Prediction of Electricity Consumption for Household Categories R-1 Based on Average Air Temperature with a Single Input Transfer Function Approach

Sediono, Eko Tjahjono, and Retno Dwi Puspitasari

Department of Mathematics Airlangga University

Email: sediono101@gmail.com

Abstract

The transfer function model is one of the quantitative prediction models that is often used for multivariate time series data prediction. This model combines several characteristics of regression analysis with ARIMA periodical characteristics. This research explained the application of a single input transfer function model in predicting the amount of electricity consumption (Yt) in Jombang Regency based on the influence of the average air temperature (Xt)). In conducting modelling, the data used electricity consumption and the average air temperature from January 2011 to June 2017. The stages that need to be done are to see the stationary data of the output series (Yt) and input series (Xt), determine the best ARIMA model output series (Yt) and input series (Xt), do prewhitening, determine the order (b, r, s) through cross correlations (CCF) plots, and determine the best model of the transfer function by describing the order (b, r, s) along with the sequence (nt). From the model produced it can be explained that the amount of electricity consumption in Jombang is influenced by the increase in electricity consumption 1 month before ($\dot{Y}_{t-1}$), minus 1202862.9 times the average air temperature this month ($\dot{X}_t$) minus the average air temperature 12 months ago ($\dot{X}_{t-12}$), minus the average air temperature 13 months ago ($\dot{X}_{t-13}$) $\cdot$ plus the residual this month (a_t) minus 0.83127 times the residual 1 month ago (a_{t-1}).

Keywords: Single input transfer function, electricity consumption, forecasting, air temperature

Introduction

Electricity is one source of energy that is needed all over the world, including Indonesia. Along with the progress of development in various fields, the need for electric energy in Indonesia has increased both in power consumption and the number of customers. Customers are grouped into households, businesses, industry and the public. National electricity demand grew an average of 8-9% by year. PT PLN (Persero) is a power company planning the development of long-term electricity system in order to meet demand for electricity, which is increasing every year. This is because electrical energy is one of the basic needs of society. One in the province of East Java is PLN Rayon Jombang. Based on data from PT PLN (Persero) Rayon great Jombang in 2017 recorded 332,076,773 KWh of electricity consumption. This increase was primarily due to an increase in population that will have an impact on human penigkatan electricity needs. But besides that, power consumption can also be caused by other factors that can influence human behaviour in the use of electricity, one of which is the air temperature.

The Intergovernmental Panel on Climate Change (IPCC) concluded that global average temperatures at the earth's surface have increased by about $0.74 \pm 0.18°$ C over the last century and is expected to rise 1.1 to 6.4 ° C between 1990 and 2100. Indonesia is located on the equator and will certainly feel the temperature changes the highest compared to other regions on earth. This temperature rise will affect the pattern of society. At the present time there is a lot of electrical equipment used to regulate the ambient temperature conditions. The use of AC (Air Conditioner) or a fan has become a pattern that is common for people of various circles. Further the energy consumption of refrigeration or air conditioning apparatus draws a relatively large amount of power compared with the power absorbed by other household electronic appliances.

Previous research by Rachmawati (2013) showed that the consumption of electricity for household category R-1 TR 450VA, 900VA, 1300VA and 2200VA was influenced by the previous month. Time series is series of observations based on time sequences and between adjacent time sequences correlated with each other (Abraham,B and Johannes, L., 2005). A Method of time series data analysis should be applicable not only for financial economics but also for another fields and forecasting (Agung, IGN, 2009). In the time series models, component of error or white noise are random variables, where the distribution of white noise is assumed to have a mean of zero and a constant variance (Bell, W.R. and Hilmer, S.,1983). Forecasting is very important in many types of organizations since predictions of future events must be incorporated into the decision making process (Bowerman,B.L. and Oconnell, R.T.,1993). See in particular (Bowerman,B.L and Tukey, J.W.(1979). A Time series is a sequence of observations taken sequentially in time (Box, G.E., Jenkins, G.M. and Reinsel, G.C., 1994). According to Brocklebank and Dickey (2003), a time series is a set of ordered observations on a quantitative characteristic of a phenomenon at equally spaced time points. The study of time series is concerned with time correlation structures. It has diverse applications ranging from oceanography to finance (Chan, N.H, 2002). Time Series forecasting analysis and prediction (Cryer, J.D, 1986) considers a quantitative form, where data is obtained from observations of phenomenon over time. This data is collected periodically in order of time to determine the data pattern of the past data that has been collected on a regular basis (Cryer, J. D. and Chan, 2008). In the time series there are four patterns, among others horizontal, trend, seasonal and cyclical (Hanke,J.E. and Wicheren, D.W.,2005) Since the mid-1980's, applied economist attempting to estimate time series econometric models have been aware of certain difficulties that arise when unit roots are present in the data (Harris,R and Sollis, R, 2003). According to Kirchgassner, G and Wolters, J (2007), it is generally assumed that present in a time series is a discrete variable. The basic concepts of time series analysis is that the factors that affect the pattern of the data set

