Electricity Load Saturation Analysis for Makassar City

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Electricity Load Saturation Analysis for Makassar City

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Abstract. One of issues in the power systems is how to meet electricity load from year to year. Therefore, conducting future electricity load analysis as a basis to develop needed new power plants including expansion of electricity network is important. This paper aims to investigate saturation period of electricity consumption in Makassar, Indonesia using logistic curve approach. To analyze more detail phases of electricity consumption growth, logistic curve models for each service area in Makassar (north, south, east, and west region) were also composed and compared using data from year 2000 to 2015. Besides that, power load density was also investigated. Prediction results shown electricity energy consumption in Makassar will enter into saturation condition from year 2033 with consumption volume is 4,748 million kWh. Consumption growth percentage decreased by year which is around 0.06% in year 2050. Other main results shown saturation phase for the four observed regions occurred in the different years, and load density level is 5.226 MVA/km^2 in year 2015. Presented information useful in developing more effective power grid in Makassar to keep optimal electricity service to consumers in the future and management.

Keywords: Electricity load saturation, load density, logistic curve, Makassar.

1. Introduction

The challenge of meeting electricity demand from consumers from year to year has become an issue in operation of power systems in many countries. Based on the data from PT. PLN (power utility), electricity energy consumption in Makassar has been increasing from 263 million kWh in year 2000 to around 1,719 million kWh in year 2015. Therefore, efforts to handle this situation such as conducting load prediction analysis is highly needed. It is caused resulted information can become a reference for stability operation of power systems and for planning in adding new power plants or electricity network in the future. Knowing load (electricity energy consumption) growth is important to achieve optimal development of existing power grid and management.

A number of previous studies on load prediction can be found in literatures [1-5]. The studies were conducted through development of suitable load demand models using a method to achieve certain objectives in related places. For example in [1], the authors modelled electricity load using ANFIS method for load prediction in Ontario province. A number of parameters such as employment, population, and GDP were used as input in their model. Reference [2] applied time series model to handle limitation of data for electricity load prediction in Indonesia. They tested three time series load models, and confirmed that grey model gives highest forecasting accuracy. Reference [3] performed electricity load forecasting considering consumer behavior using OS-ELM approach for Irish household load as a case study. Reference [4] analyzed and predicted electricity loads in U.S. using regression approach which considered 24 solar terms. Meanwhile in [5], authors applied balanced KKN algorithm in composing load model for short term prediction. Compared to original algorithm, the model improved forecasting results in accuracy and time of execution.

As electricity load in Indonesia increases over the year, in this paper, we have interesting to analyze saturation period of the load in Indonesia using Logistic curve approach and power load density. Here, Makassar with 175.77 km^2 area which has quite big electricity load was used as a case study. To explore more detail the phases of electricity energy consumption growth, besides for total load, four different logistic curve models (LCM) for each electricity service area (region) in Makassar were also composed. The logistic curve approach was applied to handle problem related the availability of other variables data (electricity load drivers). As in [6], LCM uses load data itself to observe typical growth of related load. Through literature review, we do not find similar study to the study we have done. It can be said, this is the first attempt to perfom load saturation analysis for Indonesian context. Several works on load saturation analysis can be seen in [6-8].

2. Electricity Consumption in Makassar

Figure 1 shows typical electricity consumption in Makassar for year 2015 obtained from PT. PLN with total load is 1,719 million kWh. From the figures, volume of electricity load for each region is relatively different due to many factors such as number of consumers and load composition. South region contributed highest (31%) to the toal load demand in 2015 and followed by north region (28%), east region (27%), and west region (14%). The total consumption will increase in the future based on current trend of electricity energy consumption.

