Seasonal Short-Term Electricity Demand Forecasting under Tropical Condition using Fuzzy Approach Model

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***Abstract*—Concern of this work is analysis and short-term electricity demand forecasting under tropical condition using fuzzy approach. Two different demand models are proposed for dry season and rainy season to forecast a total load demand in Makassar, Indonesia for 24 hours ahead in each season. Based on the typical characteristic of seasonal demand, three inputs (time of load, temperature, and type of day) are used for load model in dry season, and four inputs (time of load, temperature, type of day, and rainfall) for load model in rainy season. Meanwhile, output is estimated load in related seasons. Some forecasting error analyses are applied to models. Under tested cases, both seasonal models have good forecasting results with MAPE values smaller than 2.95%. Estimated demand values when holidays and non-holidays in each season which are relatively close to actual load have confirmed effectiveness of the fuzzy based models.**

***Index Terms*—Short-Term Load Forecasting; Tropical Condition; Fuzzy Approach; Dry Season; Rainy Season.**

I. INTRODUCTION

Continuity of electricity supply to consumers with good quality and economic is an important thing in operation of power systems. Moreover, increasing of load demand by time in many places which shown modern people activities are highly depend on the usage of electricity energy, added importance of the issue above. As an effort to handle this, knowing electricity load situation particularly electricity demand ahead that can be obtained through forecasting study is very useful.

Based on its duration, forecasting is generally categorized into long-term load forecasting (LTLF), medium-term load forecasting (MTLF), and short-term load forecasting (STLF). Focus of forecasting is mainly on the STLF which estimated electricity demand up to one week ahead [1]. The forecast results are necessary for day to day operation of power systems. Maintenance scheduling, unit commitment, and demand management are some operations in power systems which is done based on the ouput of related STLF analysis [2].

To perform forecasting, a number of methods have been applied for related load in many countries such as in [1,2,3,4,5,6,7,8,9]. Based on the methods, some different demand models are developed by researchers to solve forecasting problem which mainly to get better result or to improve forecasting accuracy. Accurate forecasting is needed since it can help to make right decision in expansion planning of electricity system and has big impact to profits [3,4]. Besides, it can reduce costs of operation and maintenance, and enhance continuity level of power supply [3]. With regards to this, one of the main methods that has been used successfully is fuzzy approach. Related to uncertainties of load characteristics and ability of fuzzy method to include human knowledge or experience in model such as in selecting input variables, and also to make smaller rule set when we have a lot of data caused fuzzy approach is suitable and interesting for load forecasting application [7,8]. Concerning its applications, paper of [2] proposeda fuzzy linear regression model for STLF which is composed for summer and winter seasons using weather parameters. In [8], the authors presented forecasting study for power system in India. In their case, fuzzy based STLF which implemented for peak, medium, and off-peak demand seasons gives better result than conventional method. Time and temperature variables are used as inputsfor the model. Meanwhile in the paper of [7], the authors conducted STLF study for Jordan context. A fuzzy inference model is presented with input namely last day and last week consumptions, last day and forecasted temperatures, weather, and type of day. Recently, short-term forecasting for electricity demand in Turkey using fuzzy logic and ANFIS is presented in [1]. Four day type models for each method are composed that is Monday, Weekday, Saturday, and Sunday models. Historical load demand, difference of temperature, and season data are inputs in their models.

As electricity demand pattern and its characteristic are possibly unique in one place, this paper has concerned to analyze and to forecast load demand under tropical environment by using fuzzy approach. Based on the typical characteristics of demand in each season, two different models are proposed to predict seasonal electricity demand for 24 hours ahead in Makassar, Indonesia. Three fuzzy inputs are used to model demand in dry season, and four inputs for model in rainy season. Some error analyses are applied to measure forecasting ability of models. Results show proposed fuzzy based seasonal models have good performance as indicated by applied error analyses. Presented results may give more insight to utility in seasonal forecasting to meet electricity demand in the different seasons under tropical environment.

II. PATTERN OF LOAD DEMAND UNDER TROPICAL ENVIRONMENT

In providing suitable model for forecasting task, knowing observed load demand pattern and its characteristic are useful in relation to get accurate results [7]. It is needed as obtained information from them such as load drivers (important variables related to variation of electricity load) helps in determining proper inputs in the developed forecasting model. For shape of a load pattern, it is affected by certain variables such as time, meteorological parameters, and consumers behavior which may not the same for different places.