in the past, now tend to be much the same in the future. Thus doing the analysis of time series aims to identify those factors to assist researchers in making decisions. The Time series models that are commonly used is Autoregressive (AR), Moving Average (MA) and the combination of Autoregressive Moving Average (ARMA). However, the models can only be used for cases of univariate. There are many statistical methods that can be used to predict multivariate time series, including transfer function method, the method of intervention analysis and fourier analysis. Transfer function model is a time series forecasting model which combines some of the characteristics of univariate ARIMA models and multiple regression analyses characteristics (Makridakis, Wheelwright & Hyndman, 1998). The concept of transfer function consists of a series of input, output series, and all other effects, called interference including method transfer function, Fourier analysis methods of intervention and analysis (Milhoj, 2013). The ARIMA models, discussed in the previous section, represent a general class of models that can be used very effectively in time series modelling and forecasting problems. An implicit assumption in these models is that the conditions under which the data for the time series process is collected remain the same. If, however these conditions change over time, ARIMA models can be improved by introducing certain inputs reflecting these changes in the process conditions. This will lead to what is known as transfer function noise models(Mongomery,D.G.,Jennings,C.L.and Kulahci,M, 2008). See in particular Pena,D, Tiao,G.C and Tsay R.S.(2001). Generally, in the time series, to understand the significance of the model, the correlation coefficient needs to be tested (Pantkratz, A.,1991). Transfer function model is a time series forecasting model which combines some of the characteristics of univariate ARIMA models and multiple regression analysis characteristics (Wei, 2006). Based on the above presentation, the author wants to implement a transfer function method in predicting major categories of household electricity consumption of R-1 TR 450VA, based on the average air temperature. This research analyses data concerning the monthly household electricity consumption category R-1 TR 450 VA at PLN Rayon Jombang

and the average air temperature in Jombang. This category was chosen because TR 450 VA has the largest electricity consumption for households in PLN Rayon Jombang.

Materials and Method

The data used in this research is secondary data on large power consumption and the average air temperature in Jombang. Data was taken during the period of January 2011 to December 2017. The data used is divided into data-in-till and out-of-sample. In-sample data is data from January 2011 to June 2017 and the data out-of-sample is the data of July 2017 to December 2017. Data were collected in PT (Persero) PLN Rayon and BMKG Jombang. Research variables used in this research are series of output (Y_t), a large power consumption, and a series of input (X_t) which is the average air temperature. The Step-by-step procedure to be carried out in this research is as follows:

1) Describing the electricity consumption data and the average air temperature in Jombang.

    a. Describe the variables include the average value and standard deviation,

    b. Make a chart to see the minimum and maximum values in each of the study variables.

2) Modelling and predicting the relationship between power consumption and the average air temperature, in Jombang, with input single transfer function approach.

    a. Preparing stationarity input series and output series. This stage identifies whether the series of output and input sequence is already stationary, either in flats or in variance, to see a time series plot, plot of ACF and PACF plots. If the data is not stationary then performed the differentiation and transformation. Where to sequence definition output and input series are Y_t is large power consumption and X_t is the average air temperature.

    b. Identifying the ARIMA model to create a time series plot, plot ACF and PACF plots. From the third of this plot, it can be seen whether or not the data has been stationary.

