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Artificial Neural Network Applications Use Measurements of Electrical Quantities to Estimate Electric Power

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Abstract. Prototype measurement of electrical quantities had been built and applied to the H building in faculty of engineering, University of Lampung. Electrical quantities Measurement of electrical quantities had been saved on TIK's server. However, it had not been used for estimation. Electric power is the electricity that tends to change following the electric load. So, electric power can be predictable or estimation based on measurement data in the past. The method of backpropagation artificial neural networks is a method that have a good approach to nonlinearity. The results of testing the estimation of electric power consumption had been done in the distribution panel of Electrical Engineering and Mechanical Engineering UNILA indicated that this method can be used to estimate electric power consumption for one month ahead with an accuracy of $\pm 0,884\%$. Thus this research can be applied to real-time estimation processes that can be accessed and displayed by web in real-time.

1. Introduction

On the existing problems, the quantities of electricity in the H building of UNILA had been measured by the smart monitoring prototype. Actually, the result of measurements can be used as an aspect of operation planning of a good and appropriate the electric power system, is prediction or estimation. One method for estimating or predicting nonlinearity is using ANN (Artificial Neural Networks). Variables used in this ANN method are electrical system data (electrical power of each phase), date data, day data, holiday data, and room data in the past where these data are factors that influence electricity consumption.

The purpose of this research is to prove that the backpropagation neural network method can be used to predictions or estimates from the data of electrical quantities (electric power of each phase) that was measured by the smart monitoring prototype in the H Building of the Faculty of Engineering UNILA one month ahead.

2. Literature Review

2.1 Characteristics of Electrical Systems in H Building of The Faculty of Engineering, University of Lampung

Characteristic curve of the electric quantity is the result of measurement smart monitoring prototype in H Building of the Faculty of Engineering, University of Lampung that the power system in the Faculty of Engineering UNILA is a three-phase system [1],[6].

Estimates or predictions are allegations about things or events that will occur in the future. The estimation of the electrical system is very important to know because with this estimation the development planning process in terms of the operation of electric power in accordance with the needs in the future can be planned properly [2].

2.2 Artificial Neural Network(ANN)

ANN is a computational system with architecture and operations inspired by knowledge of biological nerve cells in the brain [3],[5]. This makes ANN very suitable to solve problems with the same type as the human brain. Artificial neural network system is determined in the following 3 things:

- The patterns of relationships between neurons are called network architectures.
- The method of determining the connecting weight is called the training / learning method / algorithm.
- Activation function used.

The neuron imitation in the structure of artificial neural networks is as a processing element like picture 3 that can function like a neuron. A number of input signals a multiplied by each weight. Then the sum of all the multiplication results and the resulting output is carried out into the activator function to get the level of the output signal $F(a, w)$. Although still far from perfect, the performance of these neuron imitations is identical to the performance of the biological cells we know [3],[5]. An artificial neuron model is shown in Figure 1.

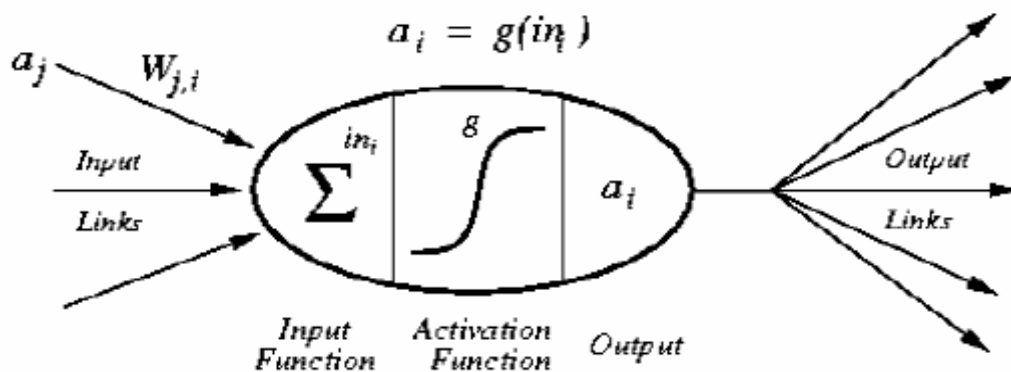


Figure 1. Neuron Artificial Model

In the neural network, there are two network architectures [4],[5], namely:

- Single Screen Network (Single Layer Network)
In this network, all input units in this network are connected to all output units, although with different weights.
- Multiple Screen Networks (Multi Layer Network)
This network is an extension of a single screen network. This network introduces one or two more hidden layers that have nodes called hidden neurons.

