Peak Load Forecasting Methods of Sulbagsel Electrical Systems

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Abstract. This research is an ex post facto study using a descriptive approach and an exploratory nature which aims to determine the peak load growth from 2019 to 2023 and the appropriate peak load forecasting method is used. Data collection techniques are carried out by using observation and documentation to obtain data and information about this research by recording and observing documents related to research. The results showed that the average peak load growth of Sulbagsel electrical system from 2019 to 2023 for the six peak load forecasting methods used, namely 1.19 for the demand forecast (DF) method with an average percentage level of confidence in the peak load forecasting results of 97.97%, for the linear regression method of 1.21 with an average percentage of the confidence level of the peak load forecasting results of 99.39%, the quadratic regression method of 0.99 with an average percentage of the confidence level of the peak load forecasting results of 97.27%, the single moving average method (SMA) of 1.12 with an average percentage of the confidence level of the peak load forecasting results of 98.14%, the double moving average (DMA) method of 1.17 with an average percentage of the confidence level of the peak load forecasting results of 97.55%, and using the load growth average method (LGA) of 1.39 with an average percentage level at the confidence of the peak load forecasting results of 103.5%.

Keywords: Sulbagsel electrical system, load forecasting method

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INTRODUCTION

The electrical energy used by the community today has become one of the main or primary needs. Along with the times today, which have entered the millennium where the use of technology that has dominated in every aspect of people's lives, of course, will be directly proportional to the need for the use of electrical energy. This is because the electronic equipment used by the community requires electrical energy as an energy source to turn on these electronic equipment. Because electrical energy has become a primary need, of course it must be fulfilled at any time. In this case, it requires a distribution system continuously from the power plant to the load centers. The ideal of a reliable electrical system is that it is able to meet daily and sustainable electrical energy needs and is able to prevent and eliminate disturbances as quickly as possible (Saadat, 1999).

The installed power capacity of the power plant needs to be maximized in line with the load growth which is increasing from year to year, especially in the electricity system of Southern Sulawesi (Sulbagsel). Power plant operational planning is based on supply and production theory. Inventory policies depend on forecasting current and future resource needs and prices. Forecasting is an important component of production management when finding optimal manufacturing policies. Forecasting is an essential process of any successful company, especially when it is production oriented or trade oriented. Forecasting is often associated in operations research with inventory management problems. Predicting future events and conditions is called forecasting, and the act of making those predictions is called forecasting.

Forecasting is a key element of decision making (Karl et al., 2021; Luo & Oyedele, 2021; Savun-Hekimoğlu et al., 2021). Its purpose is to reduce risk in decision making and reduce unexpected profits or costs. In general, the power system demand forecast can be categorized into long-term, medium-term, and short-term functions. Long-term demand forecasts typically cover the next 1 to 10 years in annual terms, and are explicitly intended for the study of long-term capital investment.

Intermediate forecasting concept is also used for scheduling maintenance and fuel for several years each month. Short-term forecasting requires knowledge of needs from 1 hour to several weeks. Information derived from short-term demand forecasting is very important for the system because operations in terms of short-term unit maintenance work, scheduling of weekly requests, each generating unit, and economical and safe power system operations (Wood et al, 2014).

Forecasting is an essential component of all operational functions, including scheduling maintenance of transmissions, scheduling of unit outages for maintenance, recycling of nuclear fuel

LITERATURE STUDY

Demand Model

Demand is the desire of consumers to buy goods at various price levels during a certain period of time. In short, demand is the number of goods demanded in a particular market at a certain price level at a certain level of income and within a certain period. In essence, consumer demand for a type of commodity reflects the balance position of consumers who have considered various goals to achieve maximum utility with the amount of income available. There are two steps for modeling demand, namely deterministic and stochastic analysis. Deterministic analysis is to find the slowest change components, such as annual demand growth, seasonal variations, weather variations, etc. Deterministic is to analyze data using some type of analysis such as curve fitting optimization (regression) analysis or frequency identification (spectrum) analysis. Stochastic components are found using a time series analysis approach, as pioneered by Box and Jenkins.

Forecast Error

All forecasting situations involve some degree of uncertainty that makes mistakes unavoidable.

The forecast error for a given forecast $\widehat{X_t}$ with respect to the actual value X_t is shown in equation (1).

$$|e_t| = \left|X_t - \hat{X}_t\right| \tag{1}$$

Therefore, we can define the mean absolute deviation (MAD) as in equation (2).

$$MAD = \frac{\sum_{t=1}^{n}|e_t|}{n} = \frac{\sum_{t=1}^{n}|X_t - \hat{X}_t|}{n} \tag{2}$$

or another method using the square average error equation (MSE) which is defined as in equation (3).

$$MSE = \frac{\sum_{t=1}^{n} e_t^2}{n} = \frac{\sum_{t=1}^{n}(X_t - \hat{X}_t)^2}{n} \tag{3}$$

Time Series

A time series is defined as a sequential series of data measured over time, such as peak demand per hour, daily, or weekly. The basic idea of forecasting is to construct a pattern that matches the available data as accurately as possible, then find the predicted value with respect to time using a defined model. In general, time series is often described as having the following components:

$$X_t = T_t + S_t + R_t,\ \ t=....-1,0,1,2,..... \tag{4}$$

Where, T_t is the trend term, St is the seasonal term, and R_t is the irregular or random component (Wood et al, 2014).

