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Evaluation of Moving Average Model and Autoregressive Moving Average Model (ARMA) for Prediction of Industrial Electricity Consumption in Nigeria

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Abstract: In this paper, evaluation of moving average model and autoregressive moving average model (ARMA) for prediction of industrial electricity consumption in Nigeria is presented. Industrial electricity consumption data obtained from Central Bank of Nigeria (CBN) Statistical Bulletin for the year 1979-2014 is used to determine the model parameters and prediction performance in terms of Root Mean Square Error (RMSE) and Coefficient of determination r^2 values. The results show that the Autoregressive Moving Average (ARMA) model with coefficient of determination value of 66.0% and RMSE value of 68.628 gives better prediction performance than the Moving Average with coefficient of determination value of 42.6% and value of 84.749. However, coefficient of determination value of 66% is not particularly adequate for acceptable prediction accuracy. In that case, for better prediction accuracy for the industrial electricity consumption in Nigeria, other models may need to be examined apart from the two models considered in this paper.

Keywords: Moving Average Model, Autoregressive Moving Average Model, Industrial Electricity Consumption, Prediction Accuracy, Time Series Models

1. Introduction

Globally, reliable and adequate electricity supply has been identified as paramount to socio-economic and technological development of every nation [1-8]. Particularly, the industrial sector with their job creation and poverty alleviation potentials is heavily reliant on electricity. In this wise, electricity is central to industrialization of any nation [9-13]. However, in Nigeria, there has been perennial acute shortage of power supply [14-16]. Some of the challenges include insufficient power generation, excessive power losses, poor maintenance of power plants, lack of political will to tackle the problems associated with the power sector.

In any case, since the last decades, Nigerian government has continued to introduce reforms in the power sector ranging from privation to expansion in the power generation and distribution capacities [17-25]. In all, there has been noticeable marginal improvement in the power supply across the nation. However, the industrial sectors are still overwhelmed by grossly inadequate power supply. The effect has been on high cost of production in Nigeria and disproportional dependence on imported goods. In order to plan for adequate power supply to the industrial sector, the existing and projected industrial energy demand profile is needed. In this wise, models need to be developed and evaluated for prediction and possibly forecasting of the industrial electricity consumption in Nigeria.

Consequently, in this paper, two time series models are considered, namely, Moving Average Model and Autoregressive Moving Average Model (ARMA) [26-34]. The two models are used to predict industrial electricity consumption in Nigeria. The prediction performance of the two models are then compared in terms of RMSE and r^2 values. The study is meant to evaluate the adequacy of the prediction performance of the selected models for industrial electricity consumption prediction. Particularly, the prediction performance is expressed in terms of Root Mean Square Error (RMSE) and Coefficient of determination (r^2).

2. Theoretical Background

In this paper, two time series models are considered, namely, Moving Average Model and Autoregressive Moving Average Model (ARMA). The two models are used to predict industrial electricity consumption in Nigeria. The prediction performance of the two models are then compared in terms of RMSE and r^2 values.

2.1. Moving Average Model (MA) (of Order 1)

The moving average model of order 1 is given as;

$$Y_t = \theta_0 - \theta_1 \varepsilon_{t-1} + U_t \tag{1}$$

θ_0 and θ_1 are the model parameters and U_t is the error term with mean 0 and constant variance.

Making U_t the subject in equation (1) gives

$$U_t = Y_t - \theta_0 - \theta_1 \varepsilon_{t-1} \tag{2}$$

$$U_t^2 = \left(Y_t - \theta_0 + \theta_1 \varepsilon_{t-1}\right)^2 \tag{3}$$

$$\text{Let } S = \sum_{i=1}^{n} U_t \tag{4}$$

Taking partial derivatives of equation (3) with respect to θ_0 and θ_1 gives

$$S = \sum_{t=1}^{n}\left(Y_t - \theta_0 + \theta_1 \varepsilon_{t-1}\right)^2 \tag{5}$$

$$\frac{\partial S}{\partial \theta_0} = 2(-1)\sum_{t=1}^{n}\left(Y_t - \theta_0 + \theta_1 \varepsilon_{t-1}\right) \tag{6}$$

$$= -2\left[\sum_{t=1}^{n} Y_t - n\theta_0 + \theta_1 \sum_{t=2}^{n} \varepsilon_{t-1}\right] \tag{7}$$

$$\frac{\partial S}{\partial \theta_1} = -2\sum_{t=1}^{n}\left[\left(\varepsilon_{t-1}\right)\left(Y_t - \theta_0 + \theta_1 \varepsilon_{t-1}\right)\right] \tag{8}$$

$$= -2\left[\sum_{t=2}^{n} \varepsilon_{t-1} Y_t - \theta_0 \sum_{t=2}^{n} \varepsilon_{t-1} + \theta_1 \sum_{t=2}^{n} \varepsilon_{t-1}^2\right] \tag{9}$$