When it seems that the data is still stationary at variance, this can be overcome by using the rank transformation (power transformation). Once the data is stationary, use ACF and PACF plots to identify the ARIMA model.

c. After identifying the model, the parameters used in the ARIMA model are estimated by Maximum Likelihood Estimation (MLE). After the estimated parameters, parameter significance test uses a test statistic t.

d. Diagnostic examination using a statistical test to determine if a particular Q series meets the white noise process.

e. Doing prewhitening rows of input and output series to eliminate all known patterns so that left only white noise.

f. Calculating the cross-correlation (cross-correlation) and autocorrelation sequence input and outputs which have white noise to find the relationship between the two.

g. Direct estimate weights implus response and determination (r, s, b) to model the transfer function linking the input and output series.

h. Initial estimate interference series (nt) and compute autocorrelation (ACF) and partial autocorrelation (PACF) for this series.

i. Assign (pn,qn) for ARIMA (pn, 0,qn) of a series of noise or interference (nt).

j. Estimating the model parameters of the model transfer function using the MLE (Maximum Likelihood Estimator).

k. Calculate the cross-correlation between the value of the input sequence with the sequence prewhitening noise. This phase is performed to check whether the sequence of noise and input sequence is independent or independent. The testing is done by using the test statistic Q.

l. Calculating the value of autocorrelation for the residual value of the model (b, s, r) that connects the input and output series, to examine the adequacy of the model noise. For

both models enough ACF and PACFsample and must demonstrate a pattern, the test also using the test statistic Q,Choosing the best model based on the value of AIC, SBC, and MSE and doing forecasting to predict in some period come.

Results and discussion

Describing Data Power Consumption and average air temperature in Jombang

Characteristics of data are seen by analyzing descriptively. The results of descriptive analysis are shown in Table 1. Based on Table 1, for a series of output the electricity consumption in Jombang, was an average per month of 5951.8 (in thousands) 551.2 KWh and a standard deviation. As for the input sequence which is the average air temperature in Jombang with an average per month is 27.954 and a standard deviation of 0.961.

Modeling and Predicting Relationship Between Electricity Consumption by Average air temperature in Jombang with Single Input Transfer Function Approach

Identifying the ARIMA model series Input (Xt)

Based on the analysis that has been done, ARIMA modelling for input sequence (Xt) resulted in a box-cox transformation with rounded value value-0.91 and the data is stationary differencing 12 and 1. Figure 1 is the result of a *plottime series*, figure 2 is the results of ACF plot and figure 3 is the results of PACF plot **data that is stationary**: ARIMA models are best obtained ARIMA (0,1,0) (0,1,0) 12 (0,0,1) 3 with the value of the MSE = 0.0000005.

Identifying Array Output(Yt)

Based on the analysis that has been done, ARIMA modelling for input sequence (Yt) resulted in a box-cox transformation with rounded value of 2.00 and a data value has been stationary differencing 1. Figure 4 is the results of a time series plot, figure 5 is the results of ACF plot and figure 6 is the results of PACF plot data that is stationary:

Best ARIMA model is ARIMA (0,1,1) (0,0,1) 12 with a value of by MSE = 6.97763E + 12.

Prewhitening series Input (Xt) And series Output (Yt)

Results prewhitening input sequence (Xt) and series output (Yt) is

$$\alpha_t = X_t - X_{t-1} - X_{t-12} + X_{t-13} + 0.536\alpha_{t-3} \tag{1}$$

$$\beta_t = Y_t - Y_{t-1} - Y_{t-12} + Y_{t-13} + 0.536\beta_{t-3} \tag{2}$$

From the results, prewhitening input sequence (α_t) the white noise and series results prewhitening output series (β_t) can look for descriptive statistics of each α_t and β_t with the following results:

Cross correlation results and Tier Prewhitening Series Input Output

Cross correlation was performed to calculate the weight of the impulse response and transfer function model building early, to determine the order of b, r, s based on a plot of CCF in figure 7 below.

Judging from the plot of the CCF in figure 7, value b, r, s are (0,0,0), b and s is 0 for CCF plot showed no lag that appears, r = 0 because the plot of the CCF has a pattern consisting of several lag then cut off.

Determining series ARIMA model series Noise and Noise

The next step is to determine the noise series model. Determination can be seen from the ACF and PACF plots in Figure 8 and Figure 9.

Based on figure 8 and figure 9 , it seems that the plot appears on the lag 1.12 ACF and PACF plots appear on the lag 1.2. After estimating the parameters, it was found that the ARIMA (0,0,1) is the best noise series model with parameter values and the value AIC = 880.5185, SBC = 884.8463. Thus the noise is a model for series

$$n_t = a_t - \theta_1 a_{t-1} \qquad (4)$$

1.1.1. Transfer Function Model Single Input

Transfer function model is formed

$$\dot{Y}_t = \dot{Y}_{t-1} + \omega_0 \dot{X}_t - \dot{X}_{t-12} - \dot{X}_{t-13} + a_t - \theta_1 a_{t-1} \qquad (5)$$

with $\dot{Y}_t = Y_t{}^2$ and $\dot{X}_t = \frac{1}{X_t{}^{1.91}}$.

