International Journal of Computational Engineering Research||Vol, 03||Issue, 9||

Arima Application as an Alternative Method of Rainfall Forecasts In Watershed Of Hydro Power Plant

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ABSTRACT

Water resources of a hydro power plant generally is influenced by rainfall in the watershed. Rainfall prediction is done by using monthly rainfall data at each station. Water resources are usually derived from some streams that flow into the hydropower reservoirs. The research was conducted by predicting rainfall at three locations. These locations are considered to have a very large impact on water resources of the plant. The method used is the time series.

KEYWORDS: water resources, hydropower, time series.

I. INTRODUCTION

Hydro power plans is a plant that uses water as the potential energy of a turbine to drive a generator. Hydro power plant in Indonesia generally uses the reservoir to accommodate the flow of water from a river. The amount of water that can be accommodated in the reservoir depends on the intensity of rainfall in the watershed at the catchment area of a hydroelectric plant.The problems that occurred in Indonesia is a lots of the hydro power plant do not operate optimally after operated more than 15 years[1,2,3,4]. It is because water resources in the power plant is degraded by time, therefore we need to conduct a study research about the sustainability of water resources by making predictions of the rainfall will occurrence in the watershed hydropower. The study was conducted in the watershed Mamasa. This watershed supplies the resource of Bakaru hydro power plans (hydropower Bakaru). Location of the plant's reservoir is geograp-hically located between $3^0$30'00"-$2^0$51'00"LS and119^{0}15'00"-119^{0}45'00" BT.

II. REVIEW OF LITERATURE

1.1 Rainfall

The amount of rainfall affects the flow of water in hydro power plans reservoirs in Bakaru.Rainfall data obtained from the Meteorological Agency, Climatology and Geophysics Maros. Data used is collected from theMamasa station, Sumororang station, and the Lembang Station. The amount of the average monthly rainfall can be seen in Table 1, the annual rainfall in the reservoir in 2012 Mamasa of 1465 mm, 4087 mm of Sumarorang station, and 3331 mm at Lembang Station. Assuming all three recording station can represent the flow of water into the reservoir hydropower before it is deducted by the sediment carried by the flow of surface water is equal to 8883 mm.

Table1. Average Rainfall at Each Station

Month	Average rainfall per year at each station (mm)					
	Mamasa (I)		Sumarorong (II)		Lembang (III)	
	1990	2012	1990	2012	1995	2012
January	94	250	155	316	286	261
February	270	44	481	275	514	458
March	61	77	210	344	310	376
April	254	246	373	346	354	313
May	93	99	307	241	375	211
June	135	135	201	227	192	231
July	70	44	256	227	209	175
August	77	22	100	210	8	19
September	117	116	185	299	135	62
October	46	218	233	211	32	220
November	30	223	225	504	319	478
December	95	63	380	362	308	527
Average rainfall per year (mm)	112	128	259	297	254	278

1.2 Time series

Time series is a series of observations of an event, occurrence, phenomenon or variables are taken from time to time. The data is recorded accurately in the time sequence and then compiled as statistics, data recording is generally done on a daily, monthly, or yearly.Analysis of time series with methods Arima Box-Jenkin has been done by BagusRahmat W, ie by doing "Rainfall Forecasting in Ngawi district" and Wahyudi Lewis published "Electrical Load Forecasting in PT. PLN APJ South Surabaya.Time series analysis is a quantitative analysis, which is used to determine the pattern of historic data. The distinctive feature of this analysis is a series of observation in one variable is viewed as a realization of a random variable with distribution, which is considered to be a function of the probability with random variance $Z_1, ..., Z_n$, for example $f_{1, ..., n}(Z_1, ... ,Z_n)$; subscript 1, ..., n the density function pointed to the fact that in general the parameters or even the density function that depends on the particular point of time is concerned, this model is called stochastic models. As a simple example of a stochastic process is considered a random walk, where in each successive changes taken independently from a probability distribution with mean zero. Then the variable Z following the forecast made at time t for k steps ahead is seen as the expectation value of z_{t+k} with the condition known observation ago to Z_n.

$$Z_t - Z_{t-1} = a_t$$

Wherea_t is a random variable with mean zero and independently drawn each period, thus making each successive step is undertaken Z is random.

Pattern of time series data is the data pattern observed on a vulnerable time. Exploration of the data to determine how the behavior of the data throughout the observation period. Time series data are assumed to be divided into three data patterns are: trend, seasonal variations and stationary.

1.2.1 Time series analysis

Analysis of time series such as Autoregressive (AR), Moving Average (MA), Autoregressive Moving Average (ARMA) and Autoregressive Integrated Moving Average (ARIMA).

