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Long-term Electricity Power Forecasting at PT PLN UP3 Kediri Using Trend and Monte Carlo Simulation Methods

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Abstract

Community consumption power in the use of electricity resources is growing very rapidly. This is because the power source is the main need for the community. Without electricity, daily needs cannot run smoothly. In various regions, especially Kediri, where the needs are changing, it is necessary to predict and provide electricity to meet the consumption needs of the people. There are many things that can be done to predict the need for electric power, one of which is forecasting. Forecasting methods that can be used include trend and Monte Carlo Simulation. The results of this study indicate that Monte Carlo simulations are better at predicting long-term electrical power requirements at ULP3 Kediri. Long-term electricity demand can be predicted with the equation: Yt =138691 + 6709 x t + 231 x t2. The results of the research can help PLN UP3 Kediri to provide electricity for consumers.

Keywords: *Long-term forecasting, Forecasting, Trend Linear, Quadratic Trend, Monte Carlo Simulation.*

Abstrak

Daya konsumsi masyarakat dalam penggunaan sumberdaya listrik berkembang sangat pesat. Hal ini dikarenakan sumber daya listrik merupakan kebutuhan utama bagi masyarakat. Tanpa adanya listrik kebutuhan sehari-hari tidak bisa berjalan dengan lancar. Di berbagai daerah khususnya Kediri yang kebutuhannya berubah-ubah, perlu memprediksi dan menyediakan listrik untuk memenuhi kebutuhan konsimsi masyarakatnya. Banyak hal yang dapat di lakukan untuk memprediksi kebutuhan daya listrik salah satunya dengan forecasting. Metode forecasting yang dapat digunakan antara lain trend dan Monte Carlo Simulation. Hasil dari penelitian ini menunjukkan simulasi Monte Carlo lebih baik dalam memprediksi kebutuhan daya listrik jangka panjang di ULP3 Kediri. Kebutuhan listrik selama jangka panjang dapat diprediksi dengan persamaan: Yt =138691 + 6709 x t + 231 x t2. Hasil penelitian dapat membantu PLN UP3 Kediri Untuk menyediakan kebutuhan listrik bagi konsumen.

Kata-kata kunci: *Peramalan Jangka Panjang, Forecasting, Trend Linear, Quadratic Trend, Monte Carlo Simulation*

1. Introduction

Electricity is a basic necessity for modern society in all walks of life. From those living in remote villages to those living in urban areas. Therefore, electrical energy is very important for the sustainability of human life. Electric power will affect national development. In terms of service, the electric power system should be able to meet the demand of society with prosperity and reliability. Prosperous means that the power system can provide prosperity to the whole society, and a reliable power system can satisfy customer service in terms of quality and quantity. The service can be well realized if the system design, system development, system implementation and maintenance of the power system are in accordance with the applicable electrical standards to support the electrical energy needs. Therefore, PLN has to design an additional supply of electricity capacity according to the needs of the community.

In electricity system reliability, power demand forecasting is needed to estimate how much electrical energy value needs to be generated to serve the load and distributed to the community. After carrying out field data analysis, it can estimate the future needs of the community. If the forecast is incorrect, there will be insufficient electrical power distributed to the community in an area. Therefore, forecasting electric power using the trend method and Monte Carlo simulation is expected to provide the best forecasting results.

The aim of this study is to forecast the demand for electricity for the community and the connected load at PLN UP3 Kediri using the trend method and Monte Carlo simulation.

2. Method

Conducted the study "Principles of Electricity Demand Forecasting: Part 1 Methodology". Forecasting is divided into 3 levels: short-term, medium-term, and long-term. Four models are available, viz: Artificial Neural Network, S-E, B&J and PEM models. [The study "Principles of Electric Demand Forecasting: Part 1 Methodology" [1]. Forecasting is divided into 3: short-term forecast, medium-term forecast and long-term forecast. Four models are available, namely Artificial Neural Network, S-E, B&J and PEM models. Conducted research entitled "Forecasting Water Needs Using Monte Carlo Simulation." The purpose of this research is to predict future water demand for management decision-making [2]. The simulation results show that the predicted value is consistent with the actual data. conducted a study, "Long-term forecasting of household sector electricity loads in East Java using trend projection and linear regression methods" [3]. Comparing these two methods will give you the best method. The data to be used are from the PLN Jatim 2020-2035 RUPTL website, and the population data are from the BPS Jatim website. The accuracy of the forecast is assessed using the Mean Absolute Percentage Error or MAPE.

