Design of Automatic Switch System of Solar Panel and Power Plant for Residential Load using Artificial Neural Network

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Abstract. Electricity needs in Indonesia are getting bigger, following the increasing population. Today, most of Indonesia’s electricity needs are provided by PLN. However, most PLN electricity sources are non-renewable energy sources. Indonesia is a tropical country that receives sunlight almost all year long, so it is possible to use solar as an alternative energy. We designed an automatic switch system that could switch the electrical energy source from solar panel to the power plant from PLN if the power from the solar panel were insufficient. The automatic switch controller in this system uses backpropagation neural networks. The artificial neural network (ANN) model in this study consisted of two inputs, two hidden layers, and one output. The residential loads used are lamps, rice cooker, and fan. From the research results, the optimum epoch value is 2000, with an automatic switching accuracy value reaching 98.6%.

1. Introduction
Electricity consumption in Indonesia is increasing every year. Based on data from the Ministry of Energy and Mineral Resources (ESDM), electricity consumption per capita in 2018 reaches 1064 kWh [1]. The use of electricity is not only consumed by residential, namely electronic equipment used at home [2], but also business and industry. The State Electricity Company (PLN) primarily meets the fulfillment of power for the needs of the Indonesian population, which deals with all aspects of electricity in Indonesia. The electricity distributed by PLN mostly comes from hydroelectric power plants, steam power plants, diesel power plants, and gas power plants. Keep in mind that the power plant still uses a lot of fuels such as coal, diesel, fuel oil, and MFO. As a tropical country crossed by the equator, Indonesia is almost illuminated by the sun throughout the year. Therefore, the concept of renewable energy using solar power is suitable for use as alternative energy. This is following Ministerial Regulation (Permen) Number 49 the Year 2018 regarding the Use of Solar Roof Power Generation Systems by consumers of PT PLN. The Ministerial Regulation aims to reduce the cost of electricity and to increase the use of renewable energy.

Solar power generation is a power plant that converts solar energy into electricity. One of the ways to convert solar energy into electrical energy is to use photovoltaic, which for the change process uses photoelectric effects. Because there are not many solar power plants in Indonesia, if the household makes a solar power system, it can be hybridized by using electricity from PLN. This hybrid system is needed to maintain the stability of electricity availability and the maximum utilization of solar panel energy. Changing from one generator to another on a hybrid system requires a switching system.

The switch controller is designed to automatically detect the availability of generating sources that supply the load. The controller unit will check the battery voltage on the solar panel if the voltage from the solar panel starts to fall and is not able to meet the needs, then other sources will replace it [3]. In previous research, there is a source controller using the buck converter often decreases when there is loading [4]. The design is based on the implementation of solar panels as a power supply that will produce maximum utilization of alternative energy. Other studies include switching from solar power...
plants to power plants from PLN with its power supply regulator using fuzzy logic control [5], manual and automatic switches [6], and programmable logic control [7]. In this paper, we present an automatic switching system of solar panel and power plant for residential loads using artificial neural networks. Where the primary goal of developing this system is to design an automatic switching system of solar cells and power plant that matches residential loads.

2. Proposed Automatic Switching System of Solar Panel and Power Plant

We developed an automatic switching system of solar panel and power plant for residential loads. The system that we developed consists of hardware and software. The main function of the hardware in our system is to convert solar energy to electricity and save it to the battery, measure voltage and current, and execute switching. The software in our system serves to determine the power supply to be used. Figure 1 presents the block diagram of the automatic switching system of solar panel and a power plant.