1) Autoregressive models (AR)

Autoregressive model is a model that illustrates that the dependent variable is affected by the dependent variable itself in the periods and previous times. In general autoregressive models (AR) has the following form.

$$Y_t = \theta_0 + \theta_1 Y_{i-1} + \theta_2 Y_{i-2} + \cdots + \theta_p Y_{1-p} - e_i$$

where:

Y_t= stationary time series

θ_0 = constant

$Y_{i-1},...,Y_{i-p}$= value past linked

$\theta_1,...,\theta_p$=coefficients or parameters of autoregressive models

e_t= residual at time t

The above model is referred to as autoregressive models (regression myself) because the model is similar to the regression equation in general, it's just that being an independent variable instead of the different variables with the dependent variable but the previous value (lag) of the dependent variable (Y_t) itself.

Number of past values used by the model, determining the level of the model. If only used one lag dependent, then the model is called the model autoregressive level one (firstorder autoregressive) or AR (1) and when used as the dependent lag, then the model is called autoregressive level p (p-th order autoregressive) or AR (p).

2) Moving Average Models(MA)

In general, the model has the form of a moving average as follows:

$$Y_t = \emptyset_0 + \emptyset_1 e_{i-1} - \emptyset_2 e_{i-2} - \cdots - \theta_n e_{1-q}$$

where:
Y_t= stationary time series
$\emptyset_0$= constant
$\emptyset_1,\ldots,\emptyset_p$= coefficient model of moving average which indicates the weight.Coefficient can have a negative or positive value, depending on the results of estimation.
e_{i-q} = residual past used by the model as q, determines the level of the model.

Difference moving average models with autoregressive models lies in the independent variable. When the independent variables in the model is the autoregressive previous value (lag) of the dependent variable (Yt) itself, then the moving average models as the independent variable is the residual value in the previous period.

3) Autoregressive moving average models(ARMA)

Often the characteristics of Y can not be explained by the AR or MA alone, but must be explained by both. Model that includes both of these processes is called ARMA models. The general form of this model are:

$$Y_t = \gamma_0 + \delta_1 Y_{i-1} + \delta_2 Y_{i-2} + \cdots + \delta_n Y_{i-p} - \lambda_1 e_{i-1} - \lambda_2 e_{i-2} - \lambda_n e_{i-q}$$

where:
Y_t= stationary time series
γ_t= constant
δ and λ = coefficient models
e_t= residuals ago

4) ARIMA Models

Arima model is a model developed intensively by George Box and Jenkins Gwilyen so that their name is often synonymous with Arima processes applied to the analysis and forecasting of time series data. Arima is actually a technique to find the most suitable pattern from a group of data (curve fitting), Arima thus fully utilizing the data of the past and present to make accurate short-term forecasting.

Arimahas very good accuration for short-term forecasting, while for long-term forecasting it is unfavorable. Will usually tend to flat / constant (flat) for a sufficiently long period.

III. RESEARCH METHODS

3.1 Types and sources of data

Rainfall data were used from 1990 to 2012, the data is derived from measurements of Mamasa station, stations and station SumarorangLembang. These stations are under the coordination of the Meteorology, Climatology and Geophysics Agency (BadanMeteorologi, Klimatologi, danGeofisika-BMKG) Maros. Rainfall data at each station are shown in Figures 1, 2 and 3 below.

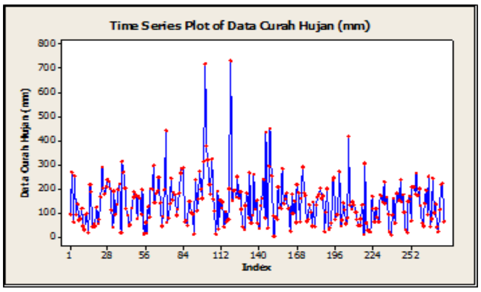

Figure 1. Rainfall Data of Mamasa Station year1990 to 2012

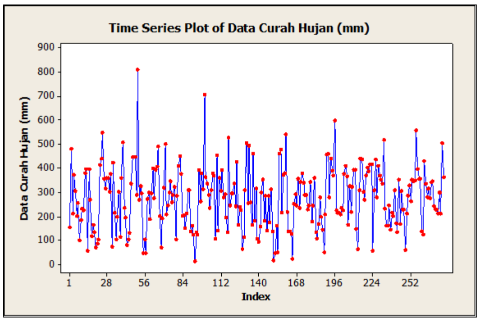

Figure2. Rainfall Data of SumarorongStation year 2009 to 2012

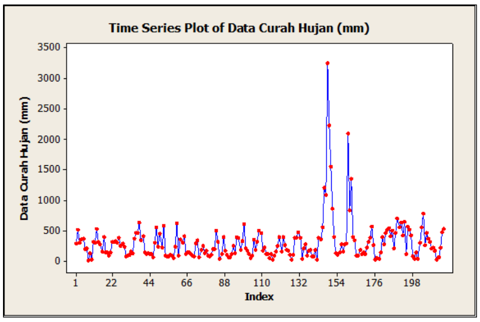

Figure3. Rainfall Data of Lembang Station year 2009 to 2012

From data above it show the static trend each figure. The next step is to check the stationary model.

3.2 Data Analysis

Data analysis using monthly rainfall data from 1990 to 2012. The method used to predict the rainfall is the method of Arima. Flow forecast rainfall data shown in the figure 4. Processing data using Minitab software.

