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

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ABSTRACT

Prediction ofelectricalenergyconsumptioninanelectrical power systemis neededto determine theelectricalenergyneedseverytime. Thispredictionis required in order to schedullingoperation ofexsistingpower plantsandpreparing for new power plantto meet theenergyneeds ofeachmonthoryear. This study was conductedtopredict theelectricalenergyneedsto 2030. Validation ofpredictionresultsare evaluatedbyRMSEvaluesfor 2011and 2012. The method usedis theAdaptiveSplinesThersholdAutoregression(ASTAR). Resultsshowedthatpredictionsforthe year 2011is0.031and theRMSEvaluesfor 2012predictionsRMSEvalueis0.322

KEYWORDS: *Energyconsumption prediction, AdaptiveSplinesthersholdAutoregression, RMSE*

I. INTRODUCTION

ELECTRICITYISA form of energythatis neededin human life. The Growth ofelectricalenergyconsumptionper capita,showsrising standards ofhuman life. Predictionis neededin order topredictelectricalenergyneedseverytime(egeverymonthoreveryyear), in recognition ofthis predictioncan beknown whentheplantrequired the addition ofnew power plant in the current electrical system.

Methodusedto predictelectricalenergyconsumptionis verydiverse, includingusingsoftwareLEAP(Long-range EnergyAlternativesPlanningSystem)has beencarried outbyAhmadAgusSetiawanet al(1).PredictionusingFuzzyLogicApplicationsandNeural Network, using theelectricenergyconsumption dataperhour, thisis donebyYadiMulyadiet al(2).Researcherstrytoapply theASTAR methodto predict electricalenergyneeds. It haschosenbecausethis methodhas beenappliedforforecastingENSOindexbySutinoandBoer(2004). Intheirstudy, it was found thatthe prediction result usingASTARmethodhasgood accuracy(3).SutinoandBoer(2004) stated that the ASTAR is amethod ofnon-linear timeseries analysisalgorithmwhichis based onmultipleadaptiveregressionsplinesorcommonlyknownasMultipleAdaptiveRegressionSplines(MARS).Problems that occurred inthe electrical power systemin South and West Sulawesiis theelectricalenergyconsumptionis greater than theavailablegeneration capacity, resulting inblackoutsduring peak loads. Therefore we needto conduct a research aboutelectricalenergyconsumption prediction, in order toestimateddemand forelectricalenergyper monthorper year.Researchconducted in South -WestSulawesi Electrical Power Systembyretrieve datamonthlynumber of customers, connected power capacity, population andenergyconsumption.

II. REVIEW OF LITERATURE

2.1.Energy Consumption

Consumption ofelectric energyinthe electrical power systemin South SulawesiandWest Sulawesihas increased every year,it is becausethesystem whichsupplythe provinceof South SulawesiandWestSulawesiareexperiencingeconomic growth(GRDP growtrate)isabout8.2%forSouth Sulawesi ProvinceandWest Sulawasi6.3%(4).

Electrical power systemin South SulawesiandWest Sulawesihasan increasing rate ofcustomers(consumers) about3.81percent, the increasingrate of connectedpower(MVA) of 2.92 percentandthe rate ofenergyconsumption(GWh) about 2.43per cent(5). Considering the development ofenergyconsumptionontheelectrical system, it is necessary toestimate (predict)the electricalenergyconsumption for year to year. Predictionaimstoestimate theconsumption ofelectrical energyconsumptionin order tomeet the needs ofelectricalenergyinelectricalpower systemin South SulawesiandWest Sulawesi continually.

2.2.Time Series

The energyconsumptionpredictiondataused areperiodic datacollectedpermonth. Data analysisdescribesthe relationshipbetween the dependent variablewiththe independentvariable. The approach usedtoestimate theenergyconsumption ofelectricityisthesimplenon-linear regressionmethodnamelyadaptivethresholdsplinesAutoregression(ASTAR).

1) Multivariate Adaptive Reg-ression Splines (MARS)

MARSmethodis developedbyFriedmanin 1991. Thismethodcananalyzelarge data(50 ≤N≤10,000). Splineregressionmodelingis implementedby forming aset ofbasefunctionsthatcan bereached-spline ordertoestimate thecoefficientsN-q*andbasisfunctionsusinga least-squares.