Setting $\frac{\partial S}{\partial \theta_0}$ and $\frac{\partial S}{\partial \theta_1} = 0$ gives

$$\sum_{t=1}^{n} Y_t - n\theta_0 + \theta_1 \sum_{t=2}^{n} \varepsilon_{t-1} = 0 \tag{10}$$

$$\sum_{t=1}^{n} n\theta_0 - \theta_1 \sum_{t=2}^{n} \varepsilon_{t-1}^2 = \sum_{i=1}^{n} Y_t \tag{11}$$

$$\sum_{t=2}^{n} \varepsilon_{t-1} Y_t - \theta_0 \sum_{t=2}^{n} \varepsilon_{t-1} + \theta_1 \sum_{t=2}^{n} \varepsilon_{t-1}^2 = 0 \tag{12}$$

$$\theta_0 \sum_{t-1}^{n} \varepsilon_{t-1} - \theta_1 \sum_{t-1}^{n} \varepsilon_{t-1}^2 = \sum_{t=2}^{n} \varepsilon_{t-1} Y_t \tag{13}$$

Arranging equations 10 to 13 in matrix form gives

$$\begin{pmatrix} n & -\sum_{t=2}^{n} \varepsilon_{t-1} \\ \sum_{t=2}^{n} \varepsilon_{t-1} & -\sum_{t=2}^{n} \varepsilon_{t-1}^2 \end{pmatrix} \begin{pmatrix} \theta_0 \\ \theta_1 \end{pmatrix} = \begin{pmatrix} \sum_{t=2}^{n} Y_t \\ \sum_{t=2}^{n} \varepsilon_{t-1} Y_t \end{pmatrix} \tag{14}$$

Let

$$M_3 = \begin{pmatrix} \sum_{t=1}^{n} Y_t & -\sum_{t=1}^{n} \varepsilon_t \\ \sum_{t=2}^{n} \varepsilon_{t-1} Y_t & -\sum_{t=2}^{n} \varepsilon_{t-1} \varepsilon_t \end{pmatrix} \tag{15}$$

$$p_3 = \begin{pmatrix} \theta_0 \\ \theta_1 \end{pmatrix}, \quad V_3 = \begin{pmatrix} \sum_{t=2}^{n} Y_t \\ \sum_{t=2}^{n} \varepsilon_{t-1} Y_t \end{pmatrix} \tag{16}$$

Then equation 14 becomes

$$p_3 M_3 = V_3 \tag{17}$$

$$p_3 = M_3^{-1} V_3 \tag{18}$$

The solution of equation (18) gives the parameters of the Moving Average model.

2.2. Autoregressive Moving Average Model, (ARMA)

The ARMA can be expressed as:

$$Y_t = \beta_0 + \beta_1 Y_{t-1} - \theta_1 \varepsilon_{t-1} + a_t \tag{19}$$

Where, $\beta_0, \beta_1, \theta_0$ *and* θ_1 are the parameters of the model and a_t is the error term.

$$a_t = Y_t - \beta_0 - \beta_1 Y_{t-1} + \theta_1 \varepsilon_{t-1} \tag{20}$$

$$a_t^2 = \left(Y_t - \beta_0 - \beta_1 Y_{t-1} + \theta_1 \varepsilon_{t-1}\right)^2 \tag{21}$$

Let D denote sum of square errors

Therefore;

$$D = \sum_{t=1}^{n} a_t^2 \tag{22}$$

To obtain the parameter of equation (22), D have to be minimized. Then,

$$\frac{\partial D}{\partial \beta_0} = 2(-1)\sum_{t=1}^{n}\left(Y_t - \beta_0 - \beta_1 Y_{t-1} + \theta_1\varepsilon_{t-1}\right) \quad (23)$$

$$= -2\sum_{t=1}^{n}\left[Y_t - n\beta_0 - \beta_1\sum_{t=2}^{n}Y_{t-1} + \theta_1\sum_{t=2}^{n}\varepsilon_{t-1}\right] \quad (24)$$