In this study, used historical hourly data (electricity demand and meteorological variables) for forecasting are from 28 January 2014 to 15 March 2014 for rainy season, and from 13 June 2014 to 23 August 2014 for dry season as meteorological variables data are not complete for other months. The demand is a total electricity load for all sectors in five areas in Makassar each season. The demand and meteorological data are taken from PT. PLN (Persero) of Makassar distribution and LAPAN, respectively. Figure 1 shows typical pattern of the observed load under tropical condition for two days in February and air temperature values on the same days. As in the figure, load demand curve mainly at daytime appeared follows temperature variation. Volume of daily electricity demand is not constant which has minimum and maximum periods. Load demand patterns between holiday and non-holiday have some differences. As in Figure 1, load on Monday particularly at daytime is higher than on Sunday with the highest demand for daytime at 15:00 and for evening at 19:00. This implies variation of the load demand changed by time and can be related with temperature condition and type of the day namely holiday or non-holiday. Next, Figure 2 plots comparison between average daily electricity demand within rainy season (1 January 2014 to 13 March 2014) and dry season (13 June 2014 to 21 August 2014). From Figure 2, load profile in both seasons are slightly different. Electricity demand at daytime during dry season is relatively higher than in rainy season. The influence of rain weather which reduced the using air-conditioner at many places in Makassar such as at offices contributes to the lower of load demand situation.

III. PROPOSED FUZZY SEASONAL LOAD MODEL FOR MAKASSAR

Dry season and rainy season in Makassar occur normally between May and October, and between November and April, respectively. Excluding rainfall, other meteorological parameters such as temperature values are not too different in the two seasons with monthly average values are between 26.9 °C in January and 29.1 °C in August for Year 2012 as an example [10]. The length of daylight duration each season is around 12 hours, from 06:00 a.m. to 06:00 p.m. However, these meteorological conditions which are experienced by existing consumers contribute in forming typical seasonal demand patterns as in Figure 2.

Based on the variation of load driver factors in each season, fuzzy based seasonal demand models (dry season and rainy season load models) are composed for STLF. For dry season (DS) load model, three fuzzy inputs which influencedelectricity demand are used namely time of load, temperature, and type of day.

