

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 0,884%. Thus this research can be applied to real-time estimation processes that can be accessed and displayed by web in real-time.

Keyword : Prototype measurement, estimation , H building in faculty of engineering University of Lampung, artificial neural networks, backpropagation

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.

LITERATURE

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],[7].

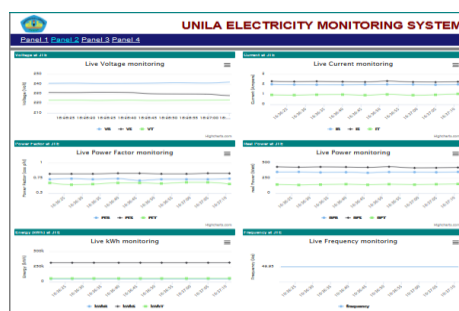


Figure 1. Curves Of Characteristics of Electrical System
Electrical Engineering University of Lampung

Estimation

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].

Electric Load Forecasting [2]

Long Term Prediction

Long-term predictions is forecasts for periods over one year. In this prediction of external factors such as problems of economic growth are the main factors in determining the direction of forecast or prediction.

Medium Term Prediction

Medium-term predictions is predictions for a period of one month to one year. In this medium-term electric energy parking lot, internal factors of electricity companies such as managerial problems of the company become the main factor in predictions or predictions.

Short Term Prediction

Short-term predictions is predictions for a period of several hours to one week (168 hours). The amount of electrical energy for each hour is determined by observing the trend of electrical energy in the past by paying attention to information that can affect the amount of the system load.

ANN (Artificial Neural Network) [3],[5]

ANN is a computational system with architecture and operations inspired by knowledge of biological nerve cells in the brain. 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.

Basic Concepts of Artificial Neural Network Modeling

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 weigher. 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].

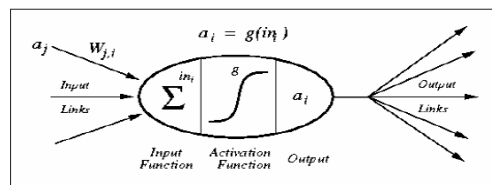


Figure 3. Neuron Artificial Model

Artificial Neural Network Architecture [4],[5]

- 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.

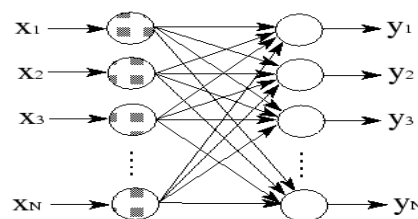


Figure 4. Single Layer Network

- 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.

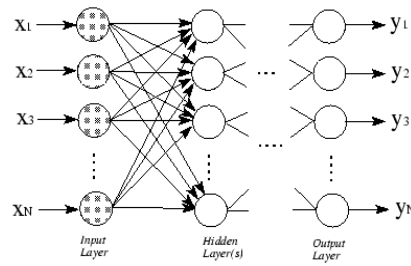


Figure 5. Multi Layer Network

RESEARCH METHODS

The research was conducted at Laboratory of the Department of Electrical Engineering, University of Lampung. The stages of the research are as follows:

Tools And Materials

Table 1. Tools And Materials

No.	Tools And Materials
1	PC with specifications of Intel Core i5-4210J 1.7 GHz with Turbo Boost up to 2.7 GHz
2	Program Weka 3.8