3. Methods

The research was conducted at Laboratory of the Department of Electrical Engineering, University of Lampung. Stages of research in the form of flowcharts are shown in Figure 2. The average error for the results of this forecast is obtained by equations (1) and (2).

Relative Absolute Error:

$$\varepsilon = \frac{|p_1 - a_1| + \dots + |p_n - a_n|}{|\bar{a} - a_1| + \dots + |\bar{a} - a_n|} \times 100\% \dots \dots \dots (1)$$

Root Relative Square Error:

$$\varepsilon = \frac{(p_1 - a_1)^2 + \dots + (p_n - a_n)^2}{(\bar{a} - a_1)^2 + \dots + (\bar{a} - a_n)^2} \times 10 \dots \dots \dots (2)$$

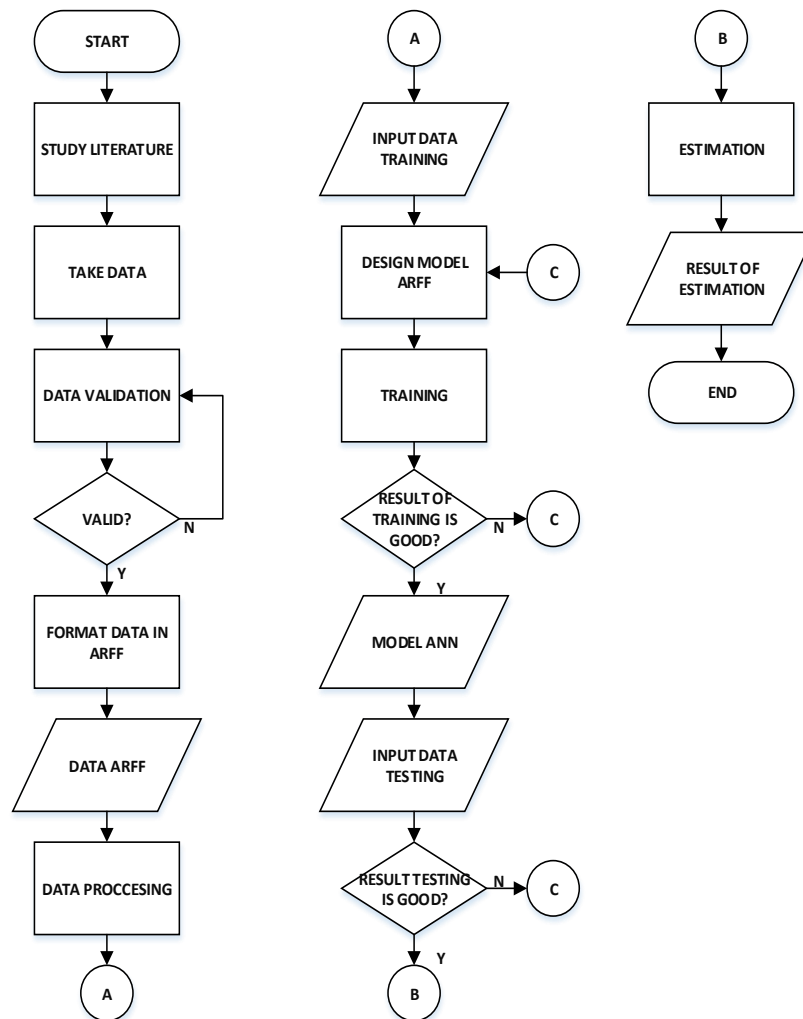


Figure 2. Research Diagram

4. Results And Discussion

The process for estimating or predicting power consumption in Building H requires relatively large data. Because of the large data, that used multilayer network architecture with backpropagation algorithm with supervised learning methods that can accommodate the amount of data.

4.1. Determination of Input and Output

This research uses 6 parameters as input in the form of the date, day, holiday, time, room, and electric current and produces an output in the form of electricity consumption. An artificial neural network input-output model is shown in Figure 3.