Auto Regresive (AR)

In this model, the Xt value of the time series is expressed linearly in terms of the previous values X_{t-1}, X_{t-2}, ... and the white noise series $(\mathcal{E}_t)$ with zero mean and variance σ^2.

$$X_t = \varphi_1 X_{t-1} - \varphi_2 X_{t-2} + \ldots.. \varphi_p X_{t-p} + \mathcal{E}_t \tag{5}$$

Moving Average (MA)

In the MA process, the value of the time series X_t is expressed linearly in terms of the current and previous values of the white noise series. This noise series is constructed from forecast errors or residues when demand observations are available. The sequence of this process depends on the longest noise value X_t which undergoes regression. This model can be written as:

$$X_t = \eta_t - \theta_1 \eta_{t-1} - \theta_2 \eta_{t-2} - \ldots\ldots \theta_q \eta_{t-q} \qquad (6)$$

Linear Regression Method

This method assumes that demand is influenced by several factors such as high and low temperatures, weather conditions, and economic growth, etc. This relationship can be stated as follows:

$$y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots\ldots + \beta_n X_n + \eta \qquad (7)$$

where y is demand, X_i is the factor affecting β_i is the regression parameter against X_i and η is the error (Wood et al, 2014).

RESEARCH METHODS

Types of Research

This research is an ex post facto study which is described quantitatively using a descriptive approach and is exploratory in nature which aims to describe the situation and conditions of the object under study.

Research Variable

Variabel The variable used in the study of the annual peak load.

Operational Definition of a Variable

The annual peak load is the amount of electrical power generated by the Sulbagsel electricity system.

Data Collection Technique

Data collection techniques used in this study are observation and documentation. The data used in this study are secondary data on the annual peak load of the Sulbagsel electricity system from 2016 to 2018 as shown in Table 1 to Table 3 (PT PLN Persero, 2018).

Table 1. The peak load of Sulbagsel electricity system in 2016

No	Month	Peak Load (MW)
1	January	972
2	February	959.6
3	March	976.9
4	April	947
5	May	996
6	June	967.7
7	July	941.7
8	August	1069.6

9	September	1088.9
10	October	1080.4
11	November	1094.6
12	December	1069.7

Table 2. The peak load of Sulbagsel electricity system in 2017

No	Month	Peak Load (MW)
1	January	1038.5
2	February	1058.8
3	March	1027.5
4	April	1065.2
5	May	1039.1
6	June	1009.3
7	July	1023.4
8	August	1015.8
9	September	1105.4
10	October	1118.4
11	November	1088.2
12	December	1100.4

Table 3. The peak load of Sulbagsel electricity system in 2018

No	Month	Peak Load (MW)
1	January	1104.9
2	February	1086
3	March	1048.6
4	April	1102.8
5	May	1097.5
6	June	1070.8
7	July	1111.4
8	August	1138.6
9	September	1121.9
10	October	1119.7
11	November	1140.7
12	December	1169.3

Data Analysis Techniques

The data analysis technique used in this research is to forecast the peak load of the Sulbagsel electricity system in 2019-2023, namely by using 6 peak load forecasting methods, namely the demand forecast method, linear regression, quadratic regression, single moving average (SMA), double moving average (DMA), and load growth average (LGA).

RESULTS AND DISCUSSION

Description of Sulawesi Electrical System

The Sulawesi electricity system before the entry of the Kendari electricity system which has interconnected with the South Sulawesi electricity system is divided into (PT PLN Persero, 2018):

1. The electricity system of Southern Sulawesi (Sulbagsel)
2. The electricity system of North Sulawesi Central Gorontalo (Sulutenggo), and
3. Kendari electrical system

The electricity System of Southern Sulawesi (Sulbagsel)

The electricity system of Southern Sulawesi (Sulbagsel) is currently an interconnection system that connects Makassar with other cities in South Sulawesi Province to the capital city of Central Sulawesi Province, namely Palu. The Sulbagsel system is operated by the Sulselrabar Load Management Unit based in Makassar.

Sulutenggo Electrical System

The operation of the Suluttenggo system electric power system is divided into 2 (two) separate subsystems, namely the North Sulawesi-Gorontalo (SulutGo) and Central Sulawesi (Palapas) subsystems, which are an interconnection system between the Minahasa, Kotamobagu, and Gorontalo areas. The North Sulawesi subsystem covers the Provinces of North Sulawesi and Gorontalo. Palapas subsystem covers Central Sulawesi Province.

Currently, the Kendari electricity system has been interconnected with the South Sulawesi electricity system. Meanwhile, the Suluttenggo electricity system changed its name to the North Sulawesi electricity system.

RESEARCH RESULTS AND DISCUSSION

Demand Forecast Method (DF)

The results of the peak load forecasting of Sulbagsel electricity system for the medium term five years from 2019-2023 using the demand forecast method are shown in Table 4 and the peak load forecast curve is shown in Figure 1.

