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Design Of Smart Automatic Transfer Switch (ATS) Electrical Energy Monitoring System As An Energy Efficiency Effort Based On The Internet Of Things (IOT)

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Abstract
The design of the Smart Automatic Transfer Switch (ATS) Electric Energy Monitoring System as an Energy Efficiency Effort Based on the Internet of Things (IoT) aims to improve the efficiency of electrical energy use by utilizing IoT technology. The system is designed to automatically switch electricity sources between the main provider, such as PLN, and backup sources, such as generators or solar power plants (PLTS), when there is a disruption in the main electricity supply. The stable availability of electrical energy is essential in daily life. However, interruptions in electricity supply can cause significant negative impacts. Therefore, the development of a system that can monitor and manage energy sources efficiently is crucial. The integration of IoT technology in the ATS system enables remote monitoring and control, allowing users to access real-time information on energy status and consumption through mobile devices or the web. The process of designing this system includes several stages, namely planning, design, assembly, and testing. The technologies used include Node MCU ESP32 microcontroller, current sensor, and web-based monitoring application. The system can detect the availability of electricity supply and perform automatic switching with a fast response time, thus minimizing downtime in the event of a disruption. The test results show that the system can improve the efficiency of energy usage and can switch energy sources within 5-7 seconds, which is crucial for maintaining the continuity of power supply. The data collected during the test shows that the use of IoT technology in ATS not only improves energy efficiency but also provides convenience in the management of electrical resources. The design of this IoT-based Smart ATS shows great potential in improving electrical energy efficiency, as well as providing an effective solution to the problem of unstable electricity supply. With further implementation, this system can be a useful model for energy management in various sectors, especially in the context of using renewable energy.
Keywords: Smart Automatic Transfer Switch (ATS), Internet of Things (IoT), Energy Efficiency, Real-time Monitoring, Renewable Energy.

1. INTRODUCTION

Electrical energy is one of the most widely used in almost all aspects of people's lives. Energy is the ability to do work or move objects, like heat, light, mechanics, chemistry, or electromagnetics. (Energi, 2012). One of the most common users of electrical energy that we encounter, besides households, is in office buildings or industry (Saputra, 2023). To support the effectiveness of activities in offices, a reliable electrical energy distribution system is needed. The reliability of the electric power distribution system is greatly influenced by the configuration of the system, the safety devices installed, and the protection system. (Sucita et al., 2018; Zemite & Gerhards, 2014). The use of electrical energy has a negative impact if used excessively, and lack of awareness among employees about the effective and efficient use of electrical energy. (Setyowati et al., 2019; U.S. Department of Energy, 2015). This can cause many losses experienced by office buildings or industries both from the consumer side because they have to pay more for the use of electrical energy, while from the PLN side as a provider of electrical energy can also experience losses in the form of fuel that is wasted in the process of generating electrical energy. To avoid waste in the use of electrical energy, an energy audit and electrical energy management can be carried out. (Raju et al., 2018). An electrical energy audit can be used to calculate the level of electrical energy consumption of an office or industrial building, where the results of calculating the level of electrical energy consumption can later be compared with the electrical energy consumption index (IKE) standard.

(Rehiara et al., 2023; Windarta et al., 2021). Electrical energy management is a program that is systematically arranged in the use of energy by recording, planning, supervising, and evaluating continuously. Currently, the development and use of renewable energy sources is beginning to be widely used. One of the common and widely used renewable energy sources today is solar energy, or sunlight. The use of solar energy as renewable energy can also support Bali Clean Energy. With the existence of renewable energy sources that are now widely developed, the industry/office buildings have even forgotten the backup energy source they have, namely, generator sets (generators) (Thompson & Pescaroli, 2023). In general, the device whose duty is to change the voltage source or supply of electrical devices connected to the electrical network is the Automatic Transfer Switch (ATS). By using 3 (three) voltage sources, namely PLN, PLTS / Inverter, and generator, where the generator is a backup voltage source that is rarely used and cannot be actively controlled. If maintenance is not carried out regularly on the backup energy source (generator), it will have an impact on the malfunction of the generator in providing backup energy in case the source from PLN and PLTS is damaged. With the development of technology, especially information technology, the process of monitoring electrical energy in office buildings or industry can be done using microcontrollers and integrated with the Internet of Things (IoT) system. (Al-Obaidi et al., 2022; Bagus et al., 2020; Himer et al., 2023). The design of the Smart Automatic Transfer Switch (S-ATS) Electrical Energy Monitoring System (SiMonEL) Based on the Internet of Things (IoT) can function dynamically to move loads as needed, backup when the PLN network is disrupted and carry out routine maintenance of generators as a backup energy source and monitor and record data (data logging) against each voltage source and load. (Kanso, 2023). This research design emphasizes novelty in aspects that produce software or technological innovations that can help in identifying and providing information about the use of electrical energy online and in real-time, and can transfer electrical energy sources using a Smart Automatic Transfer Switch (ATS) based on the Internet of Things (IoT) (Kurniawan, 2020; Saputro et al., 2023).