Research conducted "Forecasting Long-Term Electric Energy Demand of the UID-Mamana Sector in East Java Using the Analytical Time Series Method: Quadratic Trend Projection and Linear Regression Based on Minitab V19 Software" [4]. This study examines the appropriate method for forecasting the long-term electricity demand of the domestic sector in UID East Java. Based on the research results comparing the MAPE value obtained by the quadratic trend analysis time series projection method and linear regression generated by Minitab v19 software, it is obtained when the quadratic trend analysis time series projection method has better forecasting accuracy for each parameter. When the number of customers and connected power parameters show a growth rate each year, while the sold energy parameter decreases in 2021 and increases again in 2022-2025. The results show that the proposed method outperforms the conventional method, namely using the Monte Carlo method has slightly better results [5]. Medium-term load forecasting using Taylor Interval Method and Monte Carlo Method, electricity data from 1991-2012. Demonstrates the effectiveness and practical value of the approach by comparing it with the results of the Monte Carlo simulation and the interval method [6].

As a new approach for more accurate electric load forecasting by combining several Monte Carlo and neural network training methods. Turkey's electric power data from 2011 to 2014 showed that the proposed approach could be applied to electric load forecasting and has a high potential to be used effectively in system dynamics modeling [7]. The correlation analysis (Monte Carlo method) and the principal comment analysis (PCA), power system data from 2004 to 2018. The results show that the correction model and the long-term forecast model, it is obvious that error of the correction model is smaller [8]. Applying the Monte Carlo method to the power system of the Kingdom of Bahrain over a five-year period by considering the maximum electrical load, power system data from 2000 to 2004 [9]. The prediction results showed a similarity between prediction data and simulation results [10]. Combination of Wavelet Neural Networks-Particle Swarm Optimisation (Wavelet-NNPSO) method to improve forecasting accuracy assuming Length of Training Data (LOTD) In this study, Monte Carlo simulation was used to randomly select the previous big data and calculate the objective function and the resulting supply and demand values at each step of the PSO algorithm, Electricity load data from 2002 to 2018 [11]. This research focuses on predicting electricity consumption using deep learning methods, namely Long Short-Term Memory (LSTM) and Gated Recurrent Unit (GRU) models, and calculating the computation time using the Monte Carlo experimental method, Electricity consumption data from 2005 to 2020.

Prediction of electric vehicle load charging. Using the proposed method conducted in Shenzhen City and the basic approach of forecasting research using the Monte Carlo method [12]. Sequential Monte Carlo describes time series with probabilistic distribution functions applied to past observations of load data, electric power load [13]. Monte Carlo method with SAIDI (System Average Interruption Duration Index) and SAIFI (System Average Interruption Frequency Index) indicators, distribution network data [14]. The Monte Carlo simulation approach provides the opportunity to develop knowledge and information on the variability associated with annual indices and one-year data of the transmission system [15]. The Monte Carlo method can perform short-term peak load forecasting using historical data from PT PLN (Persero) East Java. Historical electricity data from PT PLN East Java [16] [17] Monte Carlo method research mainly to estimate the impact of the uncertain nature of the FOR (Forced Outage Rate) of the generator; it aims to get the reliability value of a power system in Central Java and DIY, 150 KV network system data in Central Java & DIY [18]. A Bayesian approach with advantages in numerical inference, namely by using the Markov Chain Monte Carlo method, the entire generation system in NTT [19]. Markov with Monte Carlo prediction of the stochastic behavior of various sources of uncertainty in renewable energy microgrid design, time dependence, and modeling the relationship between various sources of uncertainty.

This research was conducted to predict the long-term electricity demand to be used as a consideration for PLN ULP Kediri in preparing electricity production. This research method combines the research conducted by Tuzunturk et al. (2015) [2], Afinda et al. (2020) [3] and Purnama (2021). The novelty lies in the research site, namely PLN ULP Kediri. In addition, the novelty also lies in the method used. Previous studies only used the trend method (linear trend and quadratic trend), while in this study, Monte Carlo simulation is added. The proposed method can illustrate the reliability of forecasting future installed electrical power demand. Previous research illustrates some weaknesses that need to be addressed. Therefore, it has been described on the research novelty originality map shown below.