Figure 3. Determination of Input and Output

4.2. Results Analysis

The data used for the electric power training process for each phase are day data, date data, clock data, holiday data, room data, electric current data, and electrical power in the past from November 1, 2017 - May 13 2018. In designing the ANN model, the trial and error process is carried out in determining the learning rate, momentum, and the number of neurons in each hidden layer or hidden layer to achieve the desired output convergence.

Table 1 - Table 6 is a trial and error process to get the number of layers that have a good level of accuracy in JTE and JTM. But the results of the trial and error still have a small degree of accuracy so that the process of rearrangement is the sharing of data between holidays and work, the addition of input attributes (electric current), and the decay settings on the network so that the accuracy level is very good.

Training JTE

Table 1. Training of Electrical Power Phase R on Electrical Engineering University of Lampung

Time	Layer	Epoch	Relative Absolute Error	Root Relative Squared Error
Before Set Up				
02:55:07	63,73	1000	9,469%	10,415%
After Set Up				
Workday				
00:57:54	63,73	1000	0,884%	1,323%
Holiday				
00:39:20	63,73	1000	1,294%	1,810%

Table 2. Training of Electrical Power Phase S On Electrical Engineering University of Lampung

Time	Layer	Epoch	Relative Absolute Error	Root Relative Squared Error
Before Set Up				
01:00:08	33,43,30	1000	31,319%	37,846%
After Set Up				
Workday				
00:37:42	33,43,30	1000	1,715%	2,288%
Holiday				
01:39:13	33,43,30	1000	1,546%	2,447%

Table 3. Training of Electrical Power Phase T On Electrical Engineering University of Lampung

Time	Layer	Epoch	Relative Absolute Error	Root Relative Squared Error
Before Set Up				
03:51:03	63,73	1000	24,8292%	29,4072%
After Set Up				
Workday				
01:20:24	63,73	1000	1,726%	2,547%
Holiday				
00:37:28	63,73	1000	1,279%	1,655%

Training JTM**Table 4.** Training of Electrical Power Phase R On Mechanical Engineering University of Lampung

Time	Layer	Epoch	Relative Absolute Error	Root Relative Squared Error
Before Set Up				
04:14:24	83,93	1000	10,346%	12,760%
After Set Up				
Workday				
01:37:18	83,93	1000	0,721%	0,824%
Holiday				
01:07:18	83,93	1000	1,972%	2,692%

Table 5. Training of Electrical Power Phase S On Mechanical Engineering University of Lampung

Time	Layer	Epoch	Relative Absolute Error	Root Relative Squared Error
Before Set Up				
00:33:58	43,53,40	1000	35,771%	43,751%
After Set Up				
Workday				
00:51:42	43,53,40	1000	1,157%	1,792%
Holiday				
00:28:04	43,53,40	1000	2,987%	3,258%

Table 6. Training of Electrical Power Phase T On Mechanical Engineering University of Lampung

Time	Layer	Epoch	Relative Absolute Error	Root Relative Squared Error
Before Set Up				
01:09:20	73,83,40	1000	12,543%	12,805%
After Set Up				
Workday				
01:33:36	73,83,40	1000	1,542%	1,828%
Holiday				
00:34:54	73,83,40	1000	1,077%	1,545%