Research Diagram

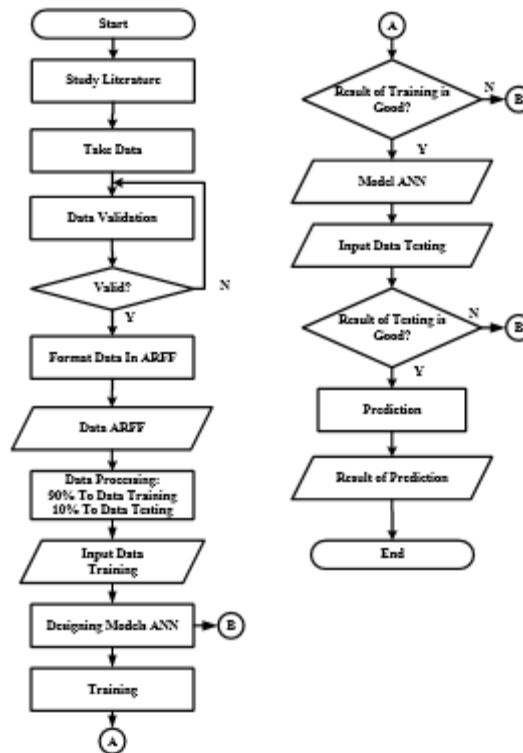


Figure 6. Research Diagram

Level of Accuracy ANN [5]

The average error from the results of this forecast is obtained by the following formula:

Relative Absolute Error:

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

Root Relative Square Error:

$$\varepsilon = \frac{(p_1 - a_1)^2 + \dots + (p_n - a_n)^2}{(a_1 - a_1)^2 + \dots + (a_n - a_n)^2} \times 100\% \dots \dots \dots (2)$$

Information

ε = Error Prediction

a_1, \dots, a_n = Actual Data

p_1, \dots, p_n = Prediction Data

\bar{a} = Average Actual Data

RESULTS

Artificial Neural Network Model Architecture

The process to estimate or predict electric power consumption in Building H requires relatively large data, multilayer net with backpropagation algorithm and supervised learning method is the architecture of the artificial neural network model chosen to build and design this estimation or prediction system. In designing this system, the network or ANN model is given a pair of data consisting of input data and desired data (target).

Determination of Input and Output



Figure 7. Determination of Input and Output

Format Data

In the dataset used to train, test, and predict the data format is changed to the format attribute-relation file format (arff). Attribute-relation file format is the file format used in WEKA.

Table 2. Format Data

@relation DayaelektrofaseR	
@attribute Tanggal	{1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31}
@attribute Hari	{1,2,3,4,5,6,7}
@attribute Jam	{1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55}
@attribute Libur	{0,1}
@attribute H17	{0,1}
@attribute H18	{0,1}
@attribute H19	{0,1}
@attribute H20	{0,1}
@attribute Arus	Numeric
@attribute Target	Numeric
@data	
	1,3,1,0,1,1,1,1,11.61232182,2299.239721
	1,3,2,0,1,1,1,1,10.88574581,2155.377671
	1,3,3,0,1,1,1,1,11.96033515,2368.146359
	.
	.
	11,5,53,0,0,0,0,0,7.513405818,1487.654352
	11,5,54,0,0,0,0,0,7.925510808,1569.25114
	11,5,55,0,0,0,0,0,8.276558086,1638.758501

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 3 - table 14 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 3. Comparison of the Number of Layers of Phase R Electric Power Training Electrical Engineering University of Lampung

Time	Layer	Epoch	Relative Absolute Error	Root Relative Squared Error
00:13:04	11	1000	25,907%	30,490%
00:20:15	22	1000	19,206%	22,186%
00:22:59	33	1000	17,057%	18,988%
00:17:35	11,22	1000	21,240%	24,852%
00:37:48	22,33	1000	16,086%	17,535%
01:01:59	33,43	1000	13,323%	14,434%
01:44:59	43,53	1000	11,317%	12,533%
02:34:41	53,63	1000	10,907%	11,992%
02:55:07	63,73	1000	9,469%	10,415%
08:59:21	103,133	1000	9,647%	10,733%

Table 4. 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 5. Comparison of the Number of Layers of Phase S Electric Power Training Electrical Engineering University of Lampung