$$\frac{\partial D}{\partial \beta_1} = 2(-1)\sum_{t=1}^{n}(Y_{t-1})\,(Y_t - \beta_0 - \beta_1 Y_{t-1} + \theta_1\varepsilon_{t-1}) \quad (25)$$

$$= -2\left[\sum_{t=2}^{n}Y_{t-1}Y_t - \beta_0\sum_{t=2}^{n}Y_{t-1} - \beta_1\sum_{t=2}^{n}Y_{t-1}^2 + \theta_1\sum_{t=2}^{n}Y_{t-1}\varepsilon_{t-1}\right] \quad (26)$$

$$\frac{\partial D}{\partial \theta_1} = 2(-1)\sum_{t=1}^{n}\left[(\varepsilon_{t-1})(Y_t - \beta_0 - \beta_1 Y_{t-1} + \theta_1\varepsilon_{t-1})\right] \quad (27)$$

$$= -2\left[\sum_{t=2}^{n}\varepsilon_{t-1}y_t - \beta_0\sum_{t=1}^{n}\varepsilon_{t-1} - \beta_1\sum_{t=2}^{n}\varepsilon_{t-1}y_{t-1} + \theta_1\sum_{t=2}^{n}\varepsilon_{t-1}^2\right] \quad (28)$$

Setting $\frac{\partial D}{\partial \beta_0}$, then;

$$\sum_{t=1}^{n}Y_t - n\beta_0 - \beta_1\sum_{t=2}^{n}Y_{t-1} + \theta_1\sum_{t=2}^{n}\varepsilon_{t-1} = 0 \quad (29)$$

$$\Rightarrow n\beta_0 - \beta_1\sum_{t=2}^{n}Y_{t-1} + \theta_1\sum_{t=2}^{n}\varepsilon_{t-1} = \sum_{t=1}^{n}Y_t \quad (30)$$

Setting $\frac{\partial D}{\partial \beta_1}$ to zero

$$\sum_{t=2}^{n}Y_{t-1}Y_t - \beta_0\sum_{t=2}^{n}Y_{t-1} - \beta_1\sum_{t=2}^{n}Y_{t-1}^2 - \theta_0\sum_{t=2}^{n}Y_{t-1} + \theta_1\sum_{t=2}^{n}Y_{t-1}\varepsilon_{t-1} = 0 \quad (31)$$

$$\beta_0\sum_{t=2}^{n}Y_{t-1} + \beta_1\sum_{t=2}^{n}Y_{t-1}^2 + \theta_1\sum_{t=2}^{n}Y_{t-1} - \sum_{t=2}^{n}Y_{t-1}\varepsilon_{t-1} = \sum_{t=2}^{n}Y_{t-1}Y_t \quad (31)$$

Setting $\frac{\partial D}{\partial \theta_1}$ to zero,

$$\frac{\partial D}{\partial \theta_1} = 2(-1)\sum_{t=1}^{n}\left[(\varepsilon_{t-1})(Y_t - \beta_0 - \beta_1 Y_{t-1} + \theta_1\varepsilon_{t-1})\right] \quad (32)$$

$$= -2\left(\sum_{t=2}^{n}\varepsilon_{t-1}Y_t - \beta_0\sum_{t=2}^{n}\varepsilon_{t-1} - \beta_1\sum_{t=2}^{n}\varepsilon_{t-1}Y_{t-1} + \theta_1\sum_{t=2}^{n}\varepsilon_{t-1}^2\right) = 0 \quad (33)$$

Divide through by -2 gives

$$\beta_0\sum_{t=2}^{n}\varepsilon_{t-1} + \beta_1\sum_{t=2}^{n}\varepsilon_{t-1}Y_{t-1} - \theta_1\sum_{t=2}^{n}\varepsilon_{t-1}^2 = \sum_{t=2}^{n}\varepsilon_{t-1}Y_t \quad (34)$$

Arranging the sets of equations 29 to-34 in matrix form give

$$\begin{pmatrix} n & \sum_{t=2}^{n}y_{t-1} & \sum_{t=2}^{n}\varepsilon_{t-1} \\ \sum_{t=2}^{n}y_{t-1} & \sum_{t=2}^{n}y_{t-2}^2 & -\sum_{t=2}^{n}y_{t-1}\varepsilon_{t-1} \\ \sum_{t=2}^{n}\varepsilon_{t-1} & \sum_{t=2}^{n}\varepsilon_{t-1}y_{t-1} & \sum_{t=2}^{n}\varepsilon_{t-1}^2 \end{pmatrix}\begin{pmatrix}\beta_0\\ \beta_1\\ \theta_1\end{pmatrix} = \begin{pmatrix}\sum_{t=1}^{n}y_t \\ \sum_{t=2}^{n}y_{t-1}y_t \\ \sum_{t=2}^{n}\varepsilon_{t-1}y_t\end{pmatrix} \quad (35)$$