2. MATERIALS AND METHODS

The scheme of this research design is divided into 3 parts, namely:

1. The Inverter Controller functions as a device that regulates the work of the inverter module to communicate and adjust the output voltage with other sources of electrical energy according to the priority and displacement conditions at that time (Parvez et al., 2016; Patowary et al., 2022),
2. The Switch Gear Controller & Display Parameter section functions as a device that regulates the work of the load transfer control device following the conditions specified in the working description of the device (Breaker & Motorized, n.d.). In this switch gear controller section, there are several device units, including:
    1) A microcontroller unit that serves as the center for processing and execution of programs that have been created according to the working description of the device.
    2) The Voltage and Current Sensor Unit functions as a sensor that reads voltage and current parameters from each source and load so that they can be processed into secondary parameters such as power, power factor, and power consumption.
    3) The I/O Extension Unit functions to multiply the I/O pins on the microcontroller, which in this device is used to connect the microcontroller with the coil control of each relay on the switch gear to allow the microcontroller to adjust each relay output from the switch gear device.
    4) Navigation Input Button Unit that functions as a medium to navigate the operating system program that has been created on the microcontroller.
    5) Display unit that functions as a media display of information and variables on the microcontroller so that users can interact and change the parameters of the settings on the device.
    6) RTC unit that functions as a time data storage unit when the system is off (inactive) and when the system is operating.
    7) The Data Logger Unit functions as a data storage medium for variables that have been calculated, such as voltage at a certain time, power, and others.

3. The Internet gateway section functions as a link between the device and the Internet so that the device can communicate with applications on smartphones.

The scope of research is carried out with 2 methods, namely by designing systems, both hardware and software, and by conducting system testing and data processing, and analysis. Research materials used in making a Smart-ATS design of an Internet of Things (IoT) based electrical energy monitoring system are divided into 3 parts, namely 1: Independent Solar System with the main constituent components including Solar Panels, Solar Charger Controler (SCC), Power storage batteries, and inverter units, (2). Switching Control System, which consists of several main constituent parts, namely the main controller board and the switch gear, and (3). Genset Communication Module, which serves to take information issued from the generator control module in the form of Modbus RS485 communication, so that it can be used to communicate and control the Genset unit.

3. RESULTS AND DISCUSSION

The work description set for the implementation of this device has 2 modes of operation, namely AUTO mode and MANUAL mode. In AUTO mode, the device will run on predetermined conditions by adjusting the variable values contained in the program. The initial steps taken are to design the system, assemble the equipment, and test the system and applications used.

PCB (Printer Circuit Board) Design

The PCB (Printed Circuit Board) design process using EAGLE software begins with the creation of a circuit schematic in the Schematic Editor, where components such as resistors, capacitors, ICs, and connectors are connected according to the circuit diagram. After the schematic is validated, the next step is to arrange the layout of the components on the circuit board using the Board Editor, followed by the process of routing connection lines manually or automatically. The Design Rule Check (DRC) feature is used to ensure the design complies with technical production standards. Once finalized, the production file is exported and sent to manufacturing for PCB printing. An illustration of the design process is shown in Figure 2 below.