![Diagram block of the proposed automatic switching system of solar panel and power plant](image)

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2.1. Hardware Design

In the proposed automatic switching system, a monocrystalline type solar panel 100Wp used to convert solar energy to electrical energy. The device for storing energy produced by the solar panel is a battery 12V 35Ah. We used solar charge controller 20A to charge the battery [8]. The tool for converting DC into AC using an inverter 1000Watt. Current sensor ACS 712 used to know the current read on the power supply (solar panel and PLN) and residential loads (lamps, rice cooker, and fan). Voltage sensor ZMPT101b used to know the voltage read on the power supply and residential loads. Arduino is a microcontroller from this system. We embed artificial neural network in this microcontroller. And then, relay two channels serve to turn on one source of electricity, solar panel or power plant.

The design of this study is a solar panel with changing sunlight intensity connected to a battery with a voltage considered constant. But the characteristics and specifications are determined in advance by considering the load data. Between the power plant and the solar panel is a switch with artificial neural network control with input voltage on the battery. With this input, it will be processed with an artificial neural network algorithm with the weight value of the results of the neuron experiment.

2.2. Software Design

We used Python to design the artificial neural network system before it is applied to Arduino Uno. An artificial neural network with a multilayer architecture consisting of three layers, namely, the input layer, is composed of several neurons whose numbers are adjusted by the input pattern. Furthermore, a hidden layer with several neurons whose name is done by trial and error, where chosen, is the one that produces convergence with the fewest iteration. The output layer consists of several neurons depending on the desired output pattern.

The input pattern used in this system is voltage data issued by the solar panel and PLN voltage for 24 hours. And then, the output pattern is the prediction of on/off switch pattern for 6 hours. The training data used in this system is the error value and duty cycle data from the solar panel. While the data for testing uses data transpose from the original data. The activation function applied is a binary sigmoid function that has a range of values from 0 to 1, so it is necessary to normalize the data using equation

\[ X' = \frac{X - b}{a - b} \]
\( X' \) is normalization data, \( X \) is preliminary data, \( a \) is the maximum value, and \( b \) is the minimum value.

Figure 2 shows the flowchart of automatic switch systems between the solar panel and PLN. The developed system is an automatic power source regulation system. The main function of this system works by utilizing the solar panel first. If the solar panel does not meet the need, then immediately switches to the power plant source. The flow of the system starts with reading the voltage and current of the solar panel. After that, the system will calculate the power generated by the solar panel. Then the system calculates the current and the power at the load. When the solar panel power is less than the load power, the power plant switch is "ON". Conversely, if the solar panel power is higher than the load power, the power plant switch is "OFF", and the program has finished.

![Flowchart of the system](image)

**Figure 2.** Flowchart of the system

3. **Experiment and Analysis**

There are four tests carried out, namely current sensor calibration, voltage sensor calibration, battery limit testing, simulation testing. We used residential loads such as six lamps, one rice cooker, and one fan.

3.1. **Current Sensor Calibration**

The purpose of the current sensor calibration is to find out whether the current sensor can work as expected or not. Current sensor testing carried out using a power supply source. The alternating current sensor calibration step is to connect the sensor pins to the Arduino UNO. The current sensor has three main pins, namely, VCC, GND, and VOUT pins. VCC and GND pins connected to VCC and GND pins on Arduino UNO. And then, the VOUT pin from the sensor is connected to pin A0 on Arduino UNO. Measurement is done by measuring the current with a power supply source. In the next step, the power...
supply output current is compared with the sensor reading. The results of the current sensor calibration show that the current sensor has pretty good accuracy, with an average percentage error of 1.57%. The current sensor has an error rate below 3%, so the current sensor is reasonable and can be used in the experiment.

3.2. Voltage Sensor Calibration

The purpose of the voltage sensor calibration is to find out whether the voltage sensor can work as expected or not. Calibration is done by comparing the measurement results of the voltage sensor readings with the calculation. The voltage sensor calibration step is to use one-way communication to exchange data between the sensor and Arduino UNO. Pin 1 of the line is connected to pin A1 on Arduino UNO devices. Pin VCC and GND are connected to pin VCC and GND on Arduino UNO. The voltage sensor calibration results show that the voltage sensor has pretty good accuracy, with an average percentage error of 2.0%. In the data, there is a quite significant difference in the number behind the comma, between the value of the voltage sensor reading and the voltage value on the kWh meter. This is caused, the voltage sensor used is ZMPT101B which has a sensitivity of 100 mV/A, so the sensor cannot detect voltage values below 1 volt accurately. Another factor that causes a large enough difference is the effect of loading on the kWh meter.