Let $M_4 = \begin{pmatrix} n & \sum_{t=2}^{n}y_{t-1} & \sum_{t=2}^{n}\varepsilon_{t-1} \\ \sum_{t=2}^{n}y_{t-1} & \sum_{t=2}^{n}y_{t-2}^2 & -\sum_{t=2}^{n}y_{t-1}\varepsilon_{t-1} \\ \sum_{t=2}^{n}\varepsilon_{t-1} & \sum_{t=2}^{n}\varepsilon_{t-1}y_{t-1} & \sum_{t=2}^{n}\varepsilon_{t-1}^2 \end{pmatrix}$, $p_4 = \begin{pmatrix}\beta_0\\ \beta_1\\ \theta_1\end{pmatrix}$ and

$V_4 = \begin{pmatrix}\sum_{t=1}^{n}y_t \\ \sum_{t=2}^{n}y_{t-1}y_t \\ \sum_{t=2}^{n}\varepsilon_{t-1}y_t\end{pmatrix}$. Hence, equation 35 becomes:

$$M_4 p_4 = V_4 \quad (36)$$

Making p_4 the subject of the formula in equation (36) gives

$$p_4 = M_4^{-1}V_4 \quad (37)$$

The solution of equation (37) gives the parameters of the ARMA model.

2.3. Performance Evaluation of the Models

2.3.1. Coefficient of Determination

The coefficient of determination r^2 is used to determine the effectiveness of using the models in predicting the predict industrial electricity consumption in Nigeria. r^2 gives the coefficient of the total variance in the department variable explained by the model.

$$r^2 = \frac{RSS}{TSS} \quad (38)$$

RSS for model is = $p_1^1 V_1 - \left(\frac{1}{n}\right)Y_t^1 JY_t$

Generally, the RSS is:

$$SSR_i = p_i^1 V_i - \left(\frac{1}{n}\right)Y_t^1 JY_t \text{, i = 1, 2, 3, 4} \quad (39)$$

TSS for model

$$1 = Y_t^1 * Y_t - \left(\frac{1}{n}\right)Y_t^1 JY_t \quad (40)$$

Where, J is the matrix,
Sum of square Error

$$(SSE) = SST - SSR \tag{41}$$

2.3.2. Root Mean Square Error (RMSE)

The Means Square Error (MSE) is computed using the formula:

$$MSE = \frac{1}{n}\sum_{i=1}^{n}\left(Y_t - \hat{Y}_t\right)^2 \tag{42}$$

The Root Means Square Error (RMSE) is given as

$$RMSE = \sqrt[2]{MSE} \tag{43}$$

Where, Y_t is the actual industrial electricity consumption and $\hat{Y}_t$ is the predicted value from the model.

3 Results and Discussions

3.1. Moving Average Model

Table 1. *Summary results of model estimation for industrial electricity consumption using moving average model.*

Variables	Coefficient	Standard. Error	$r^2_{(\%)}$	RMSE
θ_0	293.7405	24.9958	42.60	84.749
θ_1	0.8911	0.123077		

Table 1 gives results showing the model parameters and the model performance parameters namely r^2 and RMSE for the moving average model. Based on the results, the Moving Average (MA) model of order 1 for predicting the industrial electricity consumption in Nigeria is given as:

$$Yt = 293.7405 + 0.8911\ \varepsilon_{t-1} \tag{44}$$

The results also show that the Moving Average model accounted for 42.6 percent of the variation in industrial electricity consumption ($r^2 = 0.426 = 42.6\%$). The actual and the Moving Average model predicted values of industrial electricity consumption are as shown in Table 1 and figure 1.