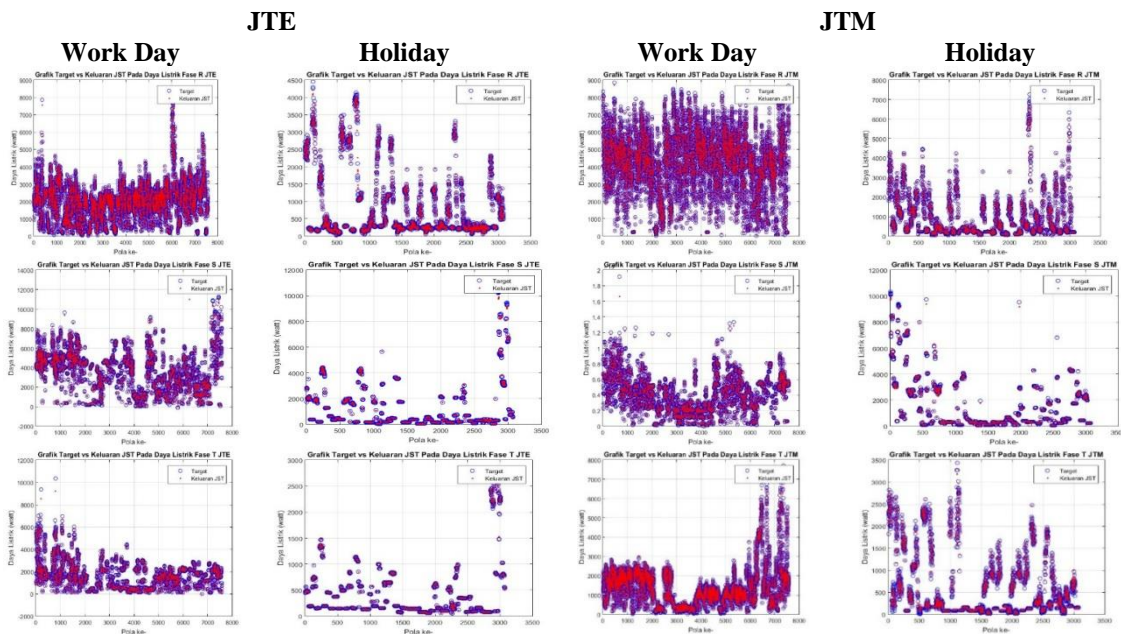


Figure 4. JTE & JTM Training Chart

In Figure 4, the electric power training for each phase in JTE and JTM is known that the accuracy of the ANN model that is built reaches $\pm 1\%$. This training is intended to get information and learn from the sprinkling of data properly.

The previous problem is that the data is not divided between working days and holidays where the input attributes possessed are very minimal so that it will slow down the convergence / convergence process. Overtraining problems (excessive training data) will also cause the network to memorize the data entered rather than generalize.

4.3. Testing ANN

Table 7 – Table 12 is the electrical power test in JTE dan JTM. Electrical power test is carried out to evaluate the network architecture of the results of the training is already good or not for the prediction process in the coming month. Testing is done by using new data outside the training data. This test uses day data, date data, clock data, holiday data, room data, electric current data, and electrical power in the past 14 May 2018 - 31 May 2018.

JTE

Table 7. Testing of Electrical Power Phase R On Electrical Engineering University of Lampung

	<i>Layer</i>	<i>Relative Absolute Error</i>	<i>Root Relative Squared Error</i>
Workday	63,73	0,883%	0,952%
Holiday	63,73	4,174%	4,470%

Table 8. Testing of Electrical Power Phase S On Electrical Engineering University of Lampung

	<i>Layer</i>	<i>Relative Absolute Error</i>	<i>Root Relative Squared Error</i>
Workday	33,43,30	2,217%	2,197%
Holiday	33,43,30	7,992%	6,875%

Table 9. Testing of Electrical Power Phase T On Electrical Engineering University of Lampung

	<i>Layer</i>	<i>Relative Absolute Error</i>	<i>Root Relative Squared Error</i>
Workday	63,73	2,035%	2,049%
Holiday	63,73	4,541%	4,199%

JTM

Table 10. Testing of Electrical Power Phase R On Mechanical Engineering University of Lampung

	<i>Layer</i>	<i>Relative Absolute Error</i>	<i>Root Relative Squared Error</i>
Workday	83,93	0,913%	1,738%
Holiday	83,93	2,658%	2,613%

Table 11. Testing of Electrical Power Phase S On Mechanical Engineering University of Lampung

	<i>Layer</i>	<i>Relative Absolute Error</i>	<i>Root Relative Squared Error</i>
Workday	43,53,40	1,393%	1,189%
Holiday	43,53,40	15,518%	13,508%

Table 12. Testing of Electrical Power Phase T On Mechanical Engineering University of Lampung

	<i>Layer</i>	<i>Relative Absolute Error</i>	<i>Root Relative Squared Error</i>
Workday	73,83,40	2,731%	6,077%
Holiday	73,83,40	3,107%	2,808%

