Household electricity network monitoring based on IoT with automatic power factors improvement using neural network method

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Abstract. The development of installed capacity in power plants in 2018 was 41,696 MW or increased from the previous year in 2017 amounted to 39,652 MW (PLN Statistics, 2018). This has an impact on the reduced availability of fuel due to overexploitation. The highest energy sold per customer group in 2018 was the household customer group that was 41.7% higher than the industrial sector customer group by 32.8% (PLN Statistics, 2018). At present the use of electronic equipment for household needs is increasingly diverse. Many equipment that is often used in daily life is electronic equipment that is inductive load. Inductive load causes the value of the power factor to fall so that the power usage (Watt) becomes less than optimal. To overcome the problem caused by the large number of inductive loads a reactive power compensator is needed which is to use a capacitor. In this final project, a system designed to be able to measure and correct power factors automatically uses the Neural Network method and can monitor power online based on IoT. The results of testing the power factor improvement system were 97.8% successful in the trained electric load and 94.8% in the untrained electrical load.

1. Introduction
The increasing demand for electrical energy has led to an increase in the power generation industry in Indonesia. The development of installed capacity in power plants in 2018 amounted to 41,696 MW or an increase from the previous year, in 2017 which was 39,652 MW [1]. The highest energy sold per customer group in 2018 was the household customer group, which was 41.7% higher than the industrial sector customer group at 32.8% [1]. Many of the equipment that is often used in everyday life is electronic equipment that is inductive load. The inductive load is known as the lagging load (current lagging the voltage). To overcome the problems caused by the large number of inductive loads, a reactive power compensator is needed to compensating a lagging current by a leading current, through connecting capacitance to the supply [2]. The reactive power compensator must be able to improve the power factor automatically under varying loads. By controlling the combination of capacitor circuit so that the capacitance value varies and requires a smaller number of capacitors. The Neural Network based power factor improvement is an accurate methods of power factor correction meanto induce the
necessary capacitance in the system [3]. In 2018 Y. Yuniarto and his team have performed power factor correction for household electrical installation. The results of this study indicate that the electric current flowing before the capacitor is installed is greater than the electric current when the capacitor is installed. As for the power factor, there was an increase in the value of the power factor, which was originally from 0.34 to 0.36 to 0.90 to 0.95. [4].

Information the use of electrical energy can be accessed via a web page using the MQTT protocol. In the use of the MQTT protocol there is a term Quality of Service (QoS). MQTT protocol become very useful because work asynchronously in real time and ensure their functioning in hostile communication environments [5]. MQTT is a protocol for popular IoT systems and can be applicable in some fields such as environmental monitoring [6] [7], industrial sector [8], energy management [9], and other sectors like transportation [10]. With the addition of IoT facilities, it will make it easier to control the use of electrical energy, which can increase modern public awareness of the importance of making efforts to save electrical energy.

2. Methodology

The purpose of this project is to improve power factor automatically. This project also and can monitor household electricity power online based on IoT. Here is the explanation about Hardware, System and the overall steps of this research can be explained as follows.

2.1. Hardware Design

This project uses several component and hardware. The hardware component and can be explain as follows:

1. Power Input
   This device is used to connect main supply of this system hardware.
2. Current Tape Sensor
   This device is used to sense electrical current. And the signal will be processed by pzem-004t power meter module.
3. Liquid Crystal Display
   It used to display information and data on the system.
4. Controller Board.
   Used as the main controller that processes data input and output system.
5. Load Power Socket
   It used as the electrical power source to be connected to the load.
6. Capacitor
   Used as reactive power compensator used to improve the power factor.

All of this component that have been explain in above shown on figure 1.

![Figure 1. Hardware Design System](image-url)
Figure 2 will show the diagram block of the project system.

2.2. **IoT System Design**
The device to be made functions as a publisher on the MQTT protocol, periodically the device will send data on a certain topic to the broker. While the device used for monitoring functions as a subscriber, the way it works is by first sending a request for certain topic and then receiving data according to the requested topic. The data that has been received is then processed and displayed so that users can find out information on the use of electric power in the installation. The diagram as shown on figure 3.

2.3. **Neural Network Algorithm**
Neural network method will function to determine the value of capacitor compensation needed to improve the power factor value. In this step, the design of the neural network algorithm is divided into several stages, namely, the formation of sample data, the training process, weight extraction, and the formation of the neural network structure. Several steps in the design of a neural network algorithm are described as follows:
1) Step 1 Create Data Sample
Data sample formation is done by taking data on the 5 predefined electrical equipment. The electrical equipment is switched on alternately to form different load variations. Then performed data collection, namely power and power factor as input to the neural network algorithm. While the output is the calculated capacitor value according to their needs. The result of the formation of sample data for the training process.

