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Electrical Energy Consumption Prediction in South–West Sulawesi Electrical Power System

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ABSTRACT

Prediction of electrical energy consumption in an electrical power system is needed to determine the electrical energy need every time. This prediction is required in order to schedule the operation of existing power plants and preparing for new power plants to meet the energy needs of each month or year. This study was conducted to predict the electrical energy need to 2030. Validation of prediction results are evaluated by RMSE values for 2011 and 2012. The method used is the Adaptive Splines Threshold Autoregression (ASTAR). Results showed that predictions for the year 2011 is 0.031 and the RMSE values for 2012 prediction RMSE value is 0.322

KEYWORDS: Energy consumption prediction, Adaptive Splines threshold Autoregression, RMSE

I. INTRODUCTION

ELECTRICITY IS A form of energy that is needed in human life. The growth of electrical energy consumption per capita, shows rising standards of human life. Prediction is needed in order to predict electrical energy need every time (every month or every year), in recognition of this prediction can be known when the plant required the addition of new power plant in the current electrical system. Method used to predict electrical energy consumption is very diverse, including using software LEAP (Long-range Energy Alternatives Planning System) has been carried out by Ahmad Agus Setiawan et al⁽¹⁾. Prediction using Fuzzy Logic Applications and Neural Network, using the electric energy consumption data per hour, this done by Yadi Mulyadi et al⁽²⁾. Researcher try to apply the ASTAR method to predict electrical energy needs. It has chosen because this method has been applied for forecasting ENSO index by Sutino and Boer (2004). In their study, it was found that the prediction result using ASTAR method has good accuracy⁽³⁾. Sutino and Boer (2004) stated that the ASTAR is a method of non-linear time series analysis algorithm which is based on multiple adaptive regression splines or commonly known as Multiple Adaptive Regression Splines (MARS). Problems that occurred in the electrical power system in South and West Sulawesi is the electrical energy consumption is greater than the available generation capacity, resulting in blackouts during peak loads. Therefore we need to conduct a research about electrical energy consumption prediction, in order to estimate demand for electrical energy per month or per year. Research conducted in South -West Sulawesi Electrical Power System by retrieve data monthly number of customers, connected power capacity, population and energy consumption.

II. REVIEW OF LITERATURE

2.1. Energy Consumption

Consumption of electric energy in the electrical power system in South Sulawesi and West Sulawesi has increased every year, it is because the system which supply the province of South Sulawesi and West Sulawesi are experiencing economic growth (GRDP growth rate) is about 8.2% for South Sulawesi Province and West Sulawesi 6.3%⁽⁴⁾.

Electrical power system in South Sulawesi and West Sulawesi has an increasing rate of customers (consumers) about 3.81 percent, the increasing rate of connected power (MVA) of 2.92 percent and the rate of energy consumption (GWh) about 2.43 percent⁽⁵⁾. Considering the development of energy consumption on the electrical system, it is necessary to estimate (predict) the electrical energy consumption for year to year. Prediction aims to estimate the consumption of electrical energy in order to meet the needs of electrical energy in electrical power system in South Sulawesi and West Sulawesi continually.

2.2. Time Series

The energy consumption prediction data used are periodic data collected per month. Data analysis describes the relationship between the dependent variable with the independent variable. The approach used to estimate the energy consumption of electricity is the implementation of non-linear regression method namely adaptive threshold splines Autoregression (ASTAR).

1) Multivariate Adaptive Regression Splines (MARS)

MARS method is developed by Friedman in 1991. This method can analyze large data (50 ≤ N ≤ 10,000). Spline regression modeling is implemented by forming a set of base functions that can be reached-spline order to estimate the coefficients N-q* and basis functions using a least-squares.

