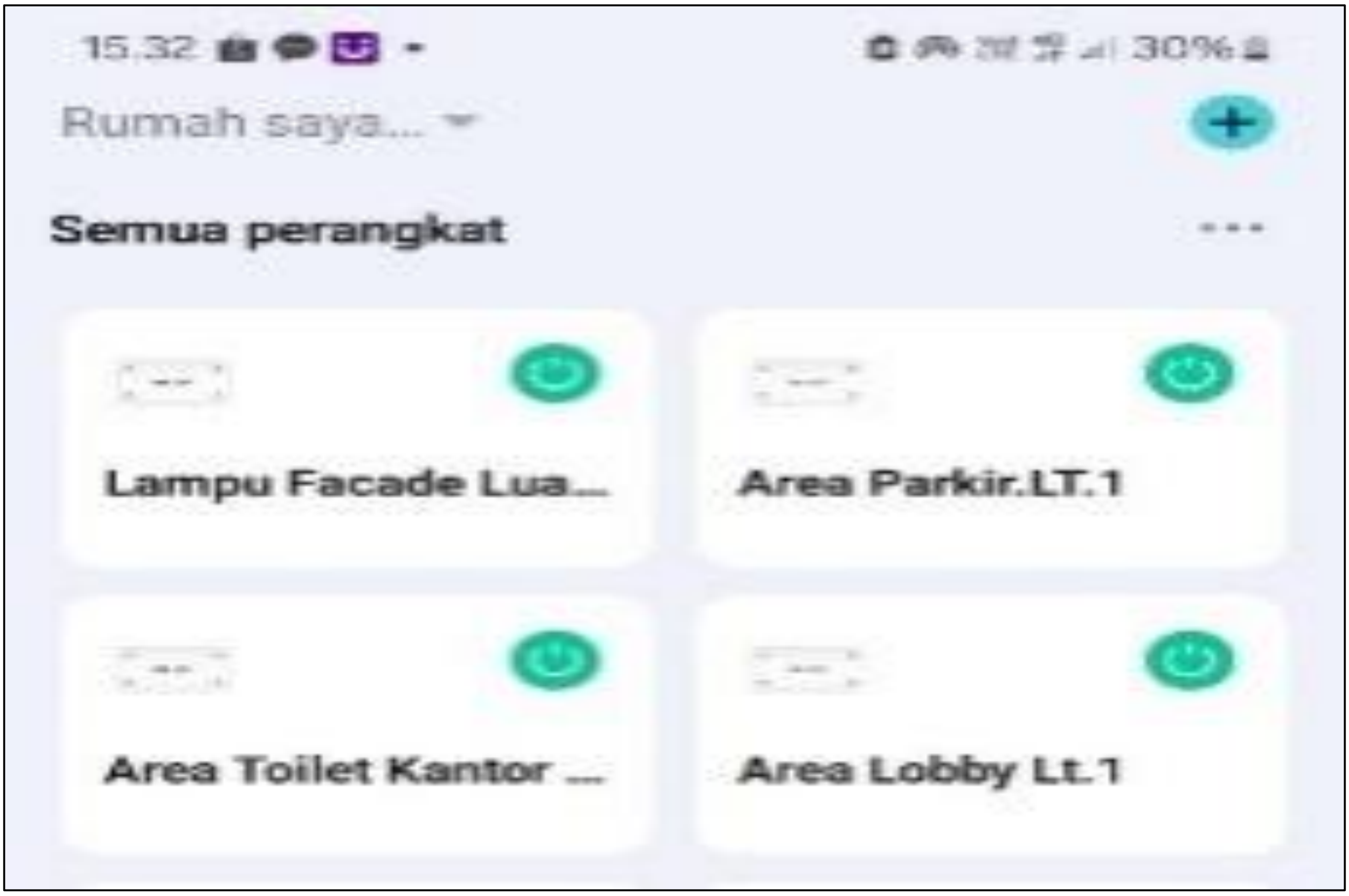



Fig 22 Display of the Application Shows the Condition of the Equipment Being On.

➢ *The Measurement Data Obtained is Power, Current, and Voltage when the Equipment Operates. When the Equipment is Operating, there are 2 (two) Measured Loads, Namely:*

- Control equipment load when the lighting load is not working
- Control equipment load and lighting load when working.