2) Step 2 Training Process
The training data process uses the NN (Feed Forward) toolbox in Matlab by using 2 hidden layers with 1 hidden layer having 12 neurons and 1 hidden layer having 1 neuron. The training process is carried out until a good performance is obtained. Then the weight extraction process is carried out to take the weight values after the training process is successful. The training data process can be seen in figure 4 below.

![Figure 4. Training Process on MATLAB](image)

3) Neural Network Structure
Making the network structure is done to facilitate the creation of a neural network algorithm on the microcontroller. To create a network structure, it is necessary to consider the number of neurons in each layer and the bias. The structure of the neural network is shown in figure 5 below.

![Figure 5. Neural Network Structure](image)

Neural network structure with input X1 and X2, while Y is the output. This network has 2 hidden layers with 12 neurons in the first hidden layer and 1 neuron in the second hidden layer.
3. Test Result
In the IoT based monitoring test, users can view data information about electrical parameters, namely voltage, current, power, power factor, energy and frequency on the web page. Users can also view additional information in the available additional information (InfoBar) as shown in figure 6 below.

![IoT Based Monitoring System](image)

**Figure 6. IoT Based Monitoring System**

At the power factor improvement testing stage, it aims to determine whether the circuit can work as expected or not. Tests are carried out on various types of loads for which the power factor value will be corrected and to observe whether there is an increase in the power factor value before and after connecting the capacitor. The load test is the load that has been used to create training data for the neural network algorithm and the second stage is to test the load that is not used to create training data. The load used and the test result can be seen in table 1 and table 2.

**Table 1. Load Test**

| Load Code | Load Name   | Type          |
|-----------|-------------|---------------|
| KK        | Small Fan   | Cosmos7 LDA   |
| KB        | Large Fan   | Cosmos 46W    |
| LK        | Fluorescent | Sonora 10W    |
| LB        | Fluorescent | Sonora 15W    |
| MX        | Mixxer      | Phillips 170W |

**Table 2. Load Test Result**

| No | Load Code | C | PF before | PF after | Error (%) |
|----|-----------|---|-----------|----------|-----------|
| 1  | MX        | 1 | 0.88      | 0.98     | 2         |
| 2  | TB        | 6 | 0.35      | 0.98     | 2         |
| 3  | TK        | 3 | 0.37      | 0.97     | 3         |
| 4  | KB        | 1 | 0.90      | 0.98     | 2         |
| 5  | KK        | 1 | 0.65      | 0.98     | 2         |
| 6  | MX+TB     | 5 | 0.67      | 0.97     | 3         |
| 7  | MX+TK     | 3 | 0.77      | 0.99     | 1         |
From the results of the first stage testing on trained loads (according to sample data) it can be concluded that the tool made is able to improve power with an average error of 2.2%. In this second testing stage, aims to determine the level of success of the neural network method for improving the power factor at unknown loads. The load test in this stage can be seen in table 3 and the results are shown in table 4.

### Table 3. Load Test

| Load Code | Load Name    | Type     |
|-----------|--------------|----------|
| LH        | Fence Lamp   | INS 45W  |

### Table 4. Test Result

| No | Load Code | C | PF before | PF after | Error (%) |
|----|-----------|---|-----------|----------|-----------|
| 1  | LH        | 2 | 0.71      | 0.97     | 3         |
| 2  | LH        | 2 | 0.71      | 0.97     | 3         |
| 3  | LH        | 1 | 0.71      | 0.86     | 14        |
| 4  | LH        | 2 | 0.71      | 0.97     | 3         |
| 5  | LH        | 1 | 0.71      | 0.86     | 14        |
| 6  | LH        | 2 | 0.71      | 0.97     | 3         |

Average of Error 2.2%
From the results of the second stage of testing, it can be concluded that for untrained loads or not training data, it can be concluded that the tool is made to improve power with an average error of 5.2%.

4. Conclusions
The Neural Network method is able to improve the power factor with a success of 97.8% for trained electrical loads and 94.8% for untrained electrical loads. The use of the MQTT protocol can optimize data communication on an IoT-based monitoring system so that it can monitor directly on the website.

5. Reference
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