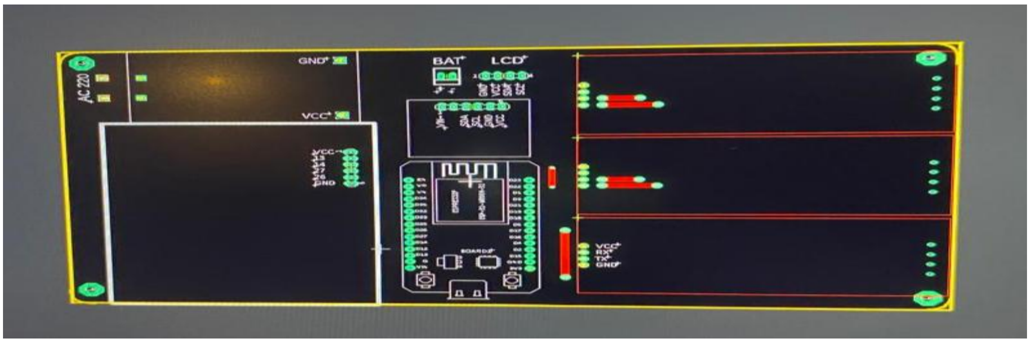


Figure 2: PCB (Printer Circuit Board) Design Process

Component Assembly

Once the PCB design for the Smart ATS (Automatic Transfer Switch) system is complete and the circuit board is printed, the next step is to assemble the electronic components onto the PCB according to the layout that has been made and integrate the system with Visual Studio Code-based applications. The process starts with sorting and placing components such as resistors, capacitors, relays, microcontrollers, communication modules, voltage sensors, and power connectors in the right position, then carefully soldering them to ensure the electrical connections are secure and free from short circuits. Once all components are installed, initial testing is done to ensure the circuit functions as designed. Next, the system was configured and interfaced with software for control and monitoring via a mobile application. After the program code is uploaded to the microcontroller and communication between the hardware and the application is successful, the assembled PCB is integrated with mechanical components such as contactors, sensors, and control panels. If the system runs according to specifications, the Smart ATS is assembled into a protective box to ensure safety and reliability. Thus, the Smart ATS system can be monitored and controlled in real time through the app. The assembly process, initial testing, and application integration are shown in Figure 3 below.

Figure 3: Assembly, initial testing, and integration of the application

Smart ATS System Testing

The Smart ATS system test aims to ensure the function, reliability, and stability of the device by automatically switching the power source when a fault occurs in the main source. Three sources of electricity were used in this test: PLTS as the main source, PLN, and Genset as backup. This scheme reflects a hybrid electricity system that prioritizes renewable energy without neglecting the continuity of supply. The testing stages carried out are as follows:

1. Auto System Testing

The auto-testing process begins with testing the main source (PLTS) active, which is shown on the LCD and displayed on the corresponding mobile application, and displays voltage, current, power, and energy in real-time as shown in Figure 4 below.

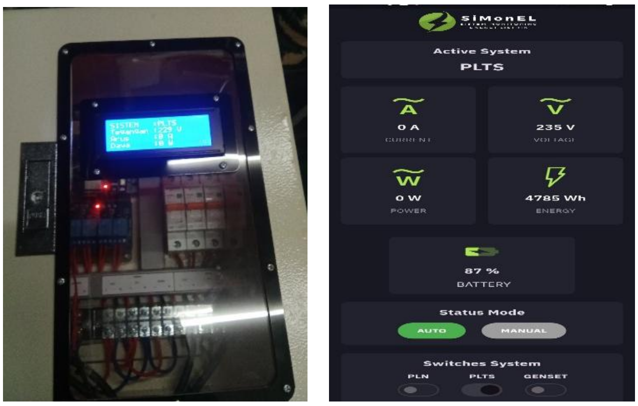


Figure 4 LCD Display View and Mobile PLTS Application on

Testing the ATS response is done by disconnecting the power from the PLTS or simulating a disturbance. The ATS will detect a voltage anomaly or a drop in battery capacity, then, within a certain time lag, switch the load to the first backup source, PLN. This process is tested to ensure a smooth transition without voltage spikes or delays that could damage equipment. The process of switching from the PLTS to the PLN backup energy source can be seen in Figure 5 below.

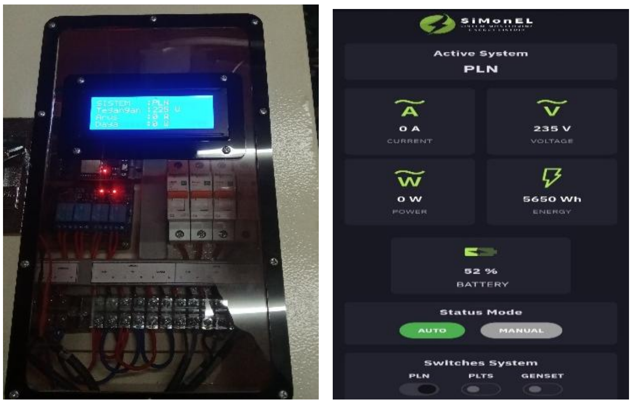


Figure 5 LCD Display and PLN Mobile Application Active

Testing the transfer to the generator is done by turning off the PLN source and the PLTS battery level has not reached 85% so that the ATS system must start the generator automatically and switch the load to the generator so that the LCD menu and the application will display the active generator as shown in Figure 6 below.