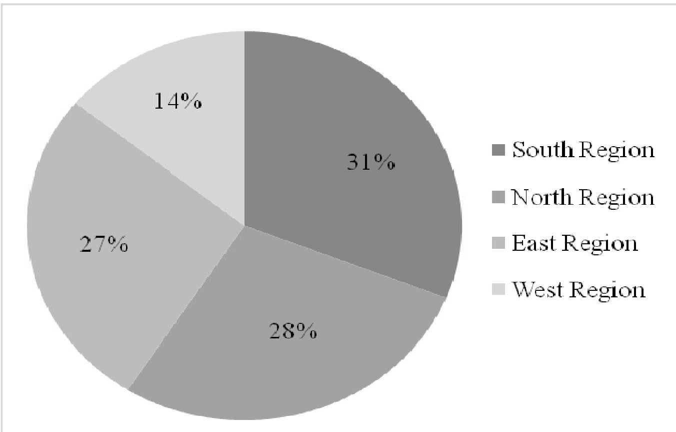

Figure 1. Electricity consumption by region for year 2015 (data from PT. PLN in Makassar).

3. Data

To investigate saturation period of the studied load, historical load data between year 2000 and year 2015 were used. The data were obtained from PT. PLN in Makassar. Here, analyzed yearly electricity load was represented by the total load of the four regions in each year. Next, LCM was applied for prediction to determine time period for each phase of load growth. Besides model for total load, load model for each service area (north, south, east, and west region) were also composed and compared to observe typical energy consumption growth in related service areas. In general, LCM is formulated as in Eq. 1 [7].

$$y = \frac{k}{1 + ae^{-bt}} \quad (1)$$

where y is predicted load. Menwhile k, a and b are constants which the values are greater than 0 [7]. Parameters of the model can be determined through mathematical method [8]. From model function, electricity energy consumption growth phases were identified that is slow / flat growth (first order derivative), rapid growth (second order derivative), and saturation growth phase (third order derivative of the curve function) [7]. Next, load density (MVA/km^2) was observed to get more information regarding load condition in Makassar city. Knowledge for load density is an important thing in managing electricity supply system for urban area which can be affected by several factors such as number and life style of users [9,10].

4. Results

4.1. Prediction of total electricity consumption

Figure 2 shows typical LCM for total electricity energy consumption in Makassar, meanwhile Figure 3 shows the growth percentage of electricity for each year. Fitting equation of the logistic curve is:

$$y_{ECMakassar} = \frac{509.2714x10^7}{1+21.57e^{-0.16752t}} \quad (2)$$

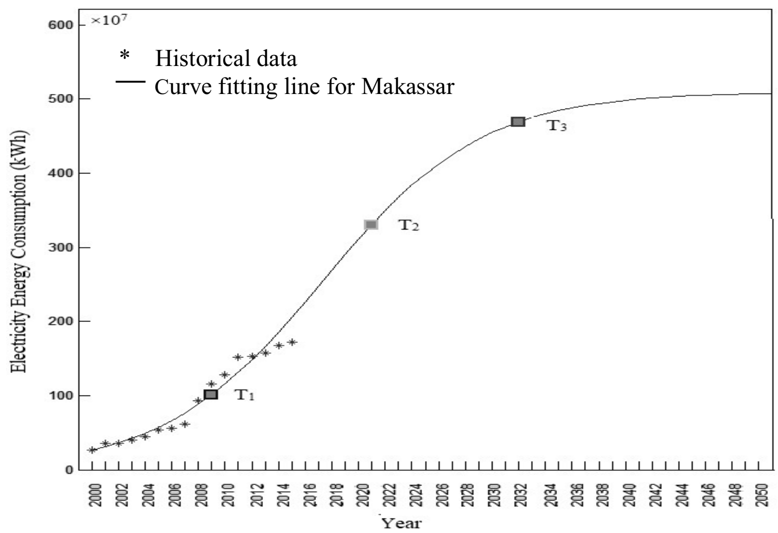

Figure 2. Typical LCM for electricity energy consumption in Makassar.