Estimator of MARSmodels can be writtenasfollows:

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

with:

a_0 = functionstembase
a_m = coefficientofthe functionto thebase-m
M =maximumbasefunction
K_m = the number of interactions
$x_{v(k,m)}$ = independentvariable
l_{km}=knotsvalueofthe independentvariable$x_{v(k,m)}$
v = numberof independentvariables

2) Adaptive Splines Threshold Autoregression (ASTAR)

AdaptiveThresholdAutoregressionSplinesis amethod ofnonlineartime seriesthatusesMARSalgorithmmethodwiththe explanatoryvariableslaggedvalue oftime series data. ASTARmodelisthe developmentofMARSwithvariableresponse andZ_t as Z_{t-j}as apredictorvariable, so thatASTARmodelscan bewritten as follows:

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

III. RESEARCH MODEL

3.1 Data Type and Source

The data usedtopredict theenergyconsumptionisthe number of customers, the connected power andthe residentsfrom 2004to 2011, datais obtainedfromPT. PLN RegionSouth-WestSulawesi. Research dataare shownin Table1 below.

Tabel 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	1,602,542	1,334.708	1,907.816	8,214,491	8,862,459	172.046	309.183
2	February	1,333,608	1,606,862	1,339.874	1,916.813	8,221,884	8,870,435	174.850	311.229
3	March	1,335,081	1,613,189	1,345.552	1,932.522	8,229,284	8,878,419	176.281	312.248
4	April	1,336,063	1,629,777	1,347.281	1,961.211	8,237,513	8,885,521	179.676	313.604
5	May	1,337,145	1,643,947	1,350.299	1,989.022	8,245,751	8,892,630	181.857	315.401
6	June	1,337,857	1,654,284	1,352.696	2,016.896	8,253,996	8,899,744	183.576	317.205
7	July	1,338,372	1,667,978	1,358.114	2,064.416	8,261,425	8,907,754	185.543	319.149
8	August	1,339,251	1,680,634	1,361.667	2,099.644	8,268,860	8,915,771	186.012	321.011
9	September	1,340,170	1,690,831	1,363.671	2,120.941	8,276,302	8,923,795	189.652	322.840
10	October	1,340,713	1,697,865	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	2,205.860	8,291,206	8,939,865	192.604	325.782
12	December	1,347,356	1,749,034	1,379.632	2,209.371	8,298,668	8,947,911	193.839	327.610

Method usedtopredict theenergyconsumptionis the ASTAR Method. Flow chartof energyconsumption prediction isshownin Figure4. All data areprocessingusingMatlabsoftware.

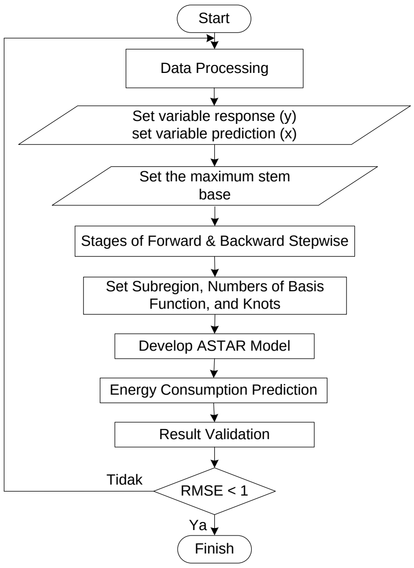


Figure 1. Flow chart of Energy Consumption Prediction using ASTAR Model

Prosess to predict the energy consumption has several step :

a. Data Processing
The dataasthe inputvariablesare: number of customer, connected power,and number ofresidents. Output datais thevariableenergyconsumption. The data wasprocessedwiththe normalization process

b. Dertermining Variable
Predictorvariablesorindependentvariable(x) isusedas theinputvariablesandthe responsevariableordependent variable(y) is theoutputvariable.