Table 4. Forecast results for the peak load of the Sulbagsel electricity system in 2019-2023

No	Month	Year	Peak Load (MW)
1	January	2019	1143.9
2	February		1147.9
3	March		1150.7
4	April		1154.0
5	May		1155.1
6	June		1158.3
7	July		1159.3
8	August		1158.0
9	September		1163.2
10	October		1169.7
11	November		1176.1
12	December		1183.6
13	January	2020	1190.1
14	February		1194.8
15	March		1200.6
16	April		1204.5
17	May		1210.3

18	June		1214.5
19	July		1216.6
20	August		1218.7
21	September		1219.7
22	October		1225.3
23	November		1231.7
24	December		1236.5
25	January	2021	1241.9
26	February		1247.5
27	March		1252.0
28	April		1253.9
29	May		1258.3
30	June		1262.2
31	July		1264.1
32	August		1267.8
33	September		1272.8
34	October		1276.7
35	November		1280.2
36	December		1284.7
37	January	2022	1290.6
38	February		1295.2
39	March		1299.8
40	April		1304.4
41	May		1309.0
42	June		1313.5
43	July		1317.9
44	August		1322.1
45	September		1326.0
46	October		1329.8
47	November		1333.6
48	December		1337.6
49	January	2023	1341.6
50	February		1345.8
51	March		1350.0
52	April		1354.2
53	May		1358.5
54	June		1362.9
55	July		1367.4
56	August		1371.7
57	September		1375.9
58	October		1380.0
59	November		1384.1
60	December		1388.3

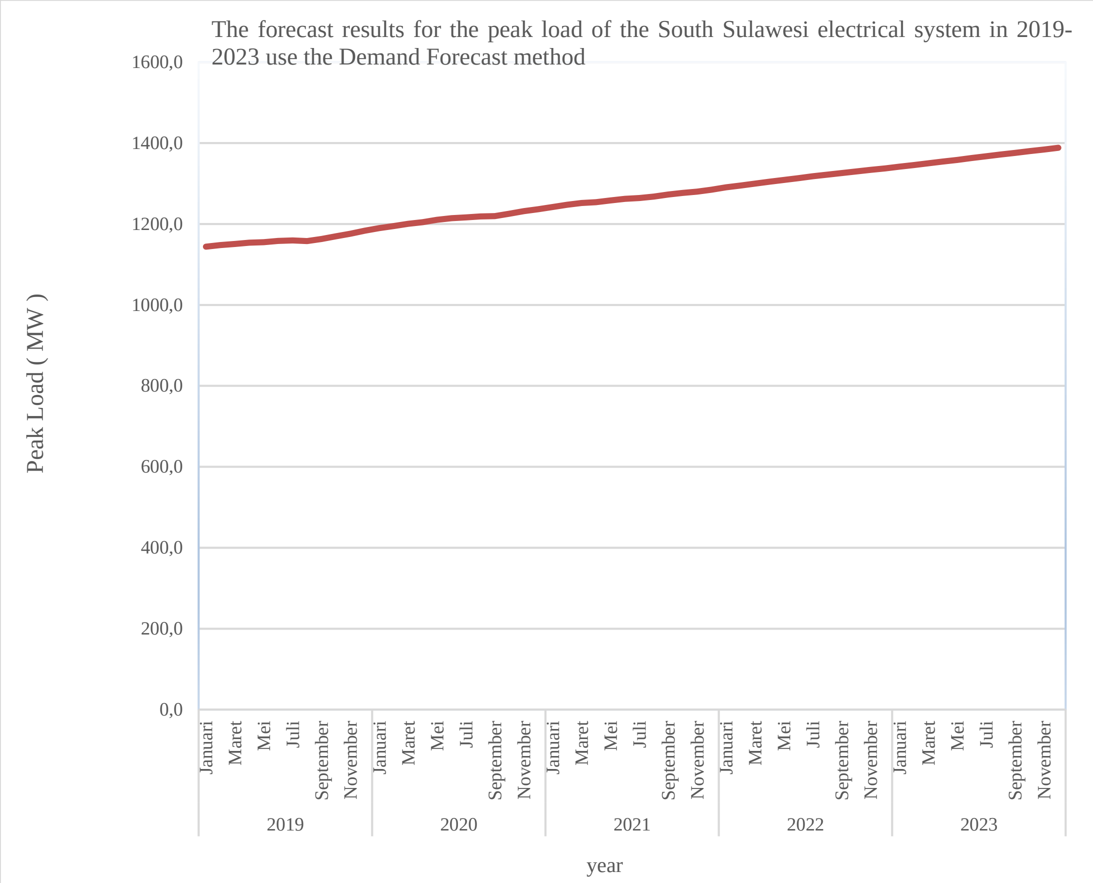

Figure 1. The peak load forecast curve for Sulbagsel electricity system in 2019-2023 uses the demand forecast method

Table 4 shows that the average load growth for forecasting the peak load of the Sulbagsel electricity system from 2019 to 2023 using the demand forecast method is 1.19. Meanwhile, the average percentage level of confidence in the results of forecasting peak loads based on real peak loads in 2019 is 97.97%.

Linear Regression Method

The results of the peak load forecasting of Sulbagsel electricity system for the medium term five years from 2019-2023 using the demand forecast method are shown in Table 5 and the peak load forecast curve is shown in Figure 2.