From derivative of Eq. (2), three phases of electricity energy consumption growth namely slow / flat growth, rapid growth, and saturation growth phase can be identified which is occured in year 2009 (T1), year 2021 (T2), and year 2032 (T3), respectively. This indicated that begins from year 2010, electricity consumption in Makasar is increasing rapidly and this condition occured until 2032. Next, consumption growth will enter into saturation phase from year 2033. Electricity energy consumption in year 2032 and 2033 is around 4,691 million kWh and 4,748 million kWh, respectively. Obtained annual growth of the consumption is decreasing from time to time as seen in Figure 3. In year 2017 the annual growth is 9.37%, and decreased around 1.45% in 2032 and become 0.04% in year 2050. This condition confirms that after reached saturation phase (high level), the next annual growth rate of load or electricity consumption will be much lower. The characteristic shows suitability with common growth law.

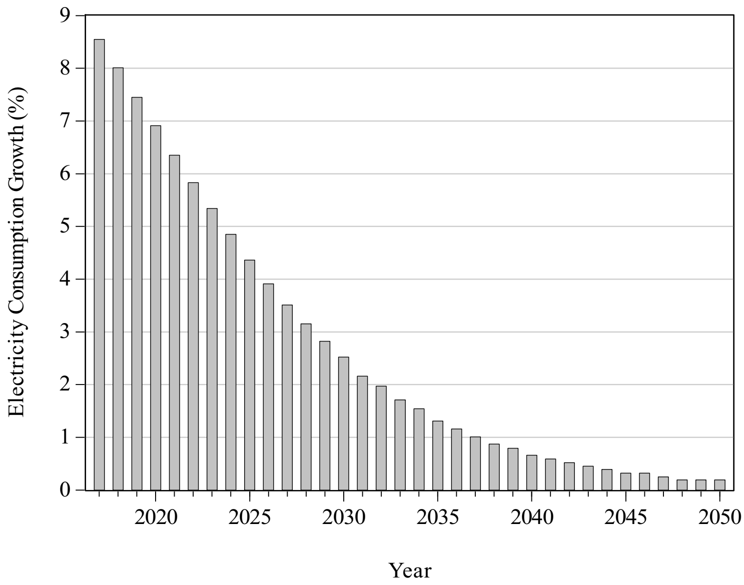

Figure 3. Annual growth of electricity consumption until year 2050.

4.2. Prediction of electricity consumption for each service area

Fitting equation of the logistic curve for each service region in Makassar namely north, south, east, and west regions are given in Eqs. (3)-(6), respectively. Meanwhile Figure 4 shows related LCM for the each region.

$$y_{ECNorthReg} = \frac{160.343x10^{7}}{1 + 16.47e^{-0.14353t}} \quad (3)$$

$$y_{ECSouthReg} = \frac{198.568x10^{7}}{1 + 23.62e^{-0.14929t}} \quad (4)$$

$$y_{ECEastReg} = \frac{295.6404x10^{7}}{1 + 81.36e^{-0.1838t}} \quad (5)$$

$$y_{ECWestReg} = \frac{177.6928x10^{7}}{1 + 49.31e^{-0.14651t}} \quad (6)$$

From the figure, the curve model or time phases consumption growth (T1, T2, and T3) are relatively different for each region. This condition is caused by load characteristics are not same in the observed areas such as number consumers and regional economic planning. Based on on the figure for north region, T1 is year 2008, T2 is 2019, and T3 is 2029. This means rapid electricity consumption is occured in this area until 2029, and after that it will become saturated started from 2030 which electricity consumption is around 1,345 million kWh. Annual consumption growth is decreasing from 8.55% in year 2017 and become 0.19% in year 2050. For south region, T1, T2, and T3 are obtained in year 2009, 2020, and 2030, respectively. Here, electricity consumption is increasing fastly until 2030 (1,566 million kWh) and enter into saturation stage from year 2031 (1,613 million kWh). Annual electricity growth is around 9.93% in year 2017 and decreasing around 0.20% in year 2050. For east region, T1 is year 2009, T2 is 2021, and T3 is 2032. In east region, electricity consumption is increasing rapidly until 2032, and will enter into saturated phase from 2033 which consumption is around 2,555 million kWh. The consumption growth is decreasing from 15.11% in year 2017 and become 0.35% in year 2045. Meanwhile for west region, T1, T2, and T3 are found in year 2011, 2023, and 2035, respectively. Electricity consumption in west region is rapidly increasing until 2035 (1,419 million kWh) and enter into saturation stage from year 2036 (1,459 million kWh). Annual electricity growth has tendency to decrease by year, namely around 12.28% in year 2017 and become 0.41% in year 2050.