The value of the parameters entered into the equation (5), change the backward shift operator into shape. The following is the transfer function model for the amount of electricity consumption in Jombang:

$$\dot{Y}_t = \dot{Y}_{t-1} - 1202862.9\dot{X}_t - \dot{X}_{t-12} - \dot{X}_{t-13} + a_t - 0.83127 a_{t-1} \qquad (6)$$

Forcesting data outsample

Equation (5) can be applied to predict a large forecast in electricity consumption for the next 6 months:

Based on Table 3, forecasting results would not be exact, but the accuracy of the forecasting can be seen through similarities in fluctuation or trend data; a comparison between data forecasting results and the actual data.

Conclusion

Based on the results and discussion in this paper, the following conclusions can be given: 1). From a large data set, Jombang electricity consumption, in the district in January - June 2017, has the characteristic of, by month, 5951.8 (in thousands) 551.2 KWh and standard deviation. The average air temperature, in Jombang, per month is 27.954 and a standard deviation of 0.961; 2). The best model to use in order to predict large electricity consumption, in Jombang, is input single transfer function model based on the average air temperature; shown by the equation :

$$\dot{Y}_t = \dot{Y}_{t-1} - 1202862.9\dot{X}_t - \dot{X}_{t-12} - \dot{X}_{t-13} + a_t - 0.83127a_{t-1}$$

$$\dot{Y}_t = Y_t^2 \text{ and } \dot{X}_t = \frac{1}{X_t^{1.91}}$$

From the model, it is explained that the large power consumption in Jombang is influenced by large increments of electricity consumption 1 month earlier ($\dot{Y}_{t-1}$), less the average temperature this month ($\dot{X}_t$) minus the average air temperature 12 months ago ($\dot{X}_{t-12}$), reduced average air temperature 13 months ago ($\dot{X}_{t-13}$) plus a residual of this month (a_t) minus the residual time one month ago (a_{t-1}).

3). From the transfer function model, for large electricity consumption in Jombang, the research presented a forecasting for the next 6 months. After a comparison between forecasting results data with actual data, there are similarities prove the 6-month trend to be valid.

Acknowledgements

Table 1. Results Descriptive Analysis

Variables	Information	Amount of data	Average	Standard deviation
Yt	Electricity consumption	78	5951.8	551.2
Xt	Average Temperature	78	27.954	0.961

Table 2. Descriptive statistics α_t and β_t

α_t			
Mean	**StdDev**	**Minimum**	**Maximum**
0.0094	0.4301	-1.7897	1.1660
β_t			
Mean	**StdDev**	**Minimum**	**Maximum**
-3.0	787.8	-1602.5	2421.9

Table 3. Results Forecasting Model Transfer Function Input Single Large Electricity Consumption

Period	Year	Month	Actual Data	trend	Results forecast	Trend
79	2017	July	6854.61	Up	7058.65	Up