The two loads from the measurement results can be see in Figures 23 and 24

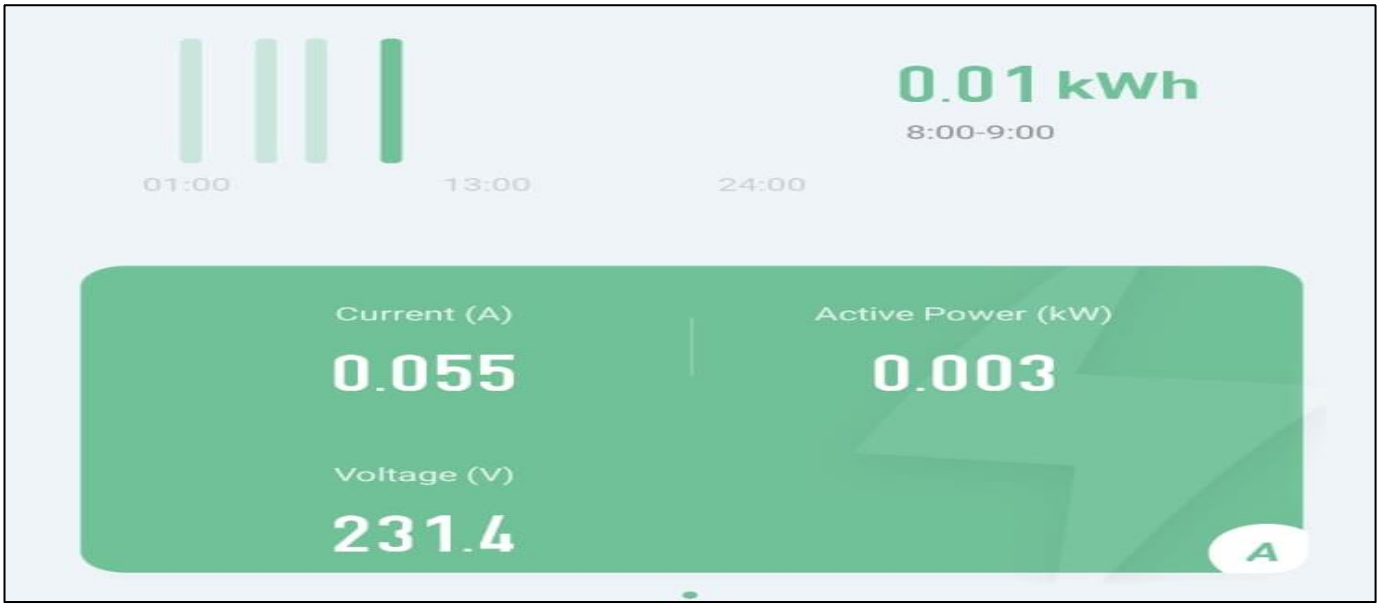



Fig 23 Smart Meter Measurement Results on the Control Load when the Lighting Load is not Working.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/24june266