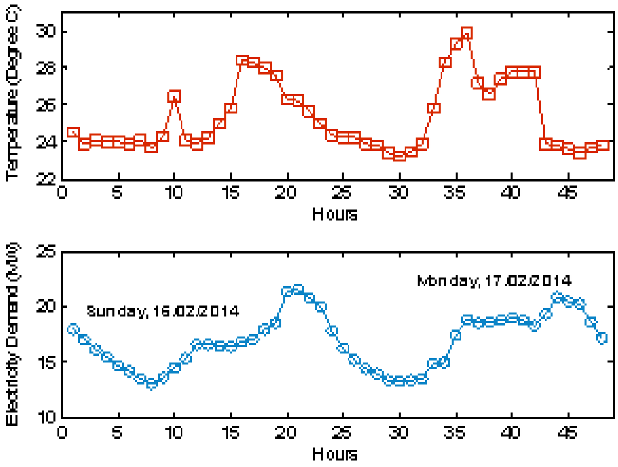


Figure 1: Load pattern on 16-17/02/2014 and temperature values

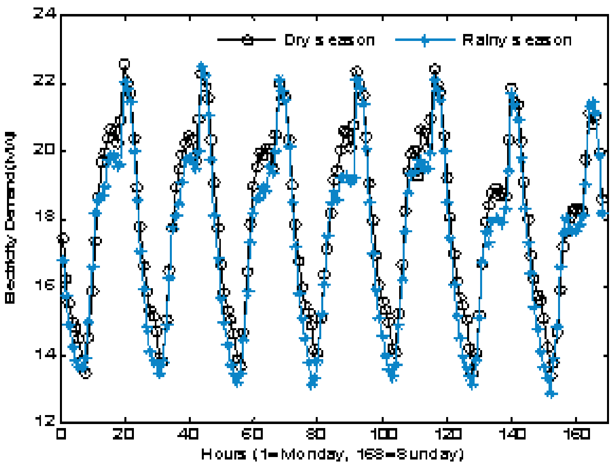
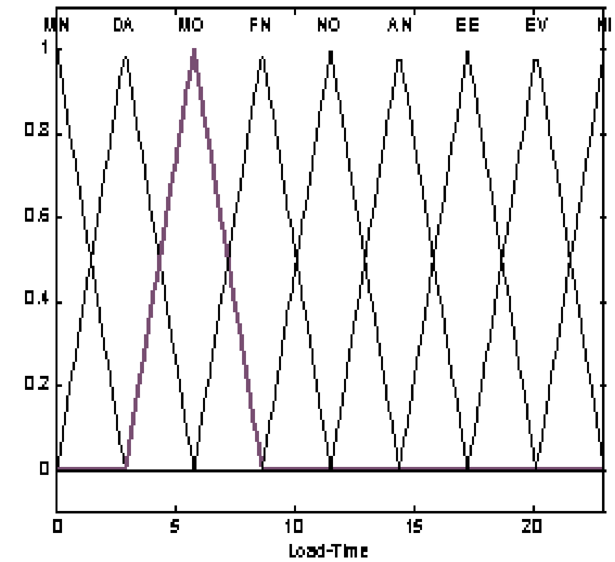


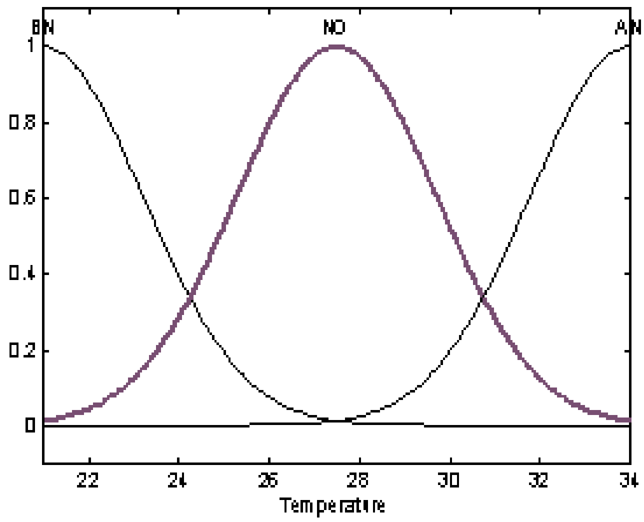
Figure 2: Comparison daily average load demand between two seasons under tropical environment.

Meanwhile, four inputs for rainy season (RS) load model, namely time of load, temperature, type of day, and rainfall. Fuzzy output is estimated load in related seasons. Beside from basic analysis of load profile as in the previous section, selected inputs for a model such as temperature and type of day (effect of holidays) is further based on the statistical analysis as in previous work which confirmed bring significantce influence on electricity demand in Makassar [11].

The fuzzy sets of model for dry season are as follows, Input-1(load-time) is divided into nine triangular membership functions namely MN (midnight), DA (dawn), MO (morning), FN (forenoon), NO (noon), AN (afternoon), EE (early evening), EV (evening), and NI (night). Input-2 (temperature) is divided into three Gaussian functions namely BN (below normal), NO (normal), and AN (above normal). Meanwhile Input-3 (day-type) has two membership functions which is a binary boundaries input for holidays (HD) or non-holidays (NHD) in the range of 0-1 as in [7] (Mamlook et al., 2009). For output estimated electricity demand (ED), it is divided into nine triangular membership functions namely VVLED (very very low ED), VLED (very low ED), LED (low ED), BNED (below normal ED), NED (normal ED), ANED (above normal ED), HED (high ED), VHED (very high ED), and VVHED (veryvery high ED). For rainy season model, the three first fuzzy inputs and



(a)