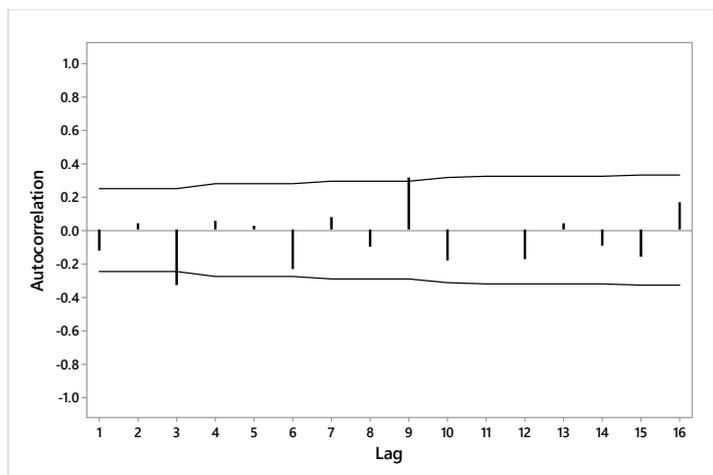| 80 | 2017 | August | 6586.32 | Down | 6694.74 | Down |
81	2017	September	6506.09	Down	6637.06	Down
82	2017	October	6892.58	Up	6803.26	Up
83	2017	November	6674.19	Down	6548.80	Down
84	2017	December	6806.87	Up	6687.21	Up
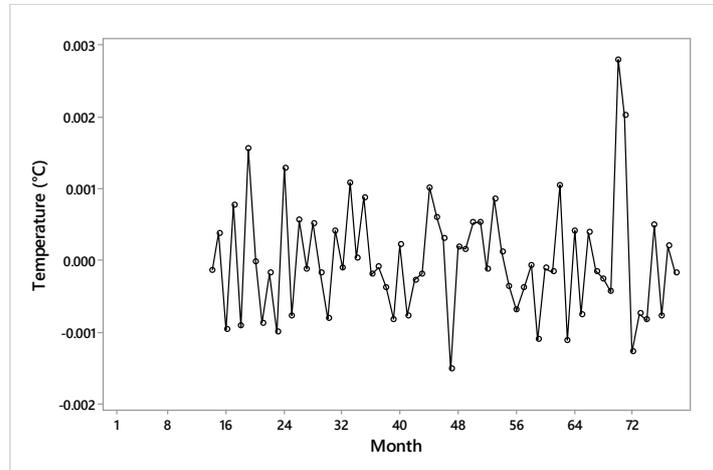
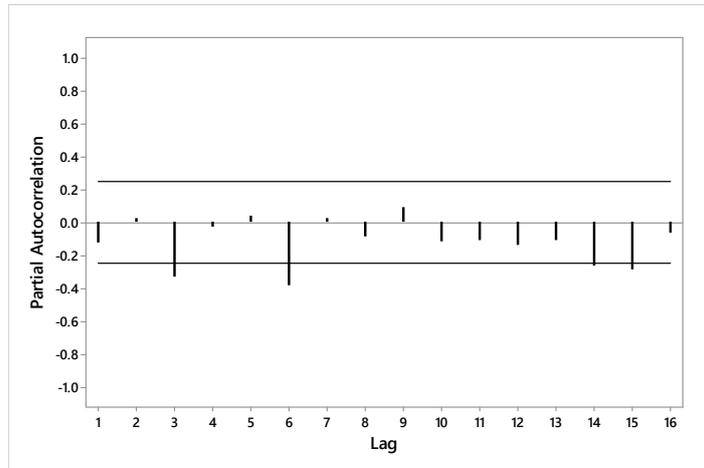Figure 1: Time Series Plot

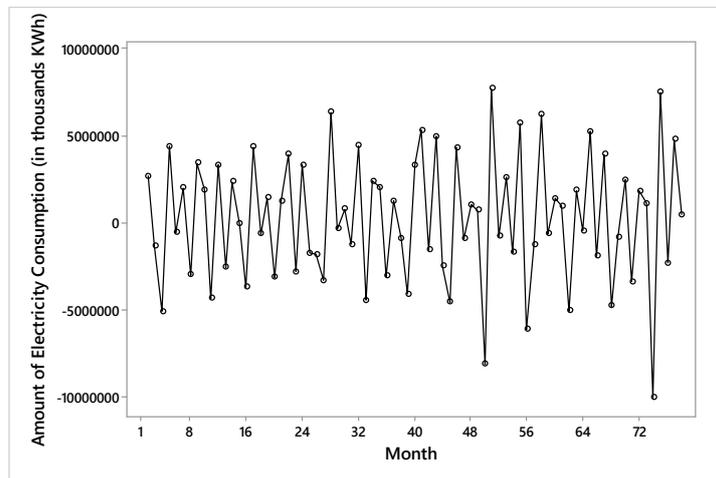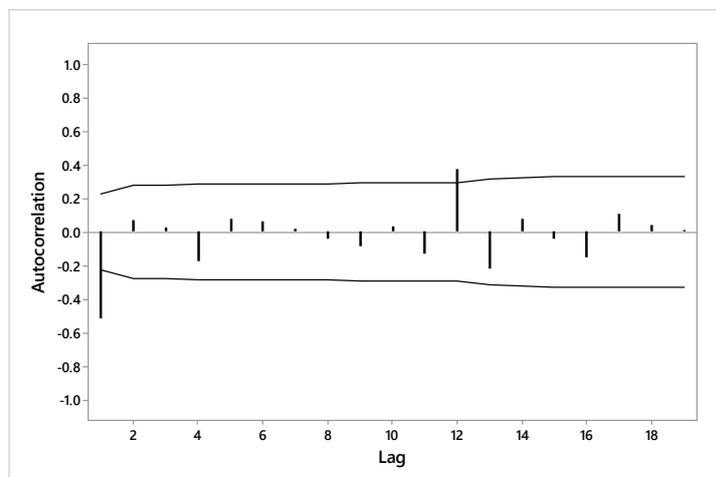Figure 2: ACF Plot