The novelty of this research is to combine deterministic forecasting methods (linear trend, quadratic trend) & stochastic forecasting (Monte Carlo method) to get the best method for forecasting future electric power. Research flowchart is presented in Figure 1.

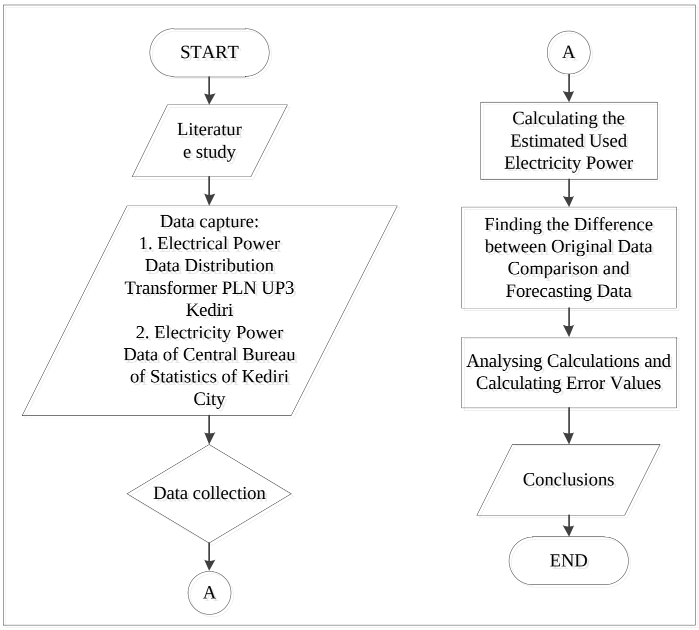

Figure 1. Research Flowchart

3. Results and Discussion

This chapter discusses the results of data forecasting at PT PLN (Persero) UP3 Kediri using the trend method and Monte Carlo simulation. The data discussed in this study is electricity load power data by looking for the level of accuracy of long-term electricity forecasting methods. Power data will be the basis of forecasting or prediction so that it will make a more accurate and reliable forecasting process in the future. Data on installed capacity, electricity generation and electricity sales at PLN UP3 Kediri for 2013 – 2021 is presented in Table 1.

Table 1. Total Installed Power, Electricity Production, And Electricity Sold at Pt. Pln (Persero) Up3 Kediri City, 2013 - 2021

Years	Power Installed (KW)	Electricity Production (KWh)	Sold Electricity (KWh)
2013	146843,00	341499990,92	313542525,00
2014	152474,00	322050178,84	297123495,00
2015	159677,00	327613475,08	300454318,00
2016	166048,00	348853767,31	319933790,00
2017	181922,00	343877153,31	319553576,00
2018	188831,00	365370793,12	334448245,00
2019	196431,00	367151749,02	334865762,00
2020	205136,00	370896756,35	339662883,00

Based on the **Table 1**, both installed capacity, electricity production and electricity sales always show a significant increase as the year progresses. Therefore, the forecasting method will use the trend method, both linear trend and quadratic trend.

3.1 Calculation of Linear Trend Forecasting Coefficient

The full content of the linear trend estimation equation is:

$$Y_t = \alpha + \beta t$$

The coefficients α and β are obtained using the Ordinary Least Square (OLS) estimation method. [The steps to obtain the estimates of α and β are as follows:

a. Find the estimated value of β with the formula:

$$\hat{\beta} = \frac{\sum(X_i - \bar{X})(Y_i - \bar{Y})}{\sum(X_i - \bar{X})^2}$$

Description:

X_i : indicates the i-th time period

$\bar{X}$: average time period of all observations

Y_i : power value at the i-th time

$\bar{Y}$: average power value of all observations

So that obtained:

$$\hat{\beta} = \frac{\sum(X_i - \bar{X})(Y_i - \bar{Y})}{\sum(X_i - \bar{X})^2}$$

$$= 540989 \div 60$$

$$= 9016.48333$$

b. Find the estimate of α with the formula:

$$\hat{\alpha} = \bar{Y} - \hat{\beta}\bar{X}$$

So that obtained:

$$\hat{\alpha} = 179542.6 - 9016.48333 \times 5$$

$$\hat{\alpha} = 134460.139$$

Based on the estimation results of α and β values, the linear trend estimation formula is obtained:

$$Y_t = \alpha + \beta t$$

3.2 Section Analysis of Trend Linear Forecasting Results

The Linear Trend method performs forecasting on data linearly. The results of forecasting electric power with a Linear Trend can be seen in **Table 2**.