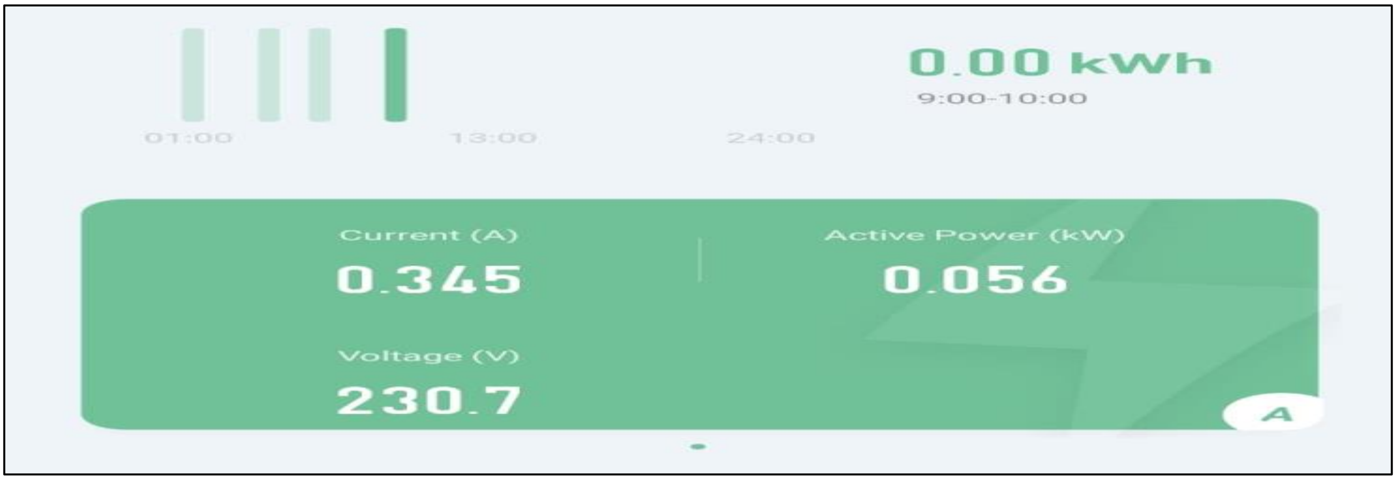
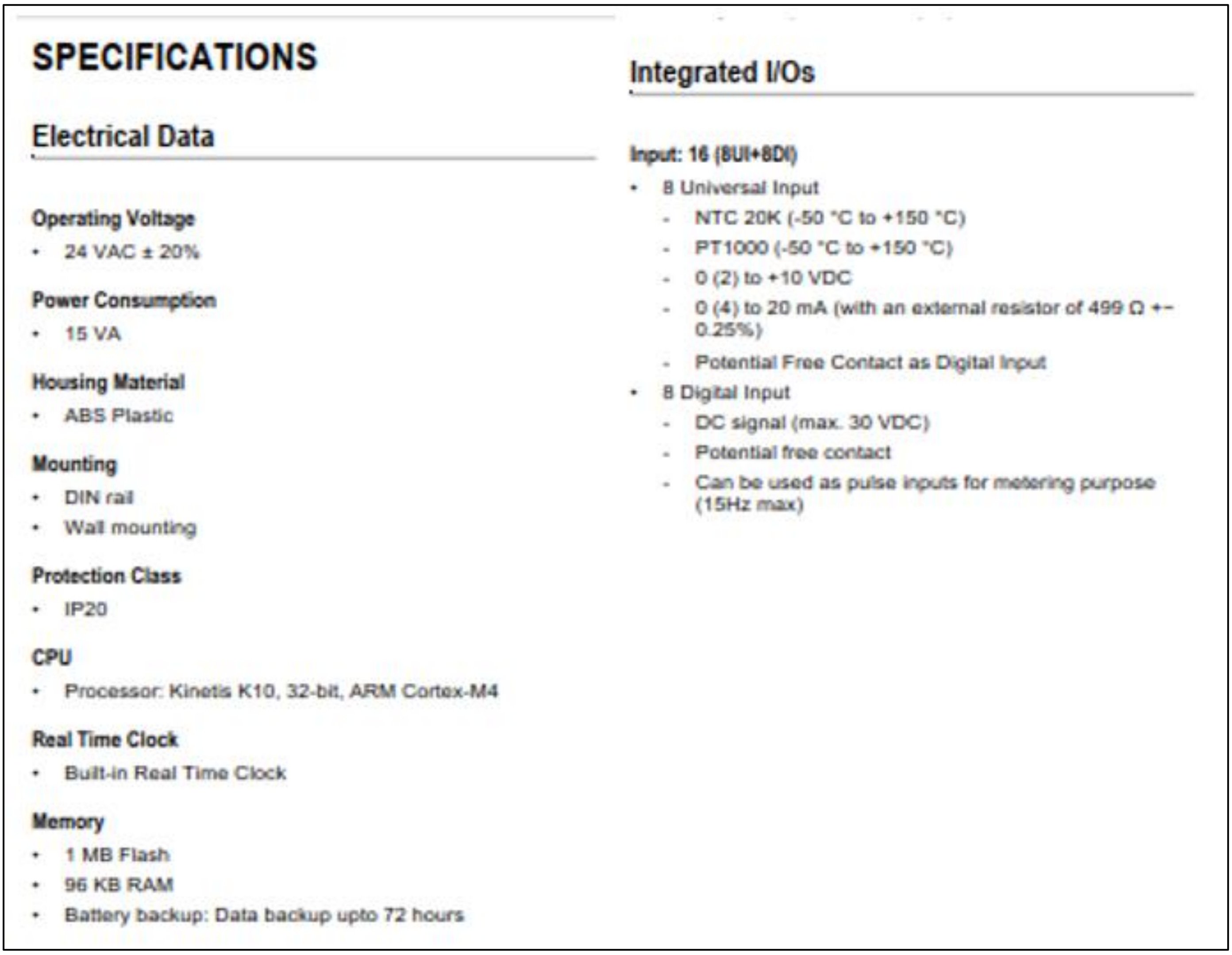



Fig 24 Smart Meter Measurement Results on the Control Load when the Lighting Load Works.