Table 5. Forecast results for the peak load of the Sulbagsel electricity system in 2019-2023

No	Month	Year	Peak Load (MW)
1	January	2019	1143.9
2	February		1148.4
3	March		1152.9
4	April		1157.5
5	May		1162.0
6	June		1166.5
7	July		1171.0
8	August		1175.6

9	September		1180.1
10	October		1184.6
11	November		1189.1
12	December		1193.7
13	January	2020	1198.2
14	February		1202.7
15	March		1207.2
16	April		1211.8
17	May		1216.3
18	June		1220.8
19	July		1225.3
20	August		1229.9
21	September		1234.4
22	October		1238.9
23	November		1243.4
24	December		1248.0
25	January	2021	1252.5
26	February		1257.0
27	March		1261.5
28	April		1266.1
29	May		1270.6
30	June		1275.1
31	July		1279.6
32	August		1284.2
33	September		1288.7
34	October		1293.2
35	November		1297.7
36	December		1302.3
37	January	2022	1306.8
38	February		1311.3
39	March		1315.8
40	April		1320.4
41	May		1324.9
42	June		1329.4
43	July		1333.9
44	August		1338.5
45	September		1343.0
46	October		1347.5
47	November		1352.0
48	December		1356.6
49	January	2023	1361.1
50	February		1365.6
51	March		1370.1
52	April		1374.7
53	May		1379.2
54	June		1383.7
55	July		1388.2
56	August		1392.8

57	September	1397.3
58	October	1401.8
59	November	1406.3
60	December	1410.9

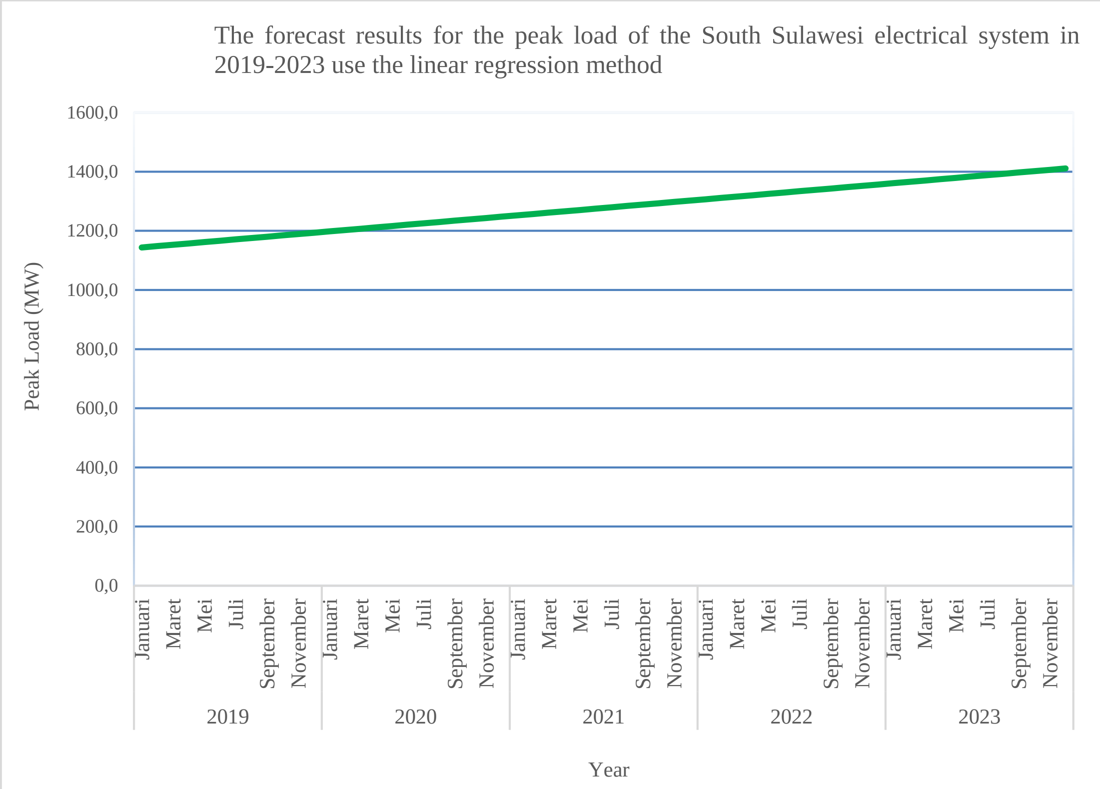

Figure 2. The peak load forecast curve for Sulbagsel electricity system in 2019-2023 uses the linear regression method

Table 5 shows that the average load growth for forecasting the peak load of the Sulbagsel electricity system from 2019 to 2023 using the linear regression method is 1.21. Meanwhile, the average percentage level of confidence in the results of forecasting peak loads based on real peak loads in 2019 is 99.39%.

Quadratic Regression Method

The results of the peak load forecasting of Sulbagsel electricity system for the medium term five years from 2019-2023 using the demand forecast method are shown in Table 6 and the peak load forecast curve is shown in Figure 3.