Table 2. *Actual and predicted industrial electricity consumption using moving average industrial electricity consumption in Nigeria (MW/h).*

S/N	Year	Actual	Predicted
1	1979	160.3	191.35
2	1980	199.7	250.99
3	1981	121	244.00
4	1982	262	178.81
5	1983	254.4	350.47
6	1984	217.2	222.51
7	1985	259.8	279.7
8	1986	280.5	277.28
9	1987	294.1	297.43
10	1988	291.1	295.32
11	1989	257.9	294.14
12	1990	230.1	265.39
13	1991	253.7	260.92
14	1992	245.3	285.11
15	1993	237.4	260.54
16	1994	233.3	270.84
17	1995	218.7	259.92
18	1996	235.3	254.62
19	1997	236.8	273.15
20	1998	218.9	261.41
21	1999	191.8	253.75
22	2000	223.8	235.01
23	2001	241.9	276.75
24	2002	146.2	263.41
25	2003	196	187.55
26	2004	398	285.48
27	2005	182.3	396.34
28	2006	383.438	125.87
29	2007	494.01	496.05
30	2008	421.6	333.24
31	2009	428.954	383.66
32	2010	395.591	354.61
33	2011	426.37	345.39
34	2012	457.92	379.33
35	2013	518.7	383.48
36	2014	594.48	434.71

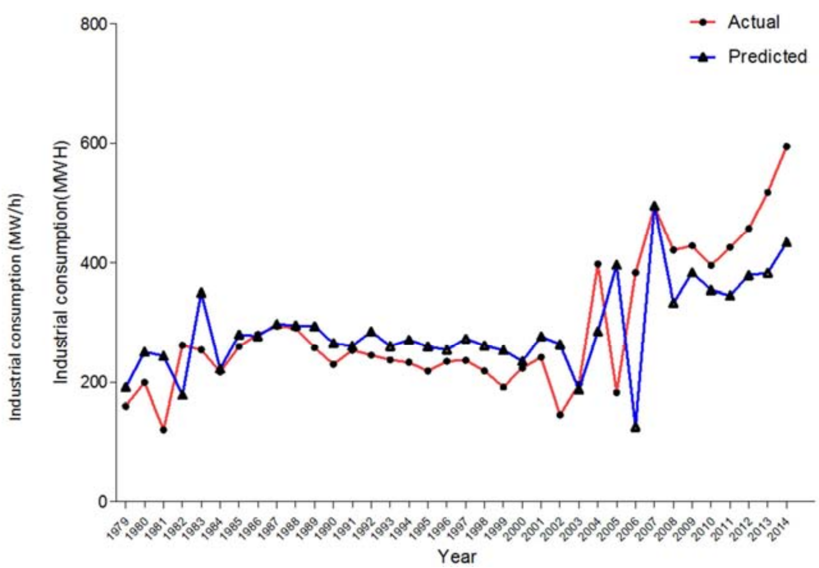

Figure 1. *Actual and predicted industrial electricity consumption in Nigeria between 1979-2014 using moving average model.*

3.2. Autoregressive Moving Average (ARMA) Model

Table 3 gives results showing the model parameters and the model performance parameters namely r^2 and RMSE for the autoregressive moving average (ARMA) model. Based on the results, the autoregressive moving average (ARMA) model for predicting the industrial electricity consumption in Nigeria is given as:

$$Y_t = 24264.43 + 9996\ Y_{t-1} - 0.5259\,\varepsilon_{t-1} \qquad (45)$$

Table 3. *Summary results of model estimation for industrial electricity consumption using autoregressive moving average (ARMA) model.*

Model Parameter	Coefficient	r^2(%)	RMSE
β_0	24264.43	66.0	68.628
β_1	0.9996		
θ_1	-0.5259		

The results also show that the ARMA model accounted for 66 percent of the variation in industrial electricity consumption (r^2 = 0.66 = 66 %). The actual and the ARMA model predicted values of industrial electricity consumption are as shown in Table 4 and figure 2.

Table 4. *Actual and predicted industrial electricity consumption using autoregressive moving average (ARMA) Industrial electricity consumption (MW/h).*

S/N	Year	Actual	Predicted
1	1979	160.3	168.04
2	1980	199.7	175.16
3	1981	121	197.57
4	1982	262	172.07
5	1983	254.4	225.46
6	1984	217.2	249.93
7	1985	259.8	245.18
8	1986	280.5	262.86
9	1987	294.1	281.96
10	1988	291.1	298.45
11	1989	257.9	305.7
12	1990	230.1	293.78
13	1991	253.7	274.35
14	1992	245.3	275.31
15	1993	237.4	271.83
16	1994	233.3	266.26
17	1995	218.7	261.39
18	1996	235.3	251.92
19	1997	236.8	254.8
20	1998	218.9	257.02
21	1999	191.8	249.71
22	2000	223.8	233.03
23	2001	241.9	239.42
24	2002	146.2	251.35
25	2003	196	212.29
26	2004	398	215.34
27	2005	182.3	312.63
28	2006	383.438	261.62
29	2007	494.01	330.07
30	2008	421.6	418.44
31	2009	428.954	430.61
32	2010	395.591	440.5
33	2011	426.37	429.89
34	2012	457.92	438.89
35	2013	518.7	458.57
36	2014	594.48	497.71