The measurement results obtained from the smart meter show that there is a fixed load that increases in the smart building system application using IoT-based power breakers. The control equipment has constant power available, with a reading result of 0.003 kW (kilowatts) in watts, equal to 3 watts on eight control pieces of equipment used for lighting control. When the lighting equipment is active, the reading result is 0.056 kW (kilowatts) in watts, equal to 560 watts. The load on the control equipment on this IoT-based power breaker is smaller than the load on the control equipment using DDC. For example, Honeywell CPO-DIO DDC equipment: 32 points on board I/O which has a fixed control equipment power of 15 watts or around 0.015kw.



# SPECIFICATIONS

## Electrical Data

**Operating Voltage**
- 24 VAC ± 20%

**Power Consumption**
- 15 VA

**Housing Material**
- ABS Plastic

**Mounting**
- DIN rail
- Wall mounting

**Protection Class**
- IP20

**CPU**
- Processor: Kinetis K10, 32-bit, ARM Cortex-M4

**Real Time Clock**
- Built-in Real Time Clock

**Memory**
- 1 MB Flash
- 96 KB RAM
- Battery backup: Data backup upto 72 hours

## Integrated I/Os

**Input: 16 (8UI+8DI)**
- 8 Universal Input
  - NTC 20K (-50 °C to +150 °C)
  - PT1000 (-50 °C to +150 °C)
  - 0 (2) to +10 VDC
  - 0 (4) to 20 mA (with an external resistor of 499 Ω +- 0.25%)
  - Potential Free Contact as Digital Input
- 8 Digital Input
  - DC signal (max. 30 VDC)
  - Potential free contact
  - Can be used as pulse inputs for metering purpose (15Hz max)

Fig 25 Direct Digital Control Specifications.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/24june266

This control equipment was tested for several days to get reading results from the work of the control equipment. Where the daily graph of equipment reading results can illustrate that the equipment is working well, in Figure 4, there is power measurement data on the equipment, which, as explained previously, there are two powers on the equipment, namely fixed power on the control equipment and variable power on the lighting equipment when it is active.