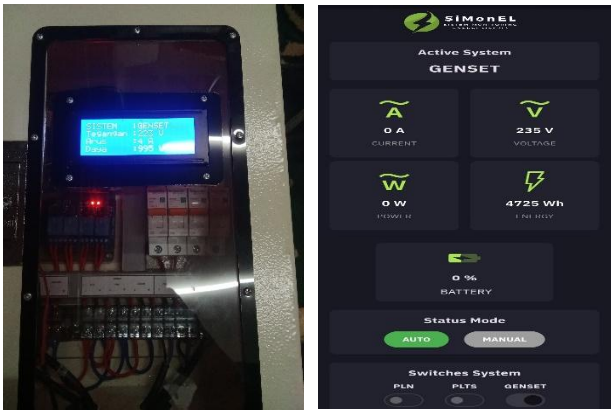
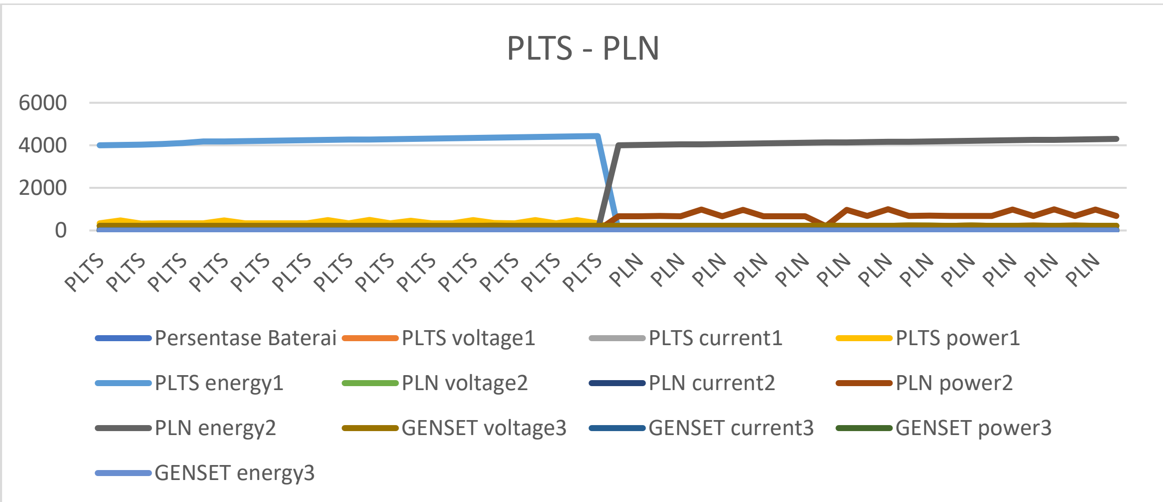


Figure 6 LCD Display and Mobile Genset Application on

This switching scenario will take place continuously based on the conditions that occur with PLTS as the main energy source, while PLN and generators serve as backup energy sources. The transfer of electrical energy sources from PLTS to backup energy sources from both PLN and Genset can be done if the PLTS battery level is below 85%, and vice versa, the transfer back to PLTS is done if the battery level has reached 85%, as shown in the following graphical image.