Table 6. Forecast results for the peak load of the Sulbagsel electricity system in 2019-2023

No	Month	Year	Peak Load (MW)
1	January	2019	1133.9
2	February		1136.8
3	March		1139.7
4	April		1142.4

5	May		1145.1
6	June		1147.6
7	July		1150.1
8	August		1152.5
9	September		1154.8
10	October		1157.1
11	November		1159.2
12	December		1161.3
13	January	2020	1163.2
14	February		1165.1
15	March		1166.9
16	April		1168.7
17	May		1170.3
18	June		1171.8
19	July		1173.3
20	August		1174.7
21	September		1175.9
22	October		1177.2
23	November		1178.3
24	December		1179.4
25	January	2021	1180.3
26	February		1181.2
27	March		1181.9
28	April		1182.7
29	May		1183.3
30	June		1183.8
31	July		1184.3
32	August		1184.6
33	September		1184.9
34	October		1185.09
35	November		1185.19
36	December		1185.21
37	January	2022	1185.15
38	February		1185.0
39	March		1184.8
40	April		1184.4
41	May		1184.0
42	June		1183.6
43	July		1182.9
44	August		1182.3
45	September		1181.6
46	October		1180.7
47	November		1179.8
48	December		1178.8

49	January	2023	1177.7
50	February		1176.6
51	March		1175.3
52	April		1173.9
53	May		1172.6
54	June		1171.1
55	July		1169.5
56	August		1167.8
57	September		1166.0
58	October		1164.2
59	November		1162.2
60	December		1160.2

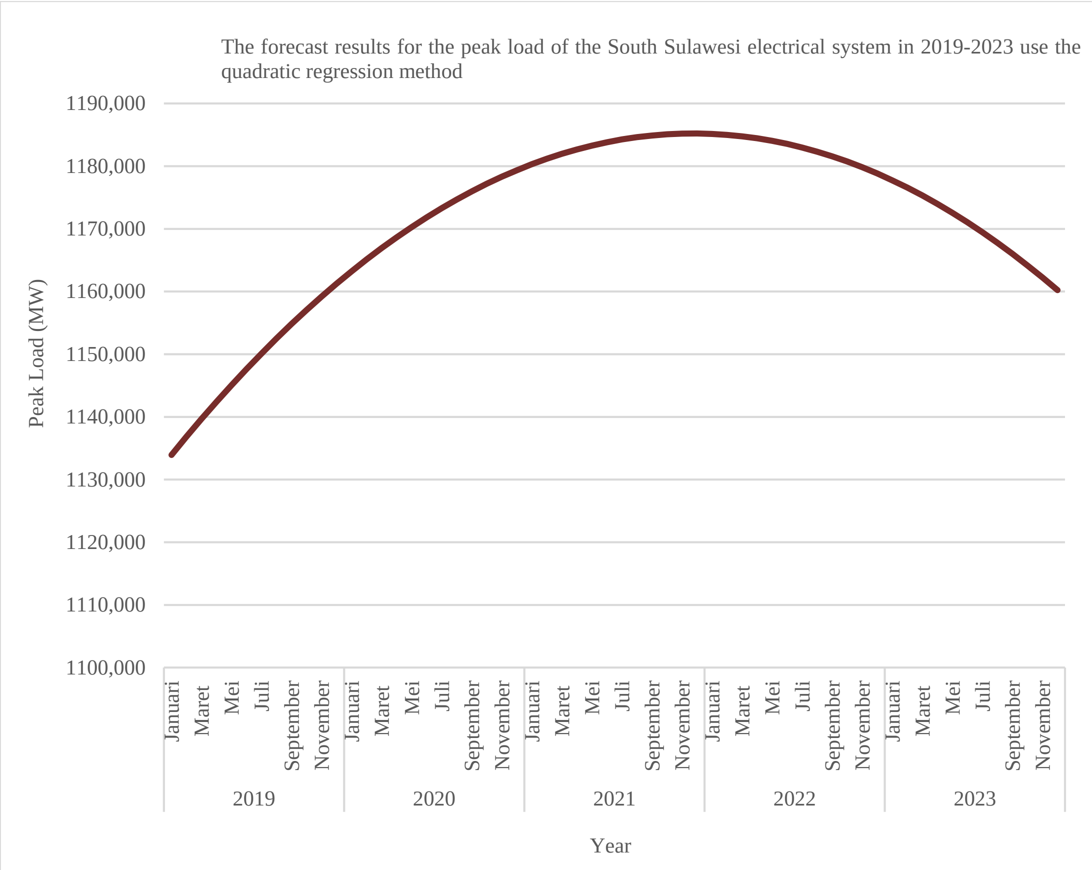

Figure 3. The peak load forecast curve for Sulbagsel electricity system in 2019-2023 uses the quadratic regression method

Table 6 shows that the average load growth for forecasting the peak load of Sulbagsel electricity system from 2019 to 2023 using the quadratic regression method is 0.99. Meanwhile, the average percentage level of confidence in the results of forecasting peak loads based on real peak loads in 2019 is 97.27%.

Single Moving Average Method (SMA)

The results of the peak load forecasting of Sulbagsel electricity system for the medium term five years from 2019-2023 using the demand forecast method are shown in Table 7 and the peak load forecast curve is shown in Figure 4.