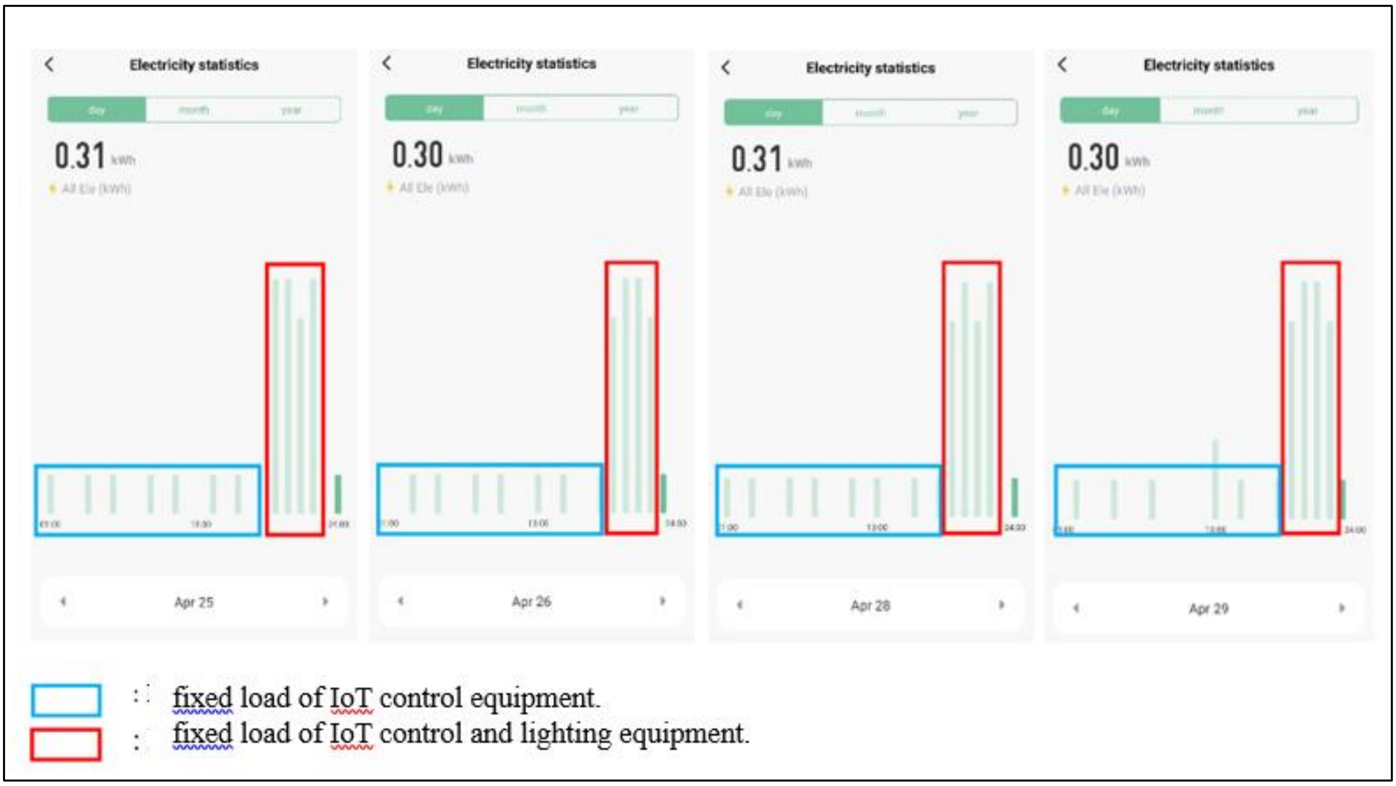



Fig 26 Equipment Measurement Data April 2024

Several images of measuring data and load spikes at each control time show the test results, which are also included in Table 14.

Table 14 Load Measurement Data.

| **No** | **Description** | **Load ( Kilo Watt )** | **Load conditions from 22.00 to 18.00 (Kilo Watt)** | **Load conditions from 18.00 to 22.00 (Kilo Watt)** | **Remarks** |
|---|---|---|---|---|---|
| 1 | Control equipment load | 0,003 | 0,06 | - | The control equipment has a load in 1 day of 0.06 KW, and from the control time settings, the equipment works normally. |
| 2 | Control and Lighting Equipment Loads | 0,056 | - | 0,224 | Control and lighting equipment has a load in 1 day at 0.224KW, and from the control time settings, the equipment works normally. |

➢ *Note :*

- Load conditions are from 22.00 to 18.00 for 20 hours; the control equipment load multiplier factor is multiplied by 20.
- Load conditions from 18.00 to 22.00 for 4 hours, the load multiplier for control and lighting equipment is multiplied by 4. And from the response time obtained when the equipment is controlled via an application on a smart phone. The response of the equipment via the network is a minimum of 447ms and a maximum of 1,132ms which can be seen from the stopwatch which is used to measure the speed of the equipment response with the application on the smartphone.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/24june266

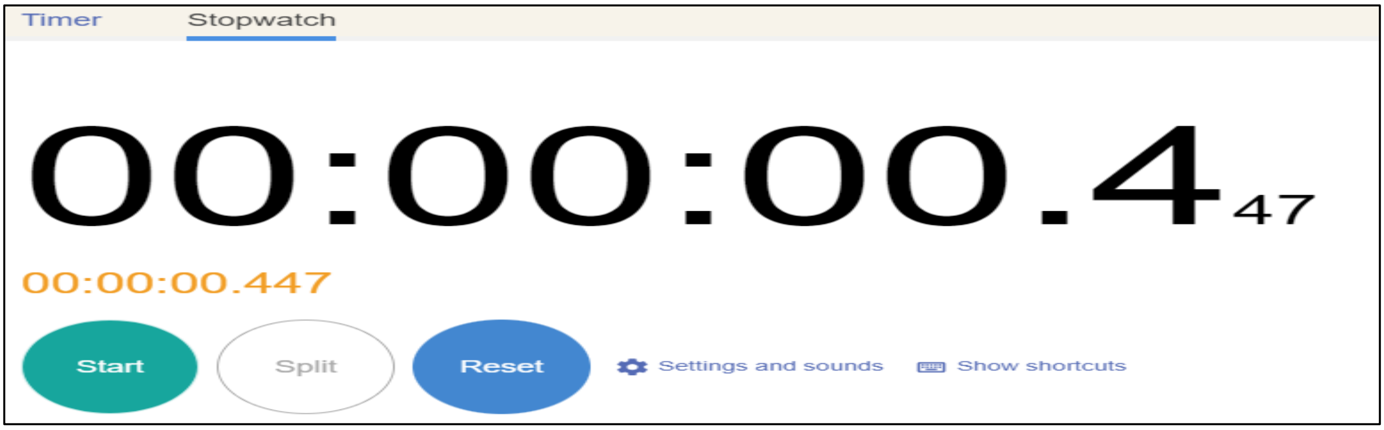



Fig 27 Data Measuring Equipment Response with an Application on a Smartphone using a Digital Stopwatch in the Shortest or Minimum Time Conditions