Estimator of MARS models can be written as follows:

$$f(x) = a_0 + \sum_{m=1}^M a_m \prod_{k=1}^{K_m} [S_{k,m}(x_{v(k,m)} - l_{k,m})]$$

with:

a₀ = function stem base

a_m = coefficient of the function to the base-m

1 = maximum base function

K_m = the number of interactions

x_{v(k,m)} = independent variable

l_{k,m} = knots value of the independent variable x_{v(k,m)}

v = number of independent variables

2) Adaptive Splines Threshold Autoregression (ASTAR)

Adaptive Threshold Autoregression Splines is a method of nonlinear time series that uses MARS algorithm with the explanatory variables lagged value of time series data. ASTAR model is the development of MARS with variable response and Z_t as Z_{t-j} as a predictor variable, so that ASTAR model can be written as follows:

$$f(x) = a_0 + \sum_{m=1}^M a_m \prod_{k=1}^{K_m} [S_{k,m}(Z_{(t-j),(k,m)} - l_{k,m})]$$

III. RESEARCH MODEL

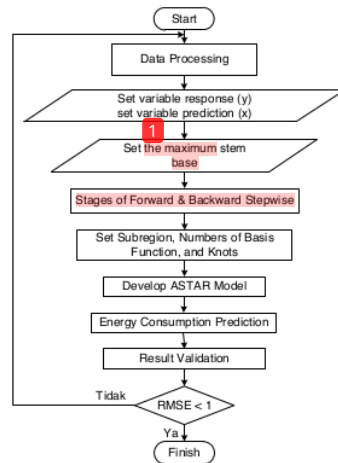
3.1 Data Type and Source

The data used to predict the energy consumption is the number of customers, the connected power and the residents from 2004 to 2011, data is obtained from PT. PLN Region South-West Sulawesi. Research data are shown in Table 1 below.

Table 1 Research Data

No	Month	Number of customers		Connected power (VA)		Number of residents		Energy Consumption (GWh)	
		2004	2011	2004	2011	2004	2011	2004	2011
1	January	1.331.026	1.022.542	1.334.709	1.907.816	8.214.401	8.862.469	172.046	300.183
2	February	1.333.008	1.016.862	1.339.874	1.918.813	8.221.884	8.870.416	174.850	311.228
3	March	1.335.091	1.013.189	1.345.992	1.932.532	8.239.284	8.878.419	176.281	312.248
4	April	1.336.083	1.020.777	1.347.281	1.961.211	8.237.513	8.885.921	179.676	313.604
5	May	1.337.145	1.043.947	1.351.209	1.989.022	8.246.751	8.892.830	181.857	315.401
6	June	1.337.857	1.054.284	1.352.886	2.019.898	8.253.896	8.899.744	183.576	317.205
7	July	1.338.372	1.067.978	1.358.114	2.064.416	8.261.425	8.907.764	185.543	319.148
8	August	1.339.251	1.080.834	1.361.867	2.089.644	8.269.860	8.915.771	186.012	321.011
9	September	1.340.170	1.097.831	1.363.671	2.120.941	8.278.302	8.923.795	189.652	322.840
10	October	1.340.713	1.097.865	1.369.321	2.136.480	8.283.751	8.931.826	191.449	324.099
11	November	1.341.767	1.708.044	1.372.910	2.205.880	8.291.206	8.939.885	192.604	325.782
12	December	1.347.356	1.749.034	1.379.832	2.209.371	8.298.668	8.947.911	193.839	327.610

Method used to predict the energy consumption is the ASTAR Method. Flow chart of energy consumption prediction is shown in Figure 4. All data are processed using Matlab software.



1 Figure 1. Flow chart of Energy Consumption Prediction using ASTAR Model

Process to predict the energy consumption has several step :

a. Data Processing

The data as the input variables are: number of customer, connected power, and number of residents. Output data is the variable energy consumption. The data was processed with the normalization process

b. Determining Variable

Predictor variables or independent variable (x) is used as the input variables and the response variable or dependent variable (y) is the output variable.

c. ASTAR Modelling

ASTAR model building stages as follows:

- Specifies the maximum base functions
- Stages of forward and backward stepwise

d. Develop ASTAR model

e. Electrical energy consumption prediction

Electrical energy consumption predictions for 2011 and 2012

f. Result Validation

Electrical energy consumption prediction results for 2011 and 2012 using a validated RMSE values are:

$$RMSE = \frac{\sqrt{\frac{1}{N} \sum_{i=h}^N (y_i - \hat{y}_i)^2}}{y_{max} - y_{min}}$$

3.2 Data Analysis

Electrical energy consumption prediction using three input variables are number of customers, connected power, and number of residents. Output variables are the energy consumption. The initial process is to normalize the data into the interval [0 1]. The output of this process will be used as input data in the prediction process with ASTAR method. The final stage of this method is denormalization, to return the signal shape of the prediction to the data input.