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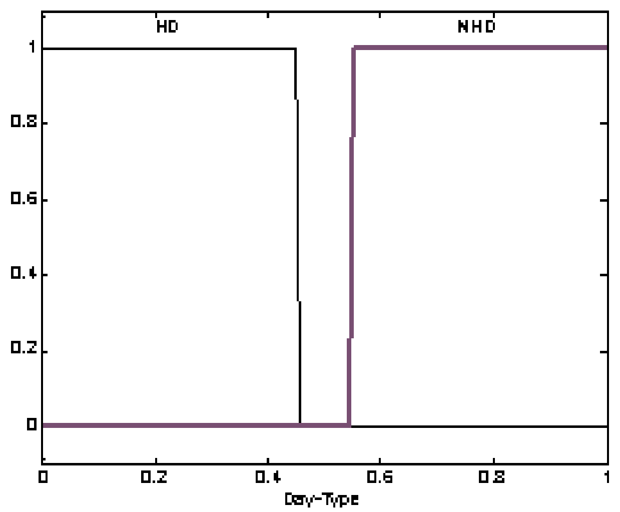
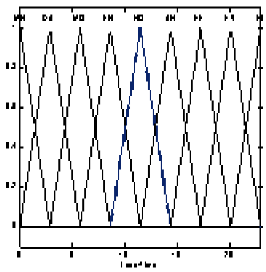


(c)

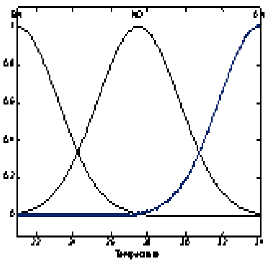
Figure 3: Membership functions for dry season model (a) Input-1, time of load in hours, (b) Input-2, temperature in °C, (c) Input-3, type of day refers to holiday or non-holiday, (d) Output, estimated load in MW.

output are same as in dry season model. Besides, it is introduced Input-4 (rainfall in mm) which is divided into three triangular functions, that is CL (cloudy), LR (light rain), and RN (rain). Figures 3 and 4 present fuzzy sets for inputs and output of the dry season and rainy season models, respectively. For applied rules, 54 fuzzy rules for dry season (DS) model and 72 fuzzy rules for rainy season (RS) model are used based on the seasonal historical data to estimate load demand under effect of selected or considered input variables in related seasons. The fuzzy sets of models are tuned to obtain suitable response associated with applied seasonal parameters as in [7]. Flowchart of the seasonal load demand forecasting is shown in Figure 5.

Next, the two proposed models are implemented for STLF in Makassar. Sample of fuzzy rule base for forecasting within dry season is given in Figure 6. Meanwhile Figure7 plots rule surface in three-dimensional of the dry season model. From Figure 7(a), load demand will increase as a response to the increasing of temperature values mainly at daytime. While Figure 7(b) presents volume of electricity load demand related to holiday and non-holiday effect's which has some differences. Holiday makes electricity demand reduced as a number of electrical devices such as computer and printer like at offices are normally off during the period.



(a)



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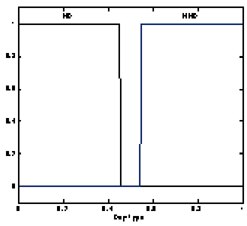

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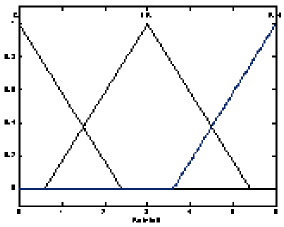

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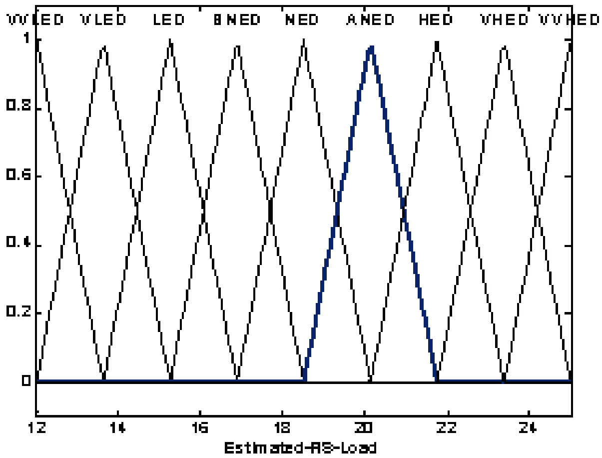


(e)

Figure 4: Membership functions for four inputs and one output of rainy season model.