Table 7. Forecast results for the peak load of the Sulbagsel electricity system in 2019-2023

No	Month	Year	Peak Load (MW)
1	January	2019	1143.2
2	February		1145.9
3	March		1148.7
4	April		1151.5
5	May		1154.3
6	June		1157.0
7	July		1159.8
8	August		1162.5
9	September		1165.3
10	October		1168.0
11	November		1170.8
12	December		1173.5
13	January	2020	1176.3
14	February		1179.0
15	March		1181.8
16	April		1184.6
17	May		1187.3
18	June		1190.1
19	July		1192.8
20	August		1195.6
21	September		1198.3
22	October		1201.1
23	November		1203.8
24	December		1206.6
25	January	2021	1209.4
26	February		1212.1
27	March		1214.9
28	April		1217.6
29	May		1220.4
30	June		1223.1
31	July		1225.9
32	August		1228.6
33	September		1231.4
34	October		1234.1
35	November		1236.9
36	December		1239.7
37	January	2022	1242.4
38	February		1245.2
39	March		1247.9

40	April		1250.7
41	May		1253.4
42	June		1256.2
43	July		1258.9
44	August		1261.7
45	September		1264.4
46	October		1267.2
47	November		1269.9
48	December		1272.7
49	January	2023	1275.5
50	February		1278.2
51	March		1280.9
52	April		1283.7
53	May		1286.5
54	June		1289.2
55	July		1291.9
56	August		1294.7
57	September		1297.5
58	October		1300.3
59	November		1303.0
60	December		1305.8

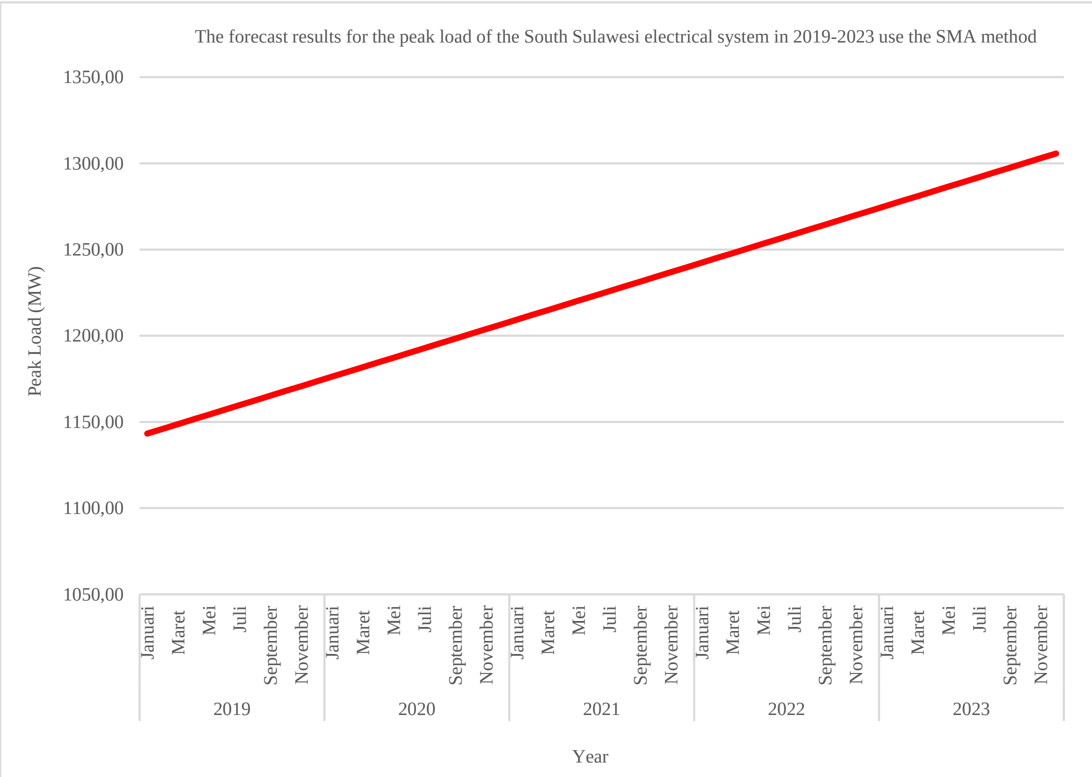

Figure 4. The peak load forecast curve for Sulbagsel electricity system in 2019-2023 uses the SMA method

Table 7 shows that the average load growth for forecasting the peak load of the Sulbagsel electricity system from 2019 to 2023 using the Single Moving Average (SMA) method is 1.12. Meanwhile, the average percentage level of confidence in the results of forecasting peak loads based on real peak loads in 2019 is 98.14%.

Double Moving Average Method (DMA)

The results of the peak load forecasting of Sulbagsel electricity system for the medium term five years from 2019-2023 using the demand forecast method are shown in Table 8 and the peak load forecast curve is shown in Figure 5.

Table 8. Forecast results for the peak load of the Sulbagsel electricity system in 2019-2023

No	Month	Year	Peak Load (MW)
1	January	2019	1126.0
2	February		1130.1
3	March		1134.1
4	April		1138.1
5	May		1142.1
6	June		1146.1
7	July		1150.1
8	August		1154.2
9	September		1158.2
10	October		1162.2
11	November		1166.2
12	December		1170.2
13	January	2020	1174.2
14	February		1178.3
15	March		1182.3
16	April		1186.3
17	May		1190.3
18	June		1194.3
19	July		1198.3
20	August		1202.4
21	September		1206.4
22	October		1210.4
23	November		1214.4
24	December		1218.4
25	January	2021	1222.4
26	February		1226.5
27	March		1230.5
28	April		1234.5
29	May		1238.5
30	June		1242.5
31	July		1246.5
32	August		1250.6
33	September		1254.6