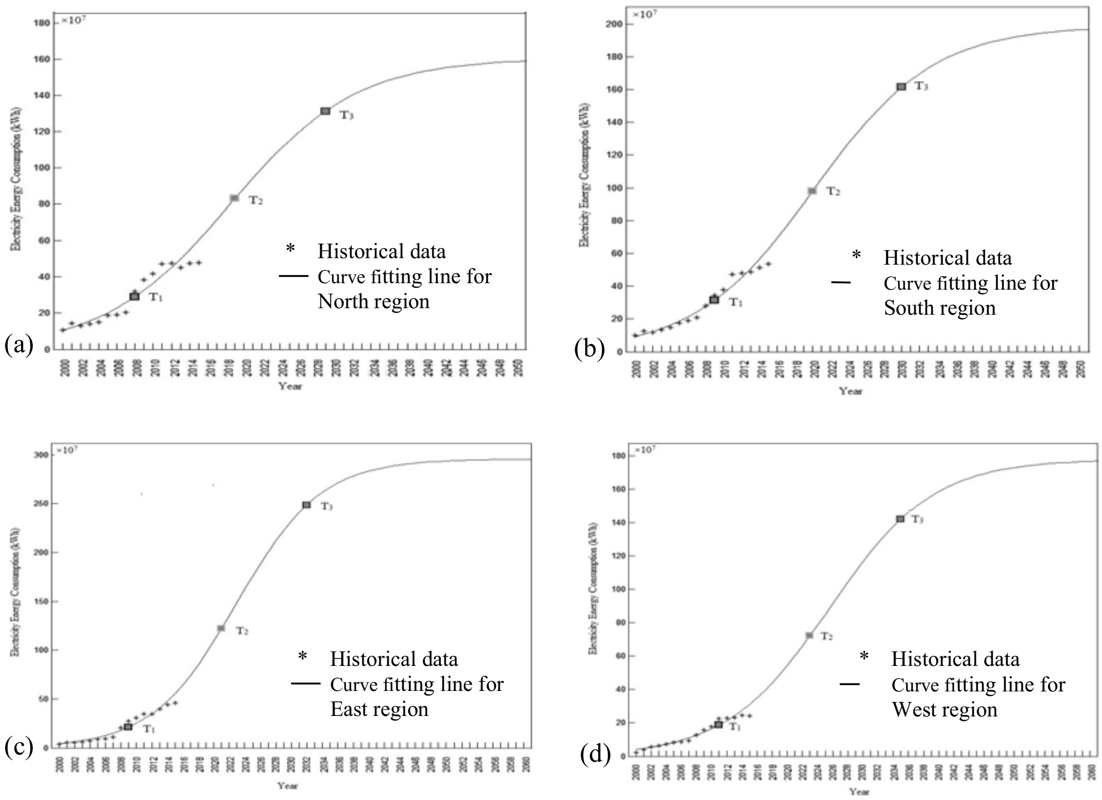

Figure 4 (a)(b)(c)(d). Logistic curve models for each service area.

4.3. Load density in Makassar

Calculation results for power load density are shown in Figure 5. Meanwhile Figure 6 shows contribution for each electricity service area (region) to the load density. From Figure 5, load density in Makassar tends to increase over the year. In year 2000, load density is 1.139 MVA/km^2 and increased around 5.226 MVA/km^2 in year 2015 which can be classified as medium density area (5-11 MVA/km^2) [9]. Besides consumers number which increased by year, lifestyle of consumers can affect level of the load density. For Figure 6, contribution percentage for each service area to the load density in Makassar are relatively different. In year 2000, power load in north region contributes highest (37.45%) and followed by south (31.18%), west (16.82%) and east region (14.55%). Meanwhile in year 2015, south region contributes highest to the load density (29.59%), and followed by east (28.28%), north (27.77%) and west region (14.37%). Basically, knowing the load density value and contribution of subareas help power utility in Makassar for expansion of electric system and management to meet future load. It includes such as placement of new power transformer or selection of load element for optimal grid in related service areas [9].