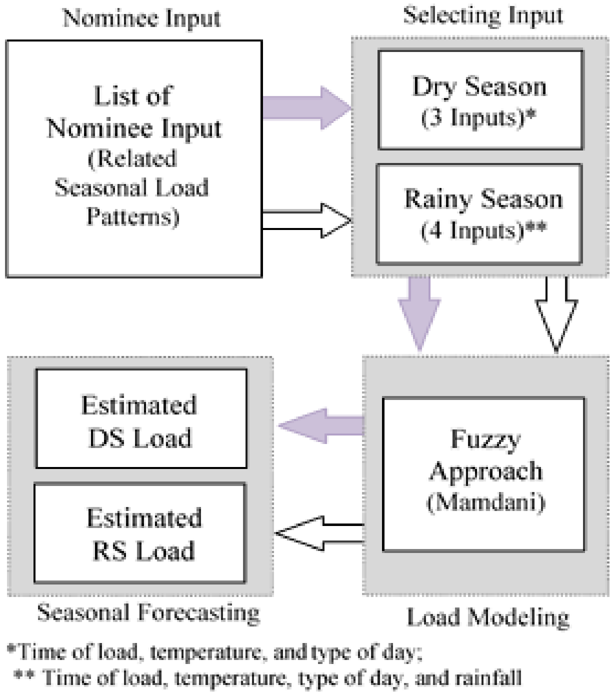


Figure 5: Flowchart of seasonal load demand forecasting under tropical condition.

IV. RESULTS AND ANALYSIS

In this section, results of fuzzy approach to estimate demand in Makassar for 24 hours ahead in each season are presented. Some standard error analyses are applied to evaluate performance of models, that is mean absolute percentage error (MAPE), and mean absolute error (MAE).Besides, mean percentage error (MPE) is also used as in [12,13]. The error analyses are formulated as in Equation (1)-(3).

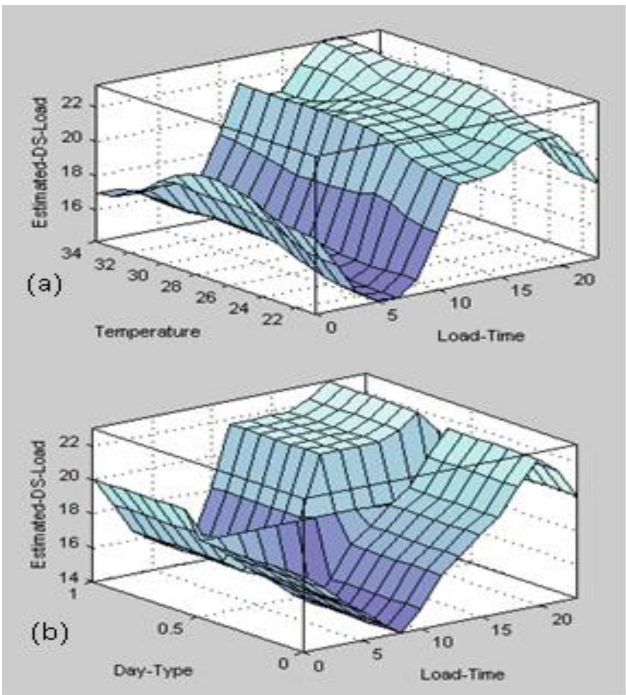


Figure 7: Surface views for dry season load model

$$MAPE = \frac{1}{n}\sum_{i=1}^{n}\frac{\left|EED_i - AED_i\right|}{AED_i}\times 100\% \qquad (1)$$

$$MAE = \frac{1}{n}\sum_{i=1}^{n}\left|EED_i - AED_i\right| \qquad (2)$$

$$MPE = \frac{1}{n}\sum_{i=1}^{n}\frac{(EED_i - AED_i)}{AED_i}\times 100\% \qquad (3)$$

where: *EEDi* = estimated values,
AEDi = actual electricity demand,
n = number of estimation data

The MAPE and MAE values state accuracy of a model which is smaller the values, the better of forecasting model. Meanwhile MPE value indicates a forecasting condition that is under-estimated or over-estimated [12,13]. Next, obtained estimated seasonal load demands are given as follows.