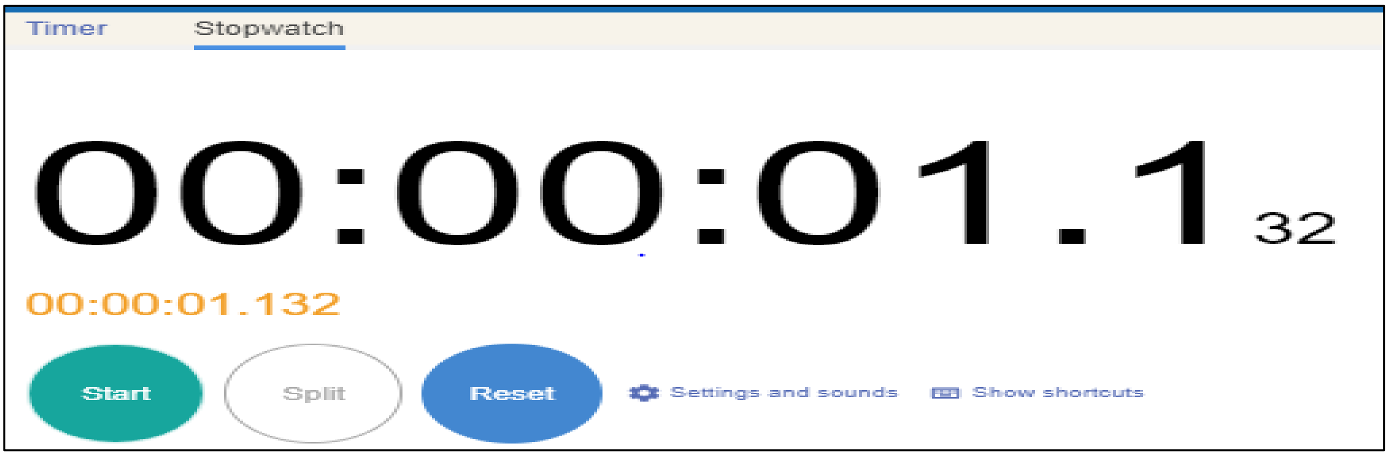



Fig 28 Data Measuring Equipment Response with an Application on a Smartphone using a Digital Stopwatch in the Shortest or Minimum Time Conditions.

## IV. RESULTS

➢ *From System Analysis and Testing, Several Results were Obtained from IoT-based Power Breakers, Namely:*

- The design cost for an IoT-based Power Breaker on the Parsada seed building application is IDR. 14,542,000 (Fourteen et al. Thousand Rupiah).
- The difference in general smart building costs with Direct Digital Control is greater than the difference in applications with IoT-based Power Breakers, 75.33% for Direct Digital Control.
- The use of IoT-based power breakers is quite effective in a smart building, where all the criteria in the automation system are sufficiently met. IoT-based Power Breakers increase energy, time, and cost efficiency.
- IoT-based Power Breaker equipment has a fixed load on the control equipment, which becomes a fixed load outside the load controlled by the IoT-based Power Breaker equipment. The load is 0.003 kW.
- There is a notification about whether the equipment is on or off in the application.
- The fixed load on the IoT-based Power Breaker is smaller than on the Honeywell CPO-DIO DDC equipment: 32 points on board I/O. The IoT-based Power Breaker has a fixed power of 0.003kw, and the Honeywell CPO-DIO DDC: 32 point on board I/O has a fixed power of 0.015kw.

## V. CONCLUSIONS

➢ *From the Data and Implementation that has been Carried out. The Internet of Things-based Power Breaker Application is used as a Building Automation System in the Lighting System. Provides Two Efficiency Benefits, Including:*

- Cost Efficiency of 75.33%.
- Power efficiency is 48,865 watts from power losses in the building control being tested.
- The time efficiency obtained when controlling using IoT is 20.835 seconds. Manual Control in 21.0835 seconds and Control with IoT-based applications in 1.341 seconds.

➢ *To Fulfill the Criteria for The Automation System. By Using Smart Breaking Equipment, Control is Obtained:*

- Real-time with a minimum time of 447ms and a maximum of 1,132ms.
- Integrated in one centralization.
- Control results in efficiency, both time and cost.
- d. Control can be controlled on one screen or monitor.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/24june266

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