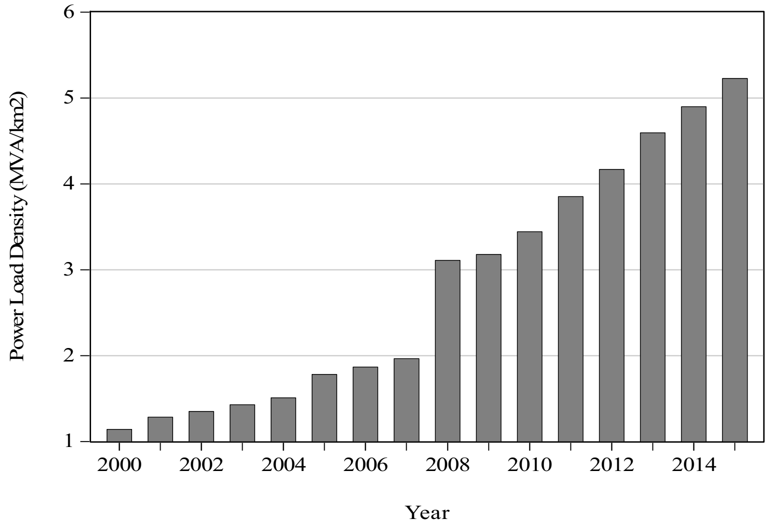

Figure 5. Power load density for Makassar.

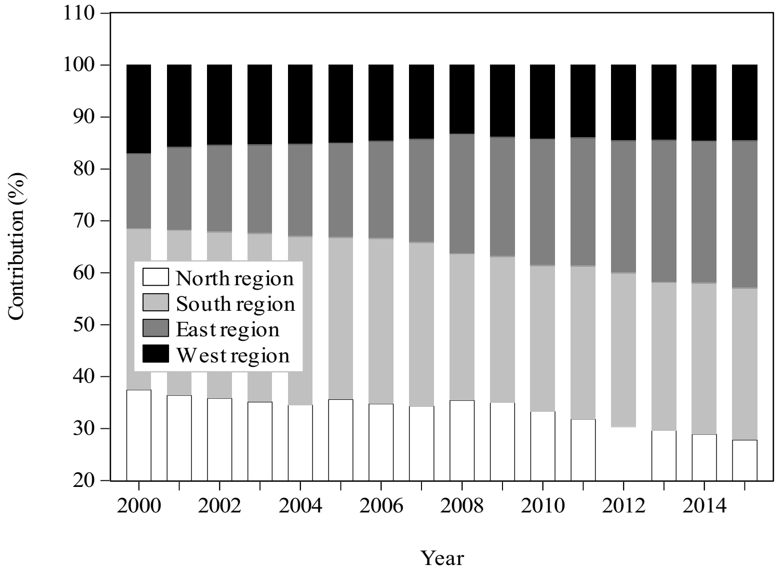

Figure 6. Contribution of each region to the load density.

5. Conclusion

This paper presents analysis of electricity load saturation in Makassar, Indonesia using logistic curve approach and load density. Besides for total load, electricity consumption growth for each electrcity service area (north, south, east, and west region) in Makassar were also analyzed and compared. From results, electricity energy consumption will enter into saturation condition from year 2033 with consumption is 4,748 million kWh. Consumption growth condition decreases over the year. Other main findings shown saturation phases for four observed regions are not same which occurred between year 2030 and year 2036. Regarding load density, Makassar has medium density namely 5.226 MVA/km^2 in year 2015. Presented information can contribute in developing more effective power grid in Makassar to keep optimal electricity service to consumers in the future. Further research will analyze more large electricity demand area in Indonesia.

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