3.3 Model Selection

Simulation models for the prediction made in 2009, 2010, 2011 and 2012. From the results of these predictions can be selected the best model to be used to determine predictions of energy consumption in the next year. Model selection is done by comparing the RMSE of each model, as shown in Table 2.

1 Table 2. Response Model Y to X

No	Model	Response variabel Y to X	RMSE Value
1	Prediction 2009	Number of residents (X ₁) and number of customers	0.09365
2	Prediction 2010	Number of residents (X ₁)	0.06439
3	Prediction 2011	Number of residents (X ₁)	0.03131
4	Prediction 2012	Number of residents (X ₁)	0.32215

Selected model is the model prediction in 2011, the energy consumption equation model are:

$$BF_1 = \max(0, X_3 - 0.435)$$

$$BF_2 = \max(0.435 - X_3)$$

$$Y = 0.509 + 1.24 BF_1 - 1.17 BF_2$$

IV. RESULT

Selected model to predict energy consumption in 2011 is the model prediction. Comparison between predicted results 2012 and real energy consumption 2012 can be seen in Table 3 and Figure 2.

Table 3. Energy Consumption Comparison

Month	Energy Consumption (GWh) 2011	
	Real data	Prediction
January	309.183	309.857
February	311.229	311.536
March	312.248	313.216
April	313.604	314.711
May	315.401	316.207
June	317.205	317.704
July	319.149	319.390
August	321.011	321.078
September	322.840	322.766
October	324.099	324.457
November	325.782	326.149
December	327.610	327.842

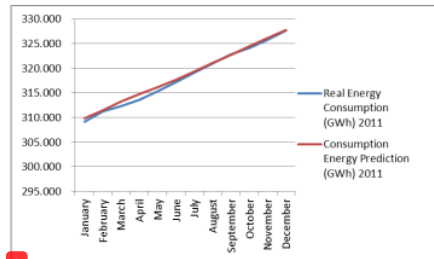
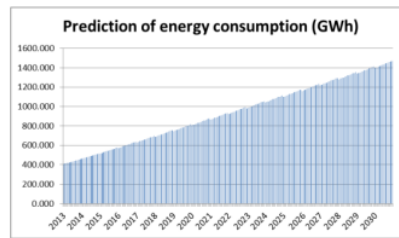


Figure 2. Energy Consumption Curve (GWh) 2011

From the results predicted in 2012 can be seen from a relatively small difference between the energy consumption of the result of the prediction and the real data, it can be concluded that the energy consumption equation model can be used to predict the energy consumption next year. Energy consumption prediction results can be seen in Table 4 and Figure 3.

Table 4. Energy Consumption Prediction Result

No	Month	Consumption Energy Prediction (GWh)			
		2013	2015	2020	2025
1	January	407.474	515.565	804.717	1099.951
2	February	411.889	521.011	811.019	1106.556
3	March	416.303	526.456	817.320	1113.160
4	April	420.718	531.901	823.621	1119.764
5	May	425.132	537.346	829.922	1126.369
6	June	429.547	542.791	836.223	1132.973
7	July	433.961	548.236	842.524	1139.578
8	August	438.376	553.681	848.826	1146.182
9	September	442.790	559.126	855.127	1152.786
10	October	447.205	564.571	861.428	1159.391
11	November	451.619	570.016	867.729	1165.995
12	December	456.034	575.461	874.030	1172.599



1 CONCLUSION

Based on the research can be concluded that:

- 1) Accuracy validation of predictions for the year 2011 and 2012 is 0.031 and 0.322. Based on the RMSE values, it can be said that in general, the model predictions ASTAR well enough to predict electrical energy consumption.
- 2) The results of the prediction of energy consumption from 2013 to 2030 tend to occur in a linear manner.

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