34	October		1258.6
35	November		1262.6
36	December		1266.6
37	January	2022	1270.7
38	February		1274.7
39	March		1278.7
40	April		1282.7
41	May		1286.7
42	June		1290.7
43	July		1294.8
44	August		1298.8
45	September		1302.8
46	October		1306.8
47	November		1310.8
48	December		1314.8
49	January	2023	1318.9
50	February		1322.9
51	March		1326.9
52	April		1330.9
53	May		1334.9
54	June		1338.9
55	July		1342.9
56	August		1346.9
57	September		1350.9
58	October		1355.0
59	November		1359.0
60	December		1363.0

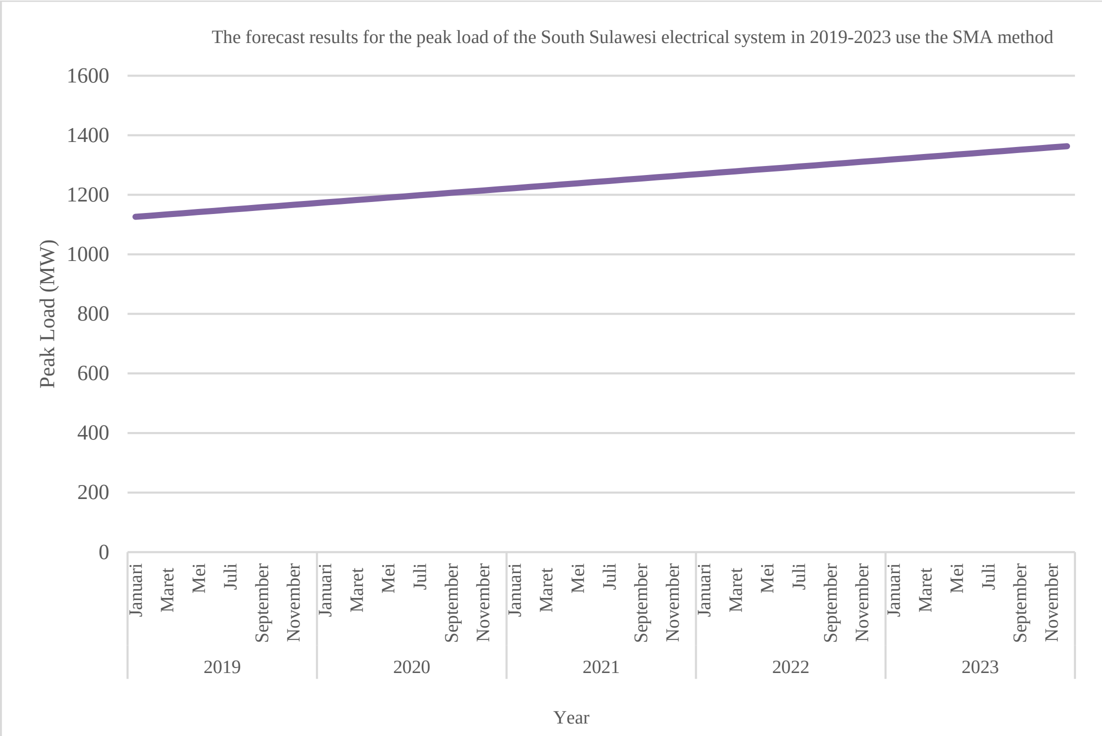

Figure 5. The peak load forecast curve for Sulbagsel electricity system in 2019-2023 uses the DMA method

Table 8 shows that the average load growth for forecasting the peak load of the Sulbagsel electricity system from 2019 to 2023 using the Double Moving Average (DMA) method is 1.17. Meanwhile, the average percentage level of confidence in the results of forecasting peak loads based on real peak loads in 2019 is 97.55%.

Load Growth Average Method (LGA)

The results of the peak load forecasting of Sulbagsel electricity system for the medium term five years from 2019-2023 using the demand forecast method are shown in Table 9 and the peak load forecast curve is shown in Figure 5.

Table 9. Forecast results for the peak load of the Sulbagsel electricity system in 2019-2023

No	Month	Year	Peak Load (MW)
1	January	2019	1175.8
2	February		1182.3
3	March		1188.8
4	April		1195.4
5	May		1202.0
6	June		1208.6
7	July		1215.3
8	August		1222.0
9	September		1228.7
10	October		1235.5

11	November		1242.3
12	December		1249.2
13	January	2020	1256.1
14	February		1263.1
15	March		1270.0
16	April		1277.0
17	May		1284.1
18	June		1291.2
19	July		1298.3
20	August		1305.5
21	September		1312.7
22	October		1320.0
23	November		1327.3
24	December		1334.6
25	January	2021	1342.0
26	February		1349.4
27	March		1356.8
28	April		1364.3
29	May		1371.9
30	June		1379.4
31	July		1387.1
32	August		1394.7
33	September		1402.4
34	October		1410.2
35	November		1418.0
36	December		1425.8
37	January	2022	1433.7
38	February		1441.6
39	March		1449.6
40	April		1457.6
41	May		1465.6
42	June		1473.7
43	July		1481.8
44	August		1490.0
45	September		1498.3
46	October		1506.5
47	November		1514.9
48	December		1523.2
49	January	2023	1531.6
50	February		1540.1
51	March		1548.6
52	April		1557.2
53	May		1565.8
54	June		1574.4