3.2.1 Selection of Model

Model selection is done by comparing the value of SS (sum square) and MSE (mean Square Error) of each model is obtained after differentiation. Description of each rainfall data at each station are described as follows:

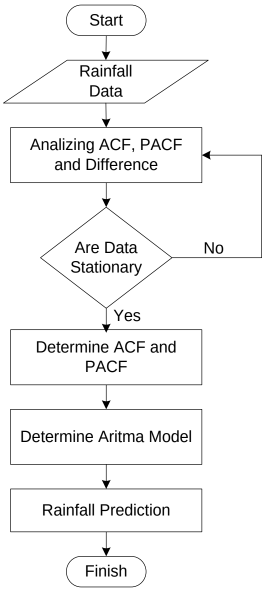

Figure 4. Flow chart prediction with ARIMA models

IV. RESULTS

Arima model results from each station are shown in Table 2.

Table 2. Rainfall Arima models

No.	Month	ARIMA Models at Station		
		I	II	III
1	January	(4,0,3)	(4,0,1)	(3,0,3)
2	February	(4,0,5)	(3,0,2)	(4,0,4)
3	March	(5,0,4)	(3,0,1)	(4,0,4)
4	April	(4,0,4)	(3,0,2)	(3,0,3)
5	May	(5,0,4)	(3,0,2)	(3.0,2)
6	June	(5,0,4)	(4,0,1)	(4,0,3)
7	July	(4,0,4)	(4,0,1)	(4,0,3)
8	August	(5,0,4)	(3,0,2)	(2,0,2)
9	September	(4,0,3)	(4,0,1)	(2,0,2)
10	October	(5,0,4)	(3,0,2)	(2,0,2)
11	November	(4,0,4)	(4,0,1)	(3,0,2)
12	December	(4,0,4)	(4,0,1)	(4,0,4)

Prediction of rainfall at each station is done by using the above model of Arima. Results predicted rainfall at each station in the form of curves shown.

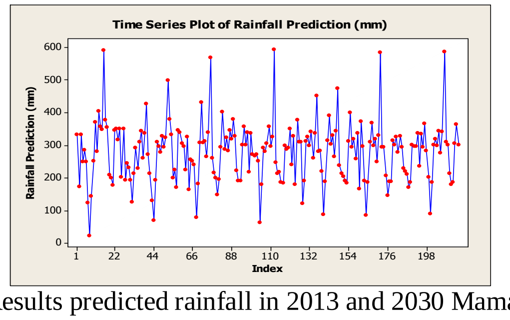

Figure 5. Results predicted rainfall in 2013 and 2030 Mamasa station

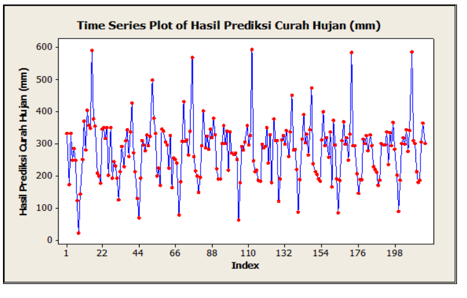

Figure 6. Results predicted rainfall in 2013 and 2030 Sumarorong station

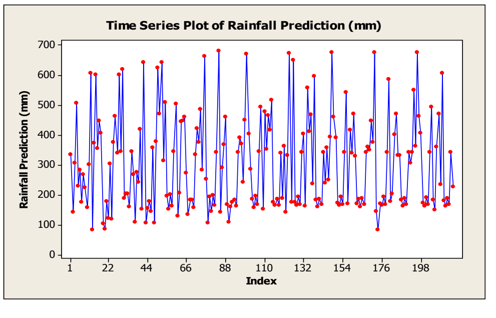

Figure 7. Results predicted rainfall in 2013 and 2030 Lembang station

Results predicted rainfall on average per year in each station can be seen on table 3.

Table 3. Average rainfall prediction at each station

Year	Prediction of average rainfall per year at station (mm)			
	I	II	III	Amount
2013	163	234	294	692
2014	125	336	265	726
2015	136	244	342	722
2016	152	261	241	653
2017	134	311	375	820
.	.	.	.	.
.	.	.	.	.
2029	146	270	361	777
2030	159	308	273	740

V. CONCLUSIONS

Of rainfall prediction results obtained by the average rainfall per year is:

1) Station Mamasa rainfall lowest annual average occurred in 2018 and 2025 is 119 mm and the highest occurred in 2013 is 163 mm.
2) Sumarorong station rainfall lowest annual average occurred in 2013 is 234 mm and the highest happened in 2014 that is 336 mm.
3) Lembang station rainfall lowest annual average occurred in 2016 is 241 mm and 2017 the highest is 375 mm.
4) Water resources hydroelectric power derived watersheds, can be predict the highest of rainfall predicted results of the three rainfall stations that gather in 2017 is about to 820 mm and in the other is between the value of 690 mm up to 780 mm.

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