Table 3. Installed Power Prediction Trend, Linear Forecasting Method

Years	Power Installed (KW)	Electricity Production (KWh)	Sold Electricity (KWh)	Difference (%)
2013	146.843,00	143.476,62	3.366,38	2,29
2014	152.474,00	152.493,11	-19,11	-0,01
2015	159.677,00	161.509,59	-1.832,59	-1,15
2016	166.048,00	170.526,07	-4.478,07	-2,70
2017	181.922,00	179.542,56	2.379,44	1,31
2018	188.831,00	188.559,04	271,96	0,14
2019	196.431,00	197.575,52	-1.144,52	-0,58
2020	205.136,00	206.592,01	-1.456,01	-0,71

The results of forecasting installed power using the linear trend method are quite good, with the difference to the actual values ranging from -2.70 percent to 2.29 percent. Some forecast points exceed the actual value, so the difference is negative. The plot between the actual value of installed power and its forecast value is shown in Figure 2.

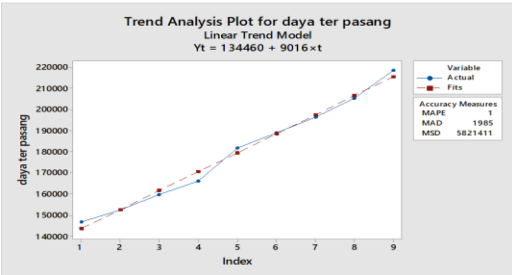

Figure 2. Plot of Actual Value with Predicted Value of Installed Power Linear Trend Method

In general, the equation to predict the value of installed power is:

$$Yt = 134460 + 9016 \times t$$

The index t represents time, with the base year being 2013 (t=1). The above equation can predict installed power over the long term. The predicted value of installed power for the next 10 years using the linear trend method is shown in Table 3.

Table 3. Prediction of Installed Power for the Next 10 Years Trend Linear Forecasting Method

Years	Power Prediction (KW)	Growth (%)
2022	224.620	4,18
2023	233.636	4,01
2024	242.652	3,86
2025	251.668	3,72
2026	260.684	3,58
2027	269.700	3,46
2028	278.716	3,34
2029	287.732	3,23

Table 3 shows the predicted value of installed power for the next 10 years using the linear trend method. The predicted value of installed power in 2031 is 305,764 KW, 2 times more than in the previous 19 years (2013). The average annual growth of electricity is 3.56 percent.

3.3 Calculation of Quadratic Trend Forecasting Coefficient

The equation for the linear trend to be estimated is as follows:

$$Y_t = \alpha + \beta_1 t + \beta_2 t^2$$

The coefficients α, β1 and β2 are obtained using the Ordinary Least Square (OLS) estimation method. The steps to obtain the estimates of α, β1 and β2 are:

a. Find the estimated value of β1 with the formula:

$$\hat{\beta}_1 = \frac{\sum x_2{}^2 \sum x_1 y - \sum x_1 x_2 \sum x_2 y}{\sum x_1^2 \sum x_2^2 - \left(\sum x_1 x_2\right)^2}$$

Where:

$$\sum x_1{}^2 = \sum x_1{}^2 - \frac{\left(\sum X_1\right)^2}{n}$$

$$\sum x_2{}^2 = \sum X_2{}^2 - \frac{\left(\sum X_2\right)^2}{n}$$

$$\sum x_1 y = \sum X_1 Y - \frac{\sum X_1 \sum Y}{n}$$

$$\sum x_2 y = \sum X_2 Y - \frac{\sum X_2 \sum Y}{n}$$

$$\sum x_1 x_2 = \sum x_1 x_2 - \frac{\sum x_1 \sum x_2}{n}$$

Description:

X1: Time (t)

X2: Square of time (t)