c. ASTARModelling
ASTARmodel buildingstages as follows:
- Specifiesthe maximumbasefunctions
- Stages offorwardandbackwardstepwise

d. Develop ASTAR model

e. Electricalenergyconsumptionprediction
Electricalenergyconsumptionpredictionsfor 2011and 2012

f. Result Validation
Electricalenergyconsumptionpredictionresultsfor 2011and 2012using avalidatedRMSEvaluesare:

$$RMSE = \frac{\sqrt{\frac{1}{N}\sum_{t=h}^{N}(y_t - \hat{y}_t)^2}}{y_{\max} - y_{\min}}$$

3.2 Data Analisis

Electricalenergyconsumptionpredictionusingthreeinputvariablesare number of customers, connected power,and number ofresidents. Outputvariablesare theenergyconsumption. The initial process is to normalizethe dataintothe interval[0 1]. The output ofthisprocesswillbe used asinput datain thepredictionprocesswithASTARmethod. The final stageofthismethodisdenormalization, to return thesignalshapeofthe predictionstothe datainput.

3.3 Model Selection

Simulationmodelsfor thepredictionmadein 2009, 2010, 2011and2012. From the results ofthese predictionscanbeselectedthe best modeltobe usedto determinepredictions ofenergyconsumptionin the next year. Model selectionis doneby comparing theRSMEofeach model, as shownin Table2.

Table 2.Response Model Y to X

No	Model	Response variabel Y to X	RMSE Value
1	Prediction 2009	Number of residents (X_3) and number of customers	0.09365
2	Prediction 2010	Number of residents (X_3)	0.06439
3	Prediction 2011	Number of residents (X_3)	0.03131
4	Prediction 2012	Number ofresidents (X_3)	0.32215

Selected modelisthe modelpredictionin 2011, the energyconsumptionequation modelare:
$BF_1 = \max(0, X_3 - 0.435)$
$BF_2 = \max(0.435 - X_3)$
$Y = 0.509 + 1.24\, BF_1 - 1.17\, BF_2$

IV. RESULT

Selectedmodelsto predictenergyconsumptionin 2011isthe modelprediction. Comparison betweenpredicted results 2012andreal energyconsumption2012can be seenin Table3andFigure 2.

Table 3.Energy ConsumptionComparation

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

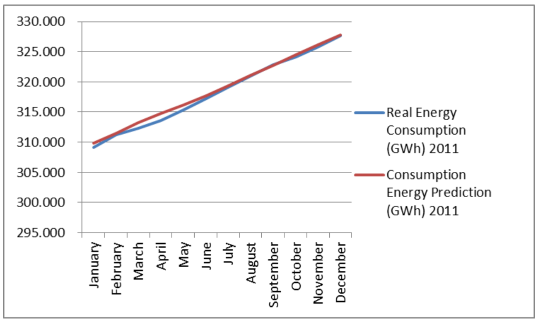
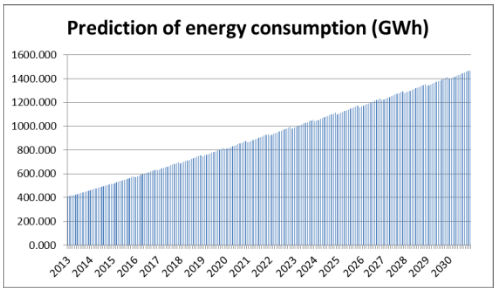


Figure 2.Energy Consumption Curve (GWh) 2011

Fromthe results predictedin 2012can beseen from arelatively smalldifferencebetweenthe energyconsumptionofthe resultsof thepredictionandthe real data, it can be concludedthat theenergyconsumptionequation modelcanbe usedtopredict theenergyconsumptionnextyear. Energyconsumptionpredictionresultscan beseen in Table4andFigure 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



CONCLUSION

Based on the research can be concluded that:

1) Accuracy validation ofpredictionsforthe year 2011andin 2012is0.031and0.322. Based ontheRMSEvalues,it can be saidthatin general, the modelpredictionsASTARwell enoughtopredictelectricalenergyconsumption.
2) The results ofthe predictionof energyconsumptionfrom 2013to 2030tend tooccurin a linear manner.

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