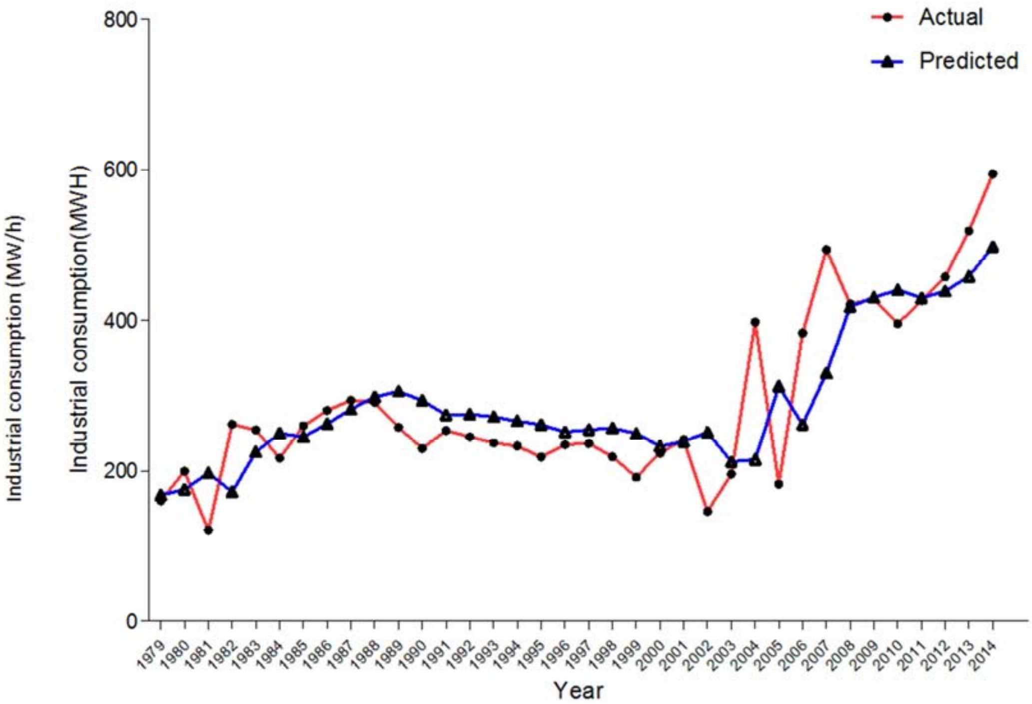

Figure 2. *Actual and predicted industrial electricity consumption in Nigeria between 1979-2014 using autoregressive moving average (ARMA) Model.*

3.3. Evaluation of the Prediction Performance of the Models

Table 5. *Comparison of the Prediction Performance of the Moving Average Model and Autoregressive Moving Average Model (ARMA) Model.*

Models	r^2(%)	RMSE
Moving Average	42.6	84.749
Autoregressive Moving Average (ARMA)	66.0	68.628

Table 5 reveals that the Autoregressive Moving Average (ARMA) model with r^2= 66.0% and RMSE = 68.628 gives better prediction performance than the Moving Average with r^2=42.6% and RMSE = 84.749. As such, the ARMA model is recommended for forecasting industrial electricity consumption in Nigeria. However, r^2 value of 66% is not particularly adequate for acceptable prediction accuracy. In that case, for better prediction accuracy, other models may need to be examined apart from the two models considered in this paper.

4. Conclusion

Moving Average Model and Autoregressive Moving Average Model (ARMA) are evaluated for their suitability in the prediction of the industrial electricity consumption in Nigeria. Industrial electricity consumption data from 1979-2014 is used to determine the model parameters and prediction performance in terms of RMSE and r^2 values. In all, ARMA model gives better prediction performance than the Moving Average model. However, the relatively low r^2 values for the two models shows that the models are not particularly adequate for prediction of the industrial electricity consumption in Nigeria. In that case, for better prediction accuracy, other models may need to be examined.

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