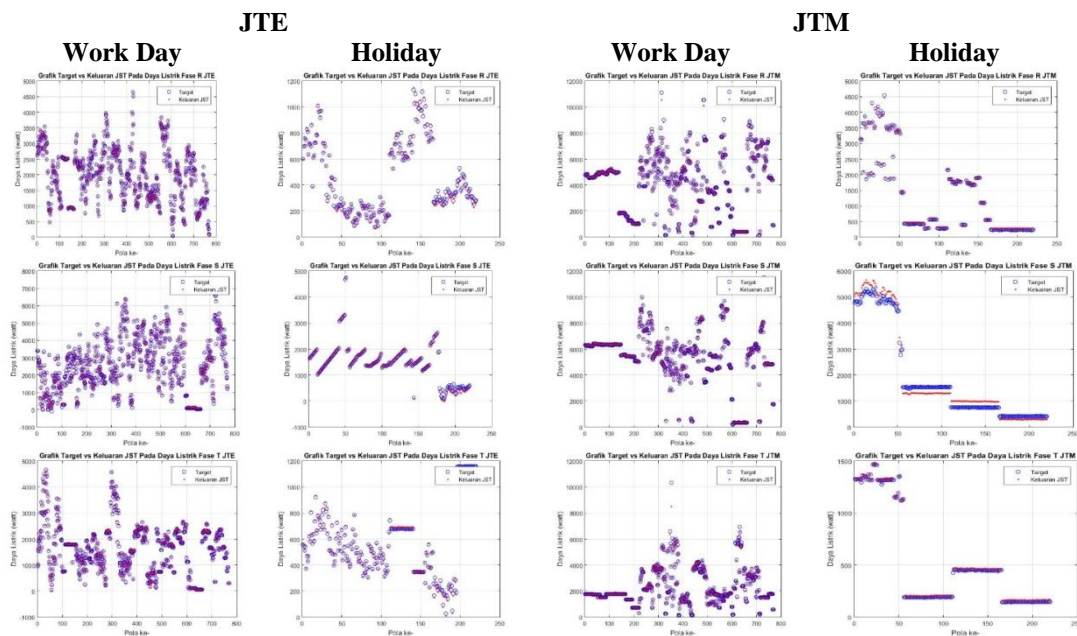


Figure 5. JTE & JTM Testing Chart

In Figure 5 is the result of electrical power testing for each phase in JTE and JTM. It is known that the accuracy of testing has the smallest relative absolute error value is 0.883% and the largest relative absolute error value is 15.518%. So it can be concluded that the resulting network had been good to learning data.

PREDICTION

BUILDING

JTE

JTM

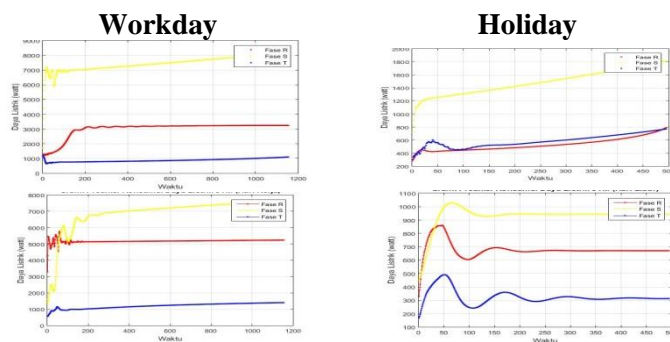


Figure 6. JTE & JTM Prediction Chart

Figure 6 is result of prediction electrical power consumption one mont ahead of data But in reality the large electrical power consumption of Mechanical Engineering and Electrical Engineering Unila depends on the user of the electricity load so that the predicted results can be smaller or larger than the prediction results depend on the activity of the user of the electricity load in the H Building of Mechanical Engineering and Electrical Engineering.

PREDICTION OF PEAK ELECTRICAL POWER

Table 13. Prediction of Peak Electrical Power

Phase	JTE		JTM	
	Actual	Prediction	Actual	Prediction
R	4063,932 W	3242,308 W	5767,069 W	6981,48 W
S	8859,332 W	8203,394 W	7629,555 W	9321,048 W
T	1678,32 W	1228,149 W	1402,607 W	1983,96 W

5. Conclusion

Some conclusions obtained from this research are:

1. Estimated electrical power requirements in Building H, Faculty of Engineering, University of Lampung can be done using the backpropagation neural network method.
2. Estimated electrical power requirements using backpropagation artificial neural networks had an accuracy of $\pm 0.884\%$.
3. The results of the estimation of electrical power requirements using the backpropagation artificial neural network method show that with more learning inputs resulting in smaller errors compared to a little input of learning.
4. In the training data and test data obtained an error ratio between the actual electric power data and the electrical power data estimation results where the resulting error is not large or close to the actual data.

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