Y: Power values

Based on the above formula obtained :

$$\sum x_1 y = \sum x_1 y - \frac{\sum x_1 \sum y}{n} = 8620404 - \frac{45 \times 1615883}{9} = 540989$$

$$\sum x_2 y = \sum x_2 y - \frac{\sum x_2 \sum y}{n} = 56650590 - \frac{285 \times 1615883}{9} = 5480962$$

$$\sum x_1 x_2 = \sum x_1 x_2 - \frac{\sum x_1 \sum x_2}{n} = 2025 - \frac{45 \times 285}{9}$$

$$\sum x_1{}^2 = \sum x_1{}^2 - \frac{\left(\sum x_1\right)^2}{n} = 285 - \frac{45^2}{9} = 60$$

$$\sum x_2{}^2 = \sum x_2{}^2 - \frac{\left(\sum x_2\right)^2}{n} = 15333 - \frac{285^2}{9} = 6308$$

$$\hat{\beta}_1 = \frac{\sum x_2{}^2 \sum x_1 y - \sum x_1 x_2 \sum x_2 y}{\sum x_1{}^2 \sum x_2{}^2 - \left(\sum x_1 x_2\right)^2}$$

$$\hat{\beta}_1 = \frac{6308 \times 540989 - 600 \times 5480962}{60 \times 6308 - (600)^2}$$

$$\hat{\beta}_1 = 6708.962$$

b. Find the estimated value of β1 with the formula:

$$\sum x_1{}^2 = \sum x_1{}^2 - \frac{\left(\sum x_1\right)^2}{n}$$

$$\sum x_2{}^2 = \sum x_2{}^2 - \frac{\left(\sum x_2\right)^2}{n}$$

$$\sum x_1 y = \sum x_1 y - \frac{\sum x_1 \sum y}{n}$$

$$\sum x_2 y = \sum x_2 y - \frac{\sum x_2 \sum y}{n}$$

$$\sum x_1 x_2 = \sum x_1 x_2 - \frac{\sum x_1 \sum x_2}{n}$$

Description:

X1: Time (t)

X2: Square of time (t)

Y: Power values

c. Find the estimate of α with the formula:

$$\hat{\alpha} = \bar{Y} - \hat{\beta}_1 \bar{X}_1 - \hat{\beta}_2 \bar{X}_2$$

Based on the above formula obtained:

$$\hat{\alpha} = 179542.556 - 6708.962 \times 5 - 230.7522 \times 31.6667$$

$$\hat{\alpha} = 138690.595$$

Based on the results of estimating the values of α, β1 and β1, the quadratic trend estimation formula is obtained as follows:

$$Y_t = +t + t^2$$

3.4 Analysis of Quadratic Trend Forecasting Results

The quadratic trend method performs a forecast on data by considering both quadratic and linear trends. The results of the quadratic trend power forecast are shown in **Table 4**.

Table 4. Quadratic Trend Forecasting Method Installed Power Prediction

Years	Power Installed (KW)	Power Prediction (KW)	Difference
2013	146.843,00	145.630,31	1.212,69
2014	152.474,00	153.031,53	(557,53)
2015	159.677,00	160.894,25	(1.217,25)
2016	166.048,00	169.218,48	(3.170,48)
2017	181.922,00	178.004,21	3.917,79
2018	188.831,00	187.251,44	1.579,56
2019	196.431,00	196.960,18	(529,18)
2020	205.136,00	207.130,43	(1.994,43)

Table 4 shows the predicted value of installed power for the next 10 years using the quadratic trend method. The predicted value with the quadratic trend method is higher than the linear trend method. The predicted value of installed power in 2031 with a quadratic trend is 349,553 KW, which is almost 2.5 times higher than in the previous 19 years (2013). The average annual growth of electric power is 4.85%.

3.5 Monte Carlo Simulation Calculation

In this study, Monte Carlo simulation was performed on the growth data of the installed electricity demand at PLN UP3 Kediri. The first step before the Monte Carlo simulation is to calculate the growth data for each year, as shown in Table 5.

Table 5. Growth of Installed Electricity Power at PLN UP3 Kediri 2014-2021

Years	Power	Growth	Rounding
2014	152474	0.038347	0.04
2015	159677	0.047241	0.05
2016	166048	0.039899	0.04
2017	181922	0.095599	0.1
2018	188831	0.037978	0.04
2019	196431	0.040248	0.05
2020	205136	0.044316	0.05
2021	218521	0.065249	0.07

Next, a Monte Carlo simulation is carried out with the steps:

a. Calculating the probability distribution can be seen in **Table 6**.

Table 6. Calculating the Probability Distribution Monte Carlo Simulation

Growth	Frequency	Probability
0,04	3	0,375
0,05	3	0,375
0,07	1	0,125
0,1	1	0,125
Total	8	1

b. Calculating the cumulative probability distribution can be seen in **Table 7**.