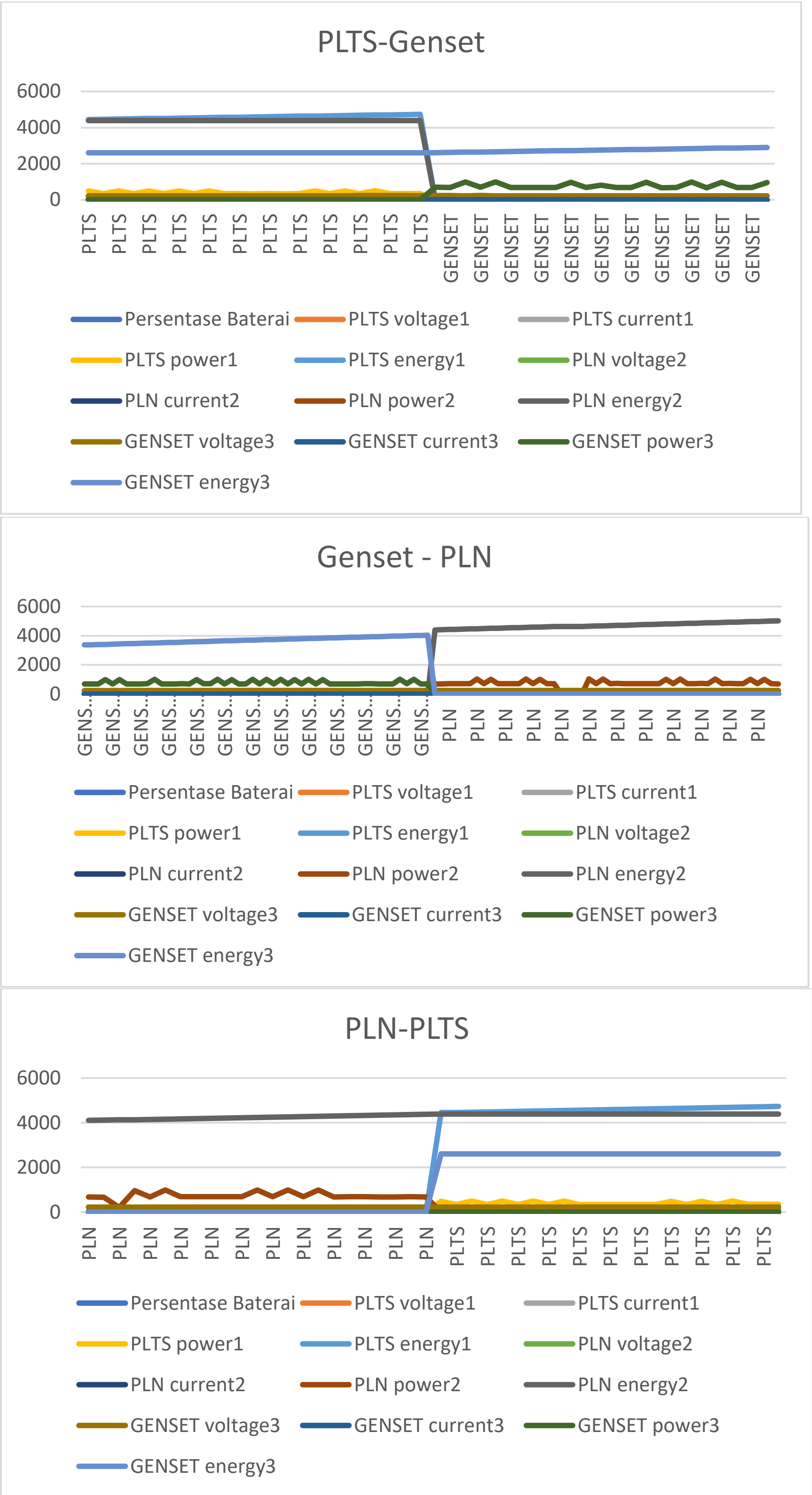


Figure 7: Auto displacement of electrical energy sources

2. Manual system testing

Manual system testing is done by testing the remote control feature in the mobile application to move the ATS system to switch sources manually according to the command, so that the display on the application shows the transfer of mode status from auto to manual, as shown in Figure 8 below.

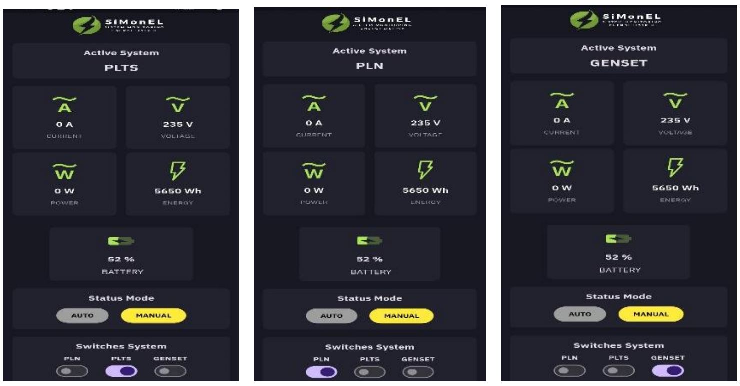


Figure 8 Application display with manual mode status of PLTS, PLN, and Genset

From the results of the tests that have been carried out, it is found that the work functions of the device have been fulfilled properly, as evidenced by the accuracy of the functions and workings of the system. These results show that the Smart ATS system algorithm is appropriate and can work well.

4. CONCLUSIONS

From the results of the discussion that have been explained, it can be concluded as follows:

1. The design of the smart ATS system is carried out through three stages, namely PCB (Printer Circuit Board) design, equipment assembly, and testing of the system and applications used.
2. The work description set for the implementation of this device has 2 modes of operation, namely AUTO mode and MANUAL mode. In AUTO mode, the device will run on predetermined conditions by adjusting the variable values contained in the program, while MANUAL mode is selected if, at a certain time, it is necessary to transfer energy.
3. The design of the IoT-based Smart ATS system successfully improves electrical energy efficiency by enabling automatic switching of power sources and real-time monitoring through mobile devices.
4. The integration of IoT in Smart ATS System is not only effective in energy efficiency but also has the potential to be a reliable solution for energy management, especially in the utilization of renewable energy.

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Ethical considerations

Not applicable

Conflict of Interest

The authors declare no conflicts of interest

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