Calibration is done by comparing the measurement results of the voltage sensor reading with the voltage input from the power supply. The results show that the voltage sensor has an accuracy of 1.00%. In the data, there is a quite significant difference in the number behind the comma, between the value of the voltage sensor reading and the power supply output voltage. The cause of this is the voltage sensor used is a voltage sensor, which has a resolution of 0.00489V, so the sensor cannot detect voltage values below 1V accurately. Besides that, it is caused by the loading effect, which causes the value to be quite significant.

3.3. Battery Limit Testing

Battery limit testing is carried out to determine the voltage limits for the switching regulator. The test is carried out on batteries that have been charged using solar panels for 6 hours. This test was conducted to determine the use of batteries in residential loads such as lamps (42W), fan (12W), and magic com (350W). Table 1 shows the results of testing battery usage.

| Time      | Load                             | Voltage | Information       |
|-----------|----------------------------------|---------|-------------------|
| 15.54     | Six lamps, rice cooker, and fan  | 13.50V  | All load on       |
| 16.33     | Six lamps, rice cooker, and fan  | 11.84V  | All load on       |
| 17.02     | Six lamps, rice cooker, and fan  | 11.55V  | All load on       |
| 17.32     | Six lamps, rice cooker, and fan  | 10.64V  | Six lamps off     |

It is found that the switch limit is determined by the voltage on the battery. At a voltage of 13.50V, all load conditions are on, but, at 10.64V six lamps off. Because at 10.64 V there is a load off condition, 10.64V is used as a setpoint for the supply of the load. The setpoint means at 10.64V system switch from the solar panel source to the power plant source.

3.4. Simulation Testing

Simulation testing and analysis of artificial neural network responses in the automatic switch system obtained some values as shown in Table 2.

| No | Duty cycle | Error | Learning 1000 | Learning 2000 | Learning 3000 | Hidden layer |
|----|------------|-------|---------------|---------------|---------------|--------------|
| 1  | 0.985      | 0.005 | 0.064         | 0.015         | 0.045         | 2            |
| 2  | 0.998      | 0.005 | 0.055         | 0.023         | 0.039         | 2            |
| 3  | 0.998      | 0.005 | 0.054         | 0.024         | 0.040         | 2            |
| 4  | 0.999      | 0.993 | 0.944         | 0.980         | 0.953         | 2            |
In Table 2, the results obtained from this training show that the average synaptic values at 1000 repetitions are 0.638, at 2000 repetitions is 0.643, and at 3000 repetitions is 0.639. Table 3 shows the results of the error percentage of each epoch obtained from the average error value for each epoch multiplied by its normalization.

| Iteration       | Error (%) |
|-----------------|-----------|
| Iteration 1000 times | 9.063     |
| Iteration 2000 times | 1.349     |
| Iteration 3000 times | 8.287     |

In Table 3, the results of this simulation show that synaptic data at 2000 repetitions are the best accuracy. The accuracy achieved in the 2000 iteration is 98.6%. This can be caused by the nature of the artificial neural network process, which, if more and more repetitions will lead to many error values, while on repetitions that are too small will result in more errors.

4. Conclusion
We have presented an automatic switch system of solar panel and a power plant for residential load using an artificial neural network. Based on the results of the experiment, it can be concluded that the parameter used to get the lowest error rate in the process of regulating the best power supply is to use 2000 repetitions with an accuracy of 98.6%. Based on battery testing, the battery will be discharging at ± 10.6V and charging at 13.5V. An artificial neural network can experience convergent failure or not close to the output because the initial guess is not good.

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