A. STLF in Dry Season

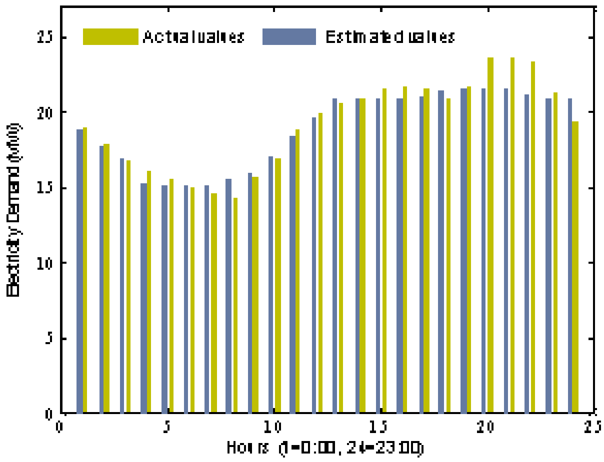
Demand forecasting results in dry season are graphically shown in Figure 8. Meanwhile, values of applied error analyses are given in the Table 1. From the figure, estimated values are relatively close to actual demands either in non-holiday or in holiday. Obtained MAPE values are around 2.93% and 2.74% for non-holiday and holiday, respectively. The MAPE values which less then 2.95% indicated short-term forecasting using the composed fuzzy load model (DS load model) is good. The MPE value which is negative for non-holiday and positive for holiday case represent under-estimated and over-estimated load situations, respectively.

Table 1
The MAPE, MAE, and MPE Values of Forecasting in Dry Season

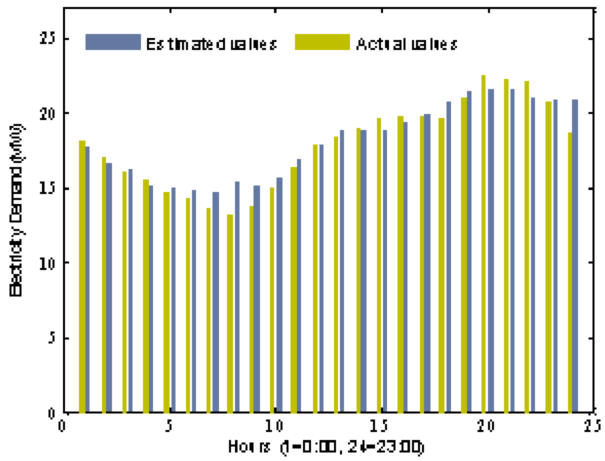
Forecasting Case	Fuzzy Model for Dry Season Load		
	MAPE	MAE	MPE
Non-Holiday: 22/08/2014	2.93%	0.64	-0.42%
Holiday: 23/08/2014	2.74%	0.68	1.75%

B. STLF in Rainy Season

For rainy season, the result of forecasting is presented in Figure 9. Meanwhile, the values of used error analyses are given in Table 2. As in the figure, hourly estimated values appear close to the actual demands for both cases. The MAPE value is around 2.74% for non-holiday's forecasting on 14 March 2014, and around 2.37%for holiday's forecasting on15 March 2014. The low of MAPE values shown composed rainy season fuzzy model (RS load model) has good performance as well as in the previous model. For MPE value, it is negative for both cases, that is -0.16% and-1.27%. This means, the load demands are in under-estimated conditions.



a) Load demand for a non-holiday (Friday,22/08/2014)



(b) Load demand for a holiday (Saturday, 23/08/2014)

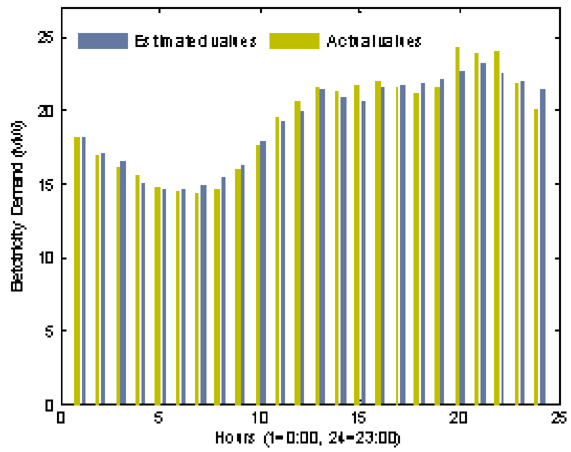
Figure 8: Actual load demand dan fuzzy estimated values in dry season

Table 2
The MAPE, MAE, and MPE Values of Forecasting in Rainy Season