Figure 3: PACF Plot
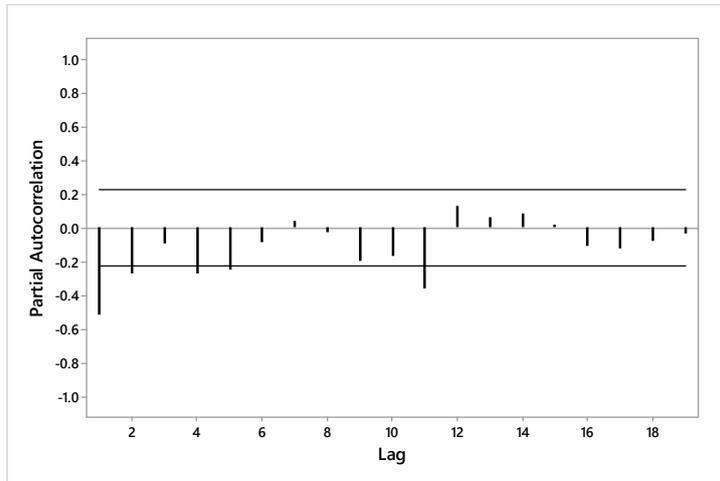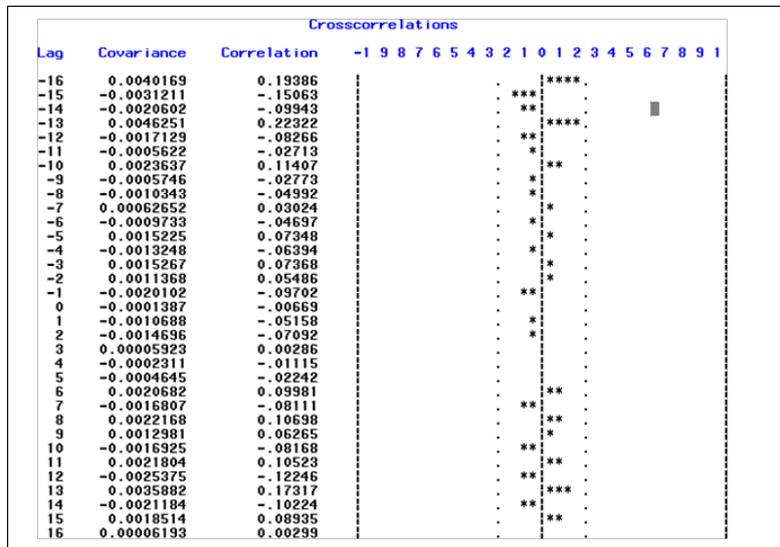

Figure 4: Time Series Plot

Figure 5: ACF Plot

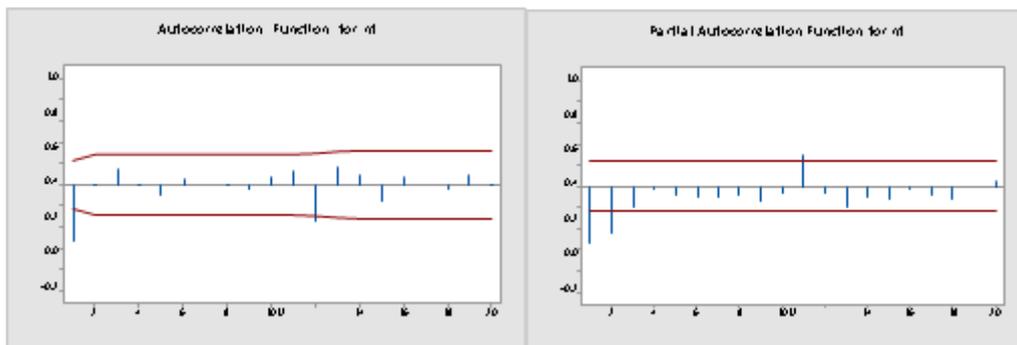Figure 6: PACF Plot

Figure 7. Plot CCF

Figure 8. Plots ACF   **Figure 9.** Plot PACF

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