Time	Layer	Epoch	Relative Absolute Error	Root Relative Squared Error
00:15:40	11,22	1000	37,965%	45,394%
00:20:57	22,33	1000	36,779%	43,186%
00:40:31	33,43	1000	34,683%	42,112%
01:35:23	103,133	1000	35,073%	48,096%
00:20:55	11,22,10	1000	43,153%	48,392%
00:45:58	22,33,20	1000	37,528%	42,985%
01:00:08	33,43,30	1000	31,319%	37,846%
02:09:36	43,53,40	1000	31,642%	38,381%
02:25:31	33,43,30	3000	40,864%	48,596%
01:30:32	33,43,30,20	1000	35,128%	44,119%

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

<i>Time</i>	<i>Layer</i>	<i>Epoch</i>	<i>Relative Absolute Error</i>	<i>Root Relative Squared Error</i>
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 7 . Comparison of the Number of Layers of Phase T Electric Power Training Electrical Engineering University of Lampung

<i>Time</i>	<i>Layer</i>	<i>Epoch</i>	<i>Relative Absolute Error</i>	<i>Root Relative Squared Error</i>
02:32:13	53,63	1000	25,3707%	29,1640%
03:51:03	63,73	1000	24,8292%	29,4072%
03:58:30	83,93	1000	26,8005%	30,7359%
02:54:36	63,73,30	1000	27,9451%	30,9780%

Table 8. Training of Electrical Power Phase T On Electrical Engineering University of Lampung

<i>Time</i>	<i>Layer</i>	<i>Epoch</i>	<i>Relative Absolute Error</i>	<i>Root Relative Squared Error</i>
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 9 . Comparison of the Number of Layers of Phase R Electric Power Training Mechanical Engineering University of Lampung

<i>Time</i>	<i>Layer</i>	<i>Epoch</i>	<i>Relative Absolute Error</i>	<i>Root Relative Squared Error</i>
00:22:46	11	1000	34,605%	40,071%
00:29:30	11,22	1000	29,543%	34,145%
00:32:45	33,43	1000	17,808%	21,515%
00:42:40	53,63	1000	14,331%	17,215%
01:33:28	63,73	1000	13,828%	16,571%
04:14:24	83,93	1000	10,346%	12,760%
06:54:00	93,103	1000	12,258%	14,380%

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

<i>Time</i>	<i>Layer</i>	<i>Epoch</i>	<i>Relative Absolute Error</i>	<i>Root Relative Squared Error</i>
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 11 . Comparison of the Number of Layers of Phase S Electric Power Training Mechanical Engineering University of Lampung

Time	Layer	Epoch	Relative Absolute Error	Root Relative Squared Error
00:05:30	11,22	1000	41,925%	49,516%
00:10:57	22,33	1000	29,275%	45,524%
00:17:10	33,43	1000	49,163%	52,343%
00:47:23	63,73	1000	39,892%	40,216%
00:12:51	11,22,10	1000	42,494%	50,886%
00:13:36	22,33,20	1000	38,729%	45,044%
00:25:24	33,43,30	1000	36,755%	43,619%
00:33:58	43,53,40	1000	35,771%	43,751%
01:41:24	53,63,50	1000	37,974%	43,738%
01:03:20	63,73,60	1000	37,164%	44,069%
01:09:10	43,53,40,30	1000	39,346%	45,789%

Table 12. 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 13. Comparison of the Number of Layers of Phase T Electric Power Training Mechanical Engineering University of Lampung

Time	Layer	Epoch	Relative Absolute Error	Root Relative Squared Error
00:33:24	53,63	1000	15,968%	15,215%
04:27:00	63,73	1000	16,294%	15,528%
00:45:16	53,63,20	1000	15,036%	15,052%
01:02:24	63,73,30	1000	13,964%	13,928%
01:09:20	73,83,40	1000	12,543%	12,805%
01:21:00	83,93,50	1000	12,605%	13,085%