55	July	1583.1
56	August	1591.9
57	September	1600.7
58	October	1609.5
59	November	1618.4
60	December	1627.3

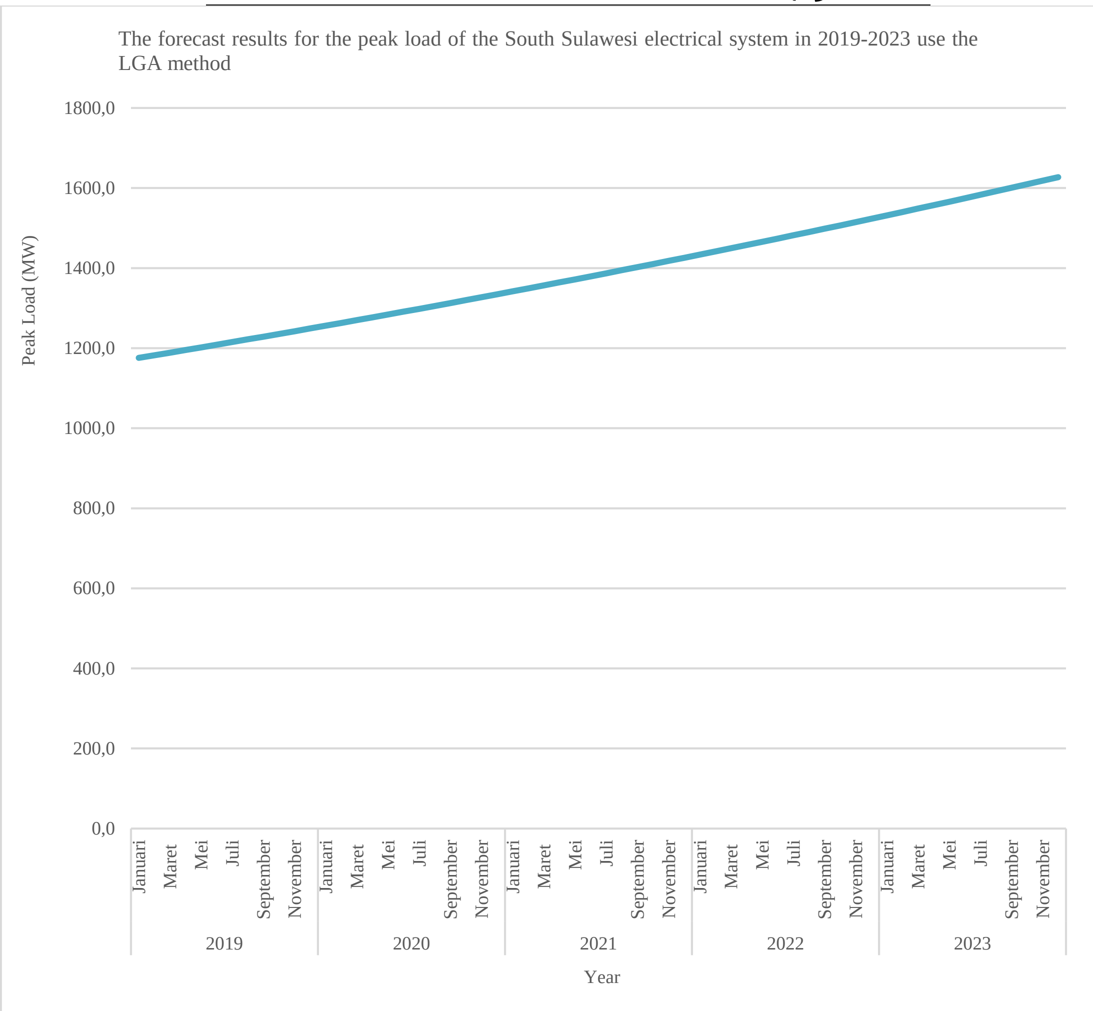

Figure 5. The peak load forecast curve for Sulbagsel electricity system in 2019-2023 uses the LGA method

Table 9 shows that the average load growth for forecasting the peak load of Sulbagsel electricity system from 2019 to 2023 using the Load Growth Average (LGA) method is 1.39. Meanwhile, the average percentage level of confidence in the results of forecasting peak loads based on real peak loads in 2019 is 103.5%.

CONCLUSSION

Based on the results of forecasting the peak load of the Sulbagsel electricity system from 2019 to 2023 using 6 peak load forecasting methods, namely the demand forecast method, the regression method, the quadratic regression method, the single moving average (SMA) method, the double moving average (DMA) method, and load growth average (LGA) method, it can be concluded that:

1. The average growth of the peak load forecasting results of the South Sulawesi electricity system from 2019 to 2023 for the six methods used, namely 1.19 for the demand forecast (DF) method with an average percentage level of confidence in the peak load forecasting results of 97.97%, for the linear regression method of 1.21 with an average percentage of the confidence level of the peak load forecasting results of 99.39%, the quadratic regression method of 0.99 with an average percentage of the confidence level of the peak load forecasting results of 97.27%, the single moving average (SMA) method of 1.12 with an average percentage of the confidence level of the peak load forecasting results of 98.14%, the double moving average (DMA) method of 1.17 with an average percentage of the confidence level of the peak load forecasting results of 97.55%, and using the load growth average (LGA) method of 1.39 with the average percentage level of confidence in the load forecasting results p the figure was 103.5%.
2. The appropriate method used for forecasting the peak load of Sulbagsel electricity system in 2019 to 2023 based on the average percentage level of confidence obtained is the linear regression method with an average percentage level of 99.39% confidence.

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