Table 7. Cumulative Probability Distribution Monte Carlo Simulation

Growth	Frequency	Probability	Cummulative
0,04	3	0,375	0,375
0,05	3	0,375	0,75
0,07	1	0,125	0,875
0,1	1	0,125	1
Total	8	1	

c. Calculating the random interval can be seen in **Table 8**.

Table 8. Calculating the Random Interval

Probability	Cummulative	Cumx100	Random Interval
0,375	0.375	37,5	1-37,5
0,375	0.75	75	37,6-75
0,125	0,875	87,5	75,1-87,5
0,125	1	100	87,6-100
1			

d. Calculating the random number

1) Random number of evaluations can be seen in Table 9.

Table 9. Random Number of Evaluations

Years	AR_2	AR_2	Average Rand
2013	54	2	28
2014	2	5	3,5
2015	45	14	29,5
2016	52	1	26,5
2017	91	75	83
2018	44	96	70
2019	25	14	19,5
2020	25	85	55
2021	79	22	50,5

2) Random Forecasting Number (AR) can be seen in **Table 10**.

Table 10. Random Forecasting Number (AR)

Years	AR_2	AR_2	Average Rand
2022	36	81	58,5
2023	80	49	64,5
2024	24	80	52
2025	61	1	31
2026	4	18	11
2027	87	77	82
2028	60	78	69
2029	12	21	16,5
2030	91	74	82,5
2031	91	83	87

e. Simulation Forecasting

1) Evaluation of Electricity Power Growth Forecasting can be seen in **Table 11**.

Table 11. Evaluation of Electricity Power Growth Forecasting

Years	AR	Estimated Growth
2013	54	2
2014	2	5
2015	45	14
2016	52	1
2017	91	75
2018	44	96
2019	25	14
2020	25	85
2021	79	22

2) Electricity Power Growth Forecasting can be seen in **Table 12.**

Table 12. Electricity Power Growth Forecasting

Years	AR	Estimated Growth
2022	58,5	0,05
2023	64,5	0,05
2024	52,0	0,05
2025	31,0	0,04
2026	11,0	0,04
2027	82,0	0,07
2028	69,0	0,05
2029	16,5	0,04
2030	82,5	0,07
2031	87,0	0,07

After knowing the predicted value of electric power growth, then find the value of electric power based on the estimated growth.

f. Evaluation of Electrical Power Estimation can be seen in **Table 13**.

Table 13. Evaluation of Electrical Power Estimation

Years	Y	Estimated Growth	Y Estimated
2013	146.843	0,04	
2014	152.474	0,04	152.716,72
2015	159.677	0,04	158.572,96
2016	166.048	0,04	166.064,08
2017	181.922	0,07	177.671,36
2018	188.831	0,05	191.018,10
2019	196.431	0,04	196.384,24
2020	205.136	0,05	206.252,55
2021	218.521	0,05	215.392,80

g. Electricity Power Forcasting can be seen in **Table 14**.

Table 14. Electricity Power Forcasting

Years	Y	Estimated Growth	Y Estimated
2021	218521		
2022	229,447,05	0,05	229.447,05
2023	240,919,40	0,05	240.919,40
2024	252,965,37	0,05	252.965,37
2025	263,083,99	0,04	263.083,99
2026	273,607,35	0,04	273.607,35
2027	292,759,86	0,07	292.759,86
2028	307,397.85	0.05	307.397,85
2029	319,693.77	0.04	319.693,77
2030	342,072.33	0.07	342.072,33
2031	366,017.40	0.07	366.017,40

3.6 Analysis of Monte Carlo Results

Monte Carlo simulation makes predictions based on probabilities and random numbers. The forecasting results with Monte Carlo simulation can be seen in **Table 15**.

Table 15. Monte Carlo Simulation Results

Years	Power Installed (KW)	Predictions (KW)	Difference (KW)	Difference (%)
2013	146.843			
2014	152.474	152.716,72	-242,72	-0,16
2015	159.677	158.572,96	1.104,04	0,69
2016	166.048	166.064,08	-16,08	-0,01
2017	181.922	177.671,36	4.250,64	2,34
2018	188.831	191.018,10	-2.187,10	-1,16
2019	196.431	196.384,24	46,76	0,02
2020	205.136	206.252,55	-1.116,55	-0,54
2021	218.521	215.392,80	3.128,20	1,43

The results of forecasting installed capacity using the quadratic trend method are quite good, with the difference from the actual value ranging from -1.16% to 1.43%, with a narrower range than the linear and quadratic trend methods. Some forecast points are above the actual, so the difference is negative.