Table 14. 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%

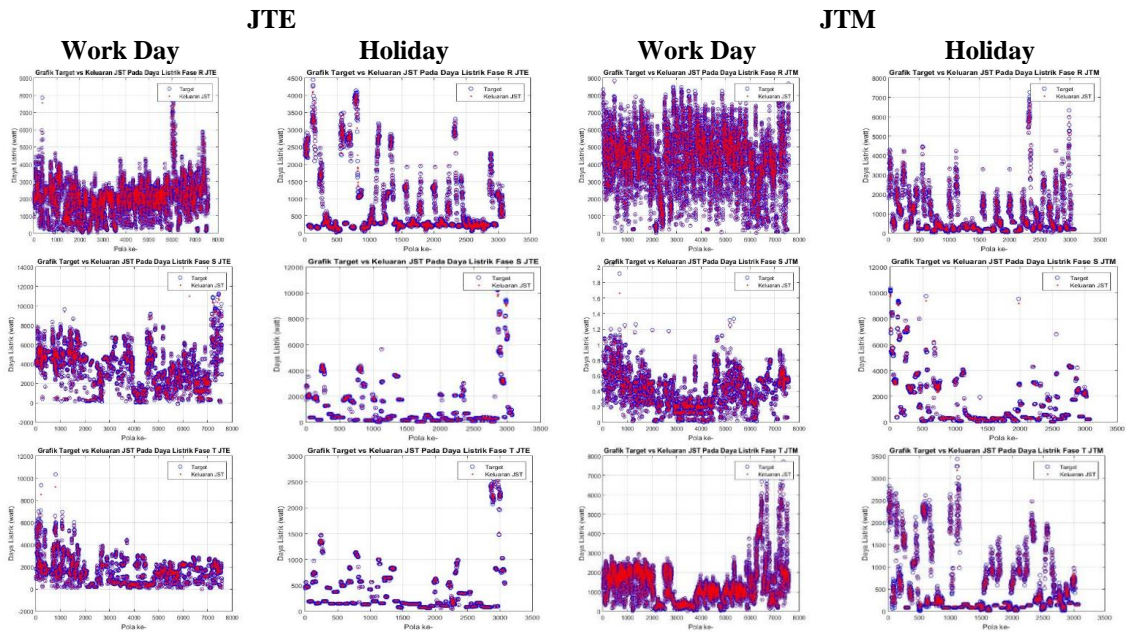


Figure 8. JTE & JTM Training Chart

In figure 8, 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.

TESTING ANN

Table 16 – table 21 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 16. 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 17. 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 18. 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 19. 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 20. 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 21. 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%

