Control System for Smart Home Energy Management

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Abstract. The increasing energy demand for residential load is often associated with a lot of energy waste due to lack of a good energy management system. In this work, we propose an intelligent energy management system (EMS) which is designed to control the electrical energy source from solar energy and the power plant from PLN resources both automatically and manually based on the Internet of Things. This control system can be controlled remotely during the process of connecting and disconnecting backup power sources that can be accessed through smartphone devices. Based on the test results of the control system of displacement of energy sources, the DC voltage sensor accuracy value is 99.44% and the PLN voltage measurement has an accuracy of 98.31%. In the control system transfer to a backup power source with manual control has an average duration of time of 0.74 seconds while the automatic control has an average duration of time of 0.98 seconds to 1.33 seconds and for automatic control with priority reading the battery capacity of 12.75 Volts can do transfer from the PLN power source to the backup power source and transfer to the PLN source if the voltage is less than 10.5 Volts with a 100% success rate.

1. Introduction
In a smart home, productivity and quality of community life depends mainly on the level of comfort inside in particular from visual and thermal comfortableness [1-3]. For example, regulations related to lighting and air conditioning systems have a major role to determine optimum design of comfort level of the building [4].

Electricity distributed by the State Electricity Enterprise (PLN) is mostly produced from coal, diesel, oil, and MFO. Meanwhile, alternative energy sources, which are environmentally friendly, are just started to be promoted through Ministerial Regulation (Permen) Number 49 of 2018 regarding the Use of Roof Solar Power Systems by consumers of PT PLN. However, the amount of power output in a solar power system depends on the intensity of solar radiation [5]. Therefore, the integration of solar power as an additional energy source can be combined with the main electricity source, namely PLN, known as On-Grid System [6].

In this study the energy system produced by solar panels will be directly connected to the battery and a converter is distributed to the load. The implementation of electric energy source control methods for on-grid solar power generation systems can also increase the efficiency of energy use, because energy flow can be adjusted according to load requirements [7].

In this study, a control system is designed to be able to transfer electricity from the main power source to a backup power source that has been stored on the battery. This control system can be operated manually or automatically and accessed remotely with Internet of Things technology. The use of Internet-based transfer control systems would control all electrical equipment in the home by
disconnecting and connecting backup power sources through a smartphone application. With this system, the user can choose the control features found on the smartphone and is able to reduce costs and the excessive use of electrical energy from PLN.

2. Design of the system

2.1 Hardware Design

![Diagram of hardware design](image)

**Figure 1.** Hardware design of electric power transfer control system.

The Smartphone application in Figure 1 functions as a medium that sends input selected by the user to perform manual or automatic switching and receive the results of sensor measurements through the cloud server. The cloud server functions as a place to exchange data that is received or sent to the Node MCU smartphone and microcontroller application. The Node MCU microcontroller functions as an input data processor that has been received from the cloud server and provides output to the relay to transfer electrical power and will send sensor measurement data and displacement indicators to the cloud server.

The ZMPT101B sensor functions to measure AC voltage at PLN to be able to carry out the displacement automatically, the ACS712-30A sensor functions to measure AC current in electrical equipment supplied by PLN, and the voltage sensor functions to determine the available battery voltage. The relay functions as an output in connecting and disconnecting backup power sources by receiving input from Node MCU.

2.2 Software Design

This smartphone application is designed for users to carry out control systems for the transfer of electrical resources for homes based on the internet of things.
Figure 2. Software Design

Figure 2 shows the software design that will be used to make transfers manually or automatically by selecting a control system to transfer electricity to the home.
3. Analysis

3.1. Sensor Calibration

The purpose of this test is to determine the accuracy of the sensor readings that will be compared with multimeter and power meter.

![Voltage Sensor Calibration](image1.png)

**Figure 3. Voltage Sensor Calibration**

![Current Sensor Calibration](image2.png)

**Figure 4. Current Sensor Calibration**
In testing the voltage sensor to the power supply, the average error value percentage is 0.56%. The biggest error value is 0.14 Volt with a voltage sensor accuracy of 99.44%. Testing the ACS712-30A sensor to the power meter obtained an average error value percentage of 31.37%. The largest error value on the ACS712-30A sensor is 0.18 A with the accuracy of the AC voltage sensor of 68.63%.

ZMPT101B sensor testing of the power meter obtained an average value of percent error of 1.59% in 3500 (VA) homes. The biggest error value at 3500 (VA) is 4.25 Volts with an AC voltage sensor accuracy of 98.42% and the ZMPT101B sensor testing of the power meter shows an average percent error value of 1.88% at 2200 (VA). The biggest error value in a house of 2200 (VA) is 5.18 Volts with an AC voltage sensor accuracy of 98.12% while the power meter shows the density value in the measurement of the PLN voltage.

3.2. Automatic Control System with Battery Capacity Calibration
This test aims to determine the duration required by the system to transfer electricity automatically by calculating the capacity of available batteries.

![Figure 5. Calibration of Automatic Control System with Battery Capacity](image)

The use of batteries in supplying electrical equipment such as 32 watt lamps, fans, and rice cookers has a voltage drop from 12.75 Volts to 10.5 Volts with a battery load supply duration of 57 minutes 43 seconds.

4. Conclusion
The system has worked properly where the system can transfer electricity resources manually and automatically. The DC voltage measurements can read the voltage value on the battery with good accuracy. The accuracy value of the sensor when compared to the power supply is 99.44%. Measurement of AC voltage in the form of a ZMPT101B sensor can read PLN voltage values with good accuracy. The sensor accuracy value when compared to the power meter has an accuracy level of 98.41%. While the electric power transfer control system for home on manual control has an average time of 0.74 seconds, the automatic control has an average time of 0.98 seconds to 1.33 seconds.
Finally, our system can transfer from the PLN power source to the backup power source showed by dropping of the battery capacity of 12.75 to 10.5 Volts with a 100% success rate.

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