The following table compares the power growth forecasts using linear, quadratic and Monte Carlo simulation methods can be seen in **Table 16**.

Table 16. *Forecasting Electricity Power Growth with the Three Methods*

Years	Growth (%)		
	Linear	Quadratic	Monte Carlo
2022	4,18	5,11	5
2023	4,01	5,05	5
2024	3,86	5,00	5
2025	3,72	4,94	4
2026	3,58	4,89	4
2027	3,46	4,82	7
2028	3,34	4,76	5
2029	3,23	4,70	4
2030	3,13	4,63	7
2031	3,04	4,56	7

Based on the growth comparison in the table above, the linear method has the lowest average power growth, while the Monte Carlo simulation has the highest average power growth. The variation in power growth with the linear method ranges from 3.04 to 4.18 percent, power growth with the quadratic method ranges from 4.56 to 5.11 percent, and power growth with the Monte Carlo simulation ranges from 4 to 7 percent.

3.7 Forecasting accuracy

The level of forecasting accuracy in time series can be seen with 3 (three) measures, namely Mean Absolute Deviation (MAD), Mean Square Deviation (MSD) and Mean Absolute Percentage Error (MAPE). The best method is the one that gives the lowest MAD, MSD and MAPE values. The results of the three indicators, both Linear Trend and Quadratic Trend methods, are shown in **Table 17**.

Table 17. The Measure of Forecasting Accuracy

Size	Trend Linear	Quadratic Trend	Simulasi Monte Carlo
MAD	1.985	1.660	1.511
MSD	5.821.411	3.999.195	4.395.491
MAPE	1,136	0,938	0,794

Based on accuracy measures, the Monte Carlo simulation method produces smaller MAD and MAPE indicator values than the linear trend and quadratic trend methods. At the same time, the MSD of the quadratic trend method is the smallest among the linear movement and Monte Carlo simulation methods. Thus, it can be concluded that the Monte Carlo simulation method is better than the linear trend and quadratic trend methods in predicting the long-term installed power in PLN UP3 Kediri. However, the accuracy of the Monte Carlo prediction value depends on the random numbers obtained, which can vary between researchers and between times, so the use of the trend method can be considered.

The accuracy of the long-term electricity demand forecast is very important for PLN. The accuracy of the forecast also allows PLN to estimate how much electricity should be produced accurately and to anticipate the shortage of installed capacity well in advance. Based on the MAD and MAPE indicators, the Monte Carlo simulation method is better at forecasting long-term electricity demand. However, based on the MSD indicator, the quadratic trend method is the best.

Previous research conducted by Purnama (2021) used the quadratic trend method better than the linear trend to predict the long-term electricity demand of the household sector in East Java UID. The prediction results in Purnama's research (2021) are very close to the actual value: the MAD value of 52.12, MSD of 3,884.45 and MAPE of 0.69. In this study, the MAD is 1,660 using the same method, the MSD is 3,999,195, and the MAPE is 0.938.

This research shows that Monte Carlo simulation is better than a linear trend and quadratic trend method to predict the amount of installed power at PLN UP3 Kediri. Afinda et al. (2020) carried out predictions using 3 (three) methods, namely: linear trend, quadratic trend and exponential trend. The results of Afinda et al.'s (2020) research show that the quadratic trend method is the best among the three. There are few Monte Carlo simulation methods for electricity forecasting, so comparisons with this research cannot be used. Tuzunturk et al. (2015) conducted a Monte Carlo simulation to forecast long-term water demand and found that the simulation was consistent with the actual. The Monte Carlo simulation method is not based on modeling but on random number simulation, so that it may differ between researchers and periods.

4. Conclusion

The results obtained from the MAD and MAPE Monte Carlo simulation method is better. In contrast, MSD quadratic trend method is better, so it can be concluded that the Monte Carlo simulation method is better at predicting long-term electricity demand in UP3 Kediri. Of course, considering the quadratic trend method will be better for long-term forecasts. Using the quadratic trend method, long-term electricity demand can be predicted using the equation: $Y_t = 138691 + 6709\ x\ t + 231\ x\ t^2$

By 2031, the electricity demand will be 349,553 KW, with an average annual growth rate of 4.85 percent. PLN UP3 Kediri will use the results of this study to estimate the long-term power demand in the Kediri area so that PLN management can also prepare long-term power supply estimates.

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