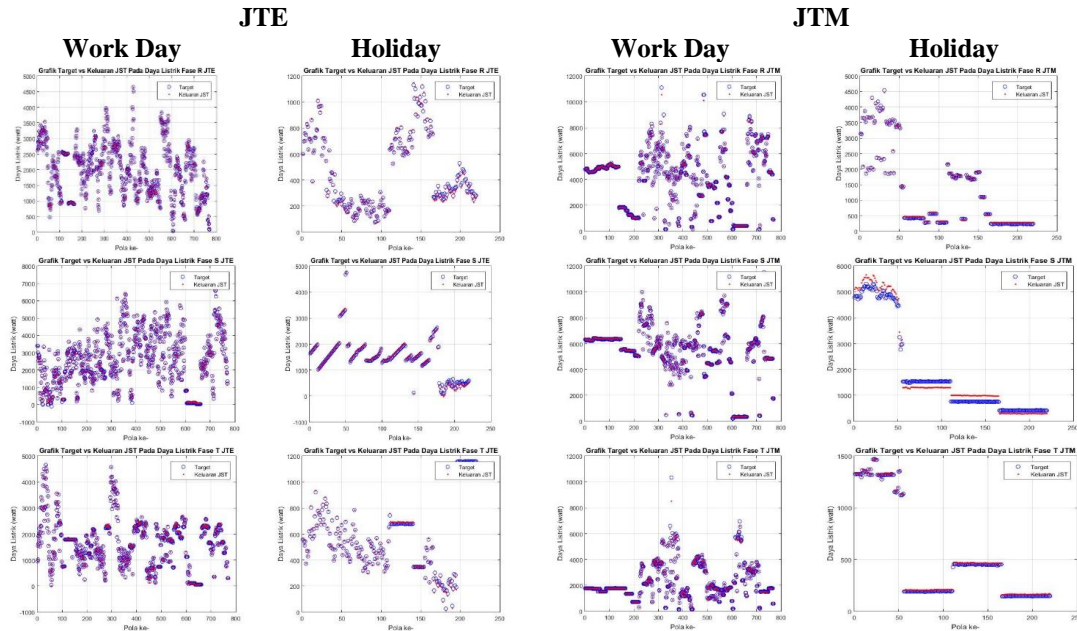


Figure 9. JTE & JTM Testing Chart

In figure 9 is the result of electrical phase 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

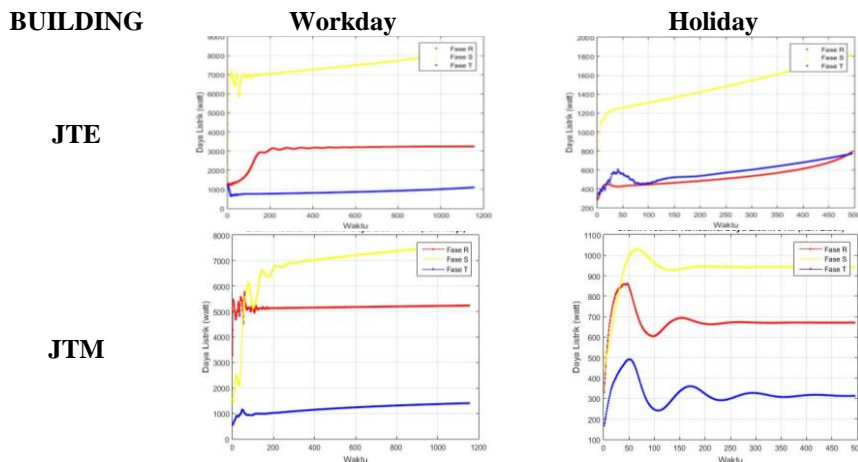


Figure 10. JTE & JTM Prediction Chart

Figure 10 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 22. 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

CONCLUSIONS

Some conclusions obtained from this research are:

1. The results of the prediction of electric power using backpropagation artificial neural network method show that with more learning inputs it produces a smaller error compared to the little learning input.
2. Relative absolute error on training result of electric power phase R,S,T in electrical engineering on work day are 0,884% ; 1,715% ; and 1,726% and on holiday are 1,294% ; 1,546% ; and 1,278%..
3. Relative absolute error on training result of electric power phase R,S,T in mechanical engineering on work day are 0,721% ; 1,157% ; and 1,542% and on holiday are 1,72% ; 2,987% ; and 1,022%.
4. Relative absolute error on testing result of electric power phase R,S,T in electrical engineering on work day are 0,883% ; 2,217% ; and 2,035% and on holiday are 4,174% ; 7,942% ; and 4,541%.
5. Relative absolute error on testing result of electric power phase R,S,T in mechanical engineering on work day are 0,913% ; 1,3535 ; and 2,731% and on holiday are 2,653% ; 15,518% ; and 3,107%.
6. Peak electrical power R,S,T in electrical engineering are 3242,308 W ; 8203,394 W ; 1228,149 W and mechanical engineering are 6981,48 W ; 9321,048 W ; 1983,96 W.
7. To get good training results and test results, we need to pay attention to the number of neurons in the hidden layer used during training. The suitability of the use of the number of neurons in the hidden layer has an effect on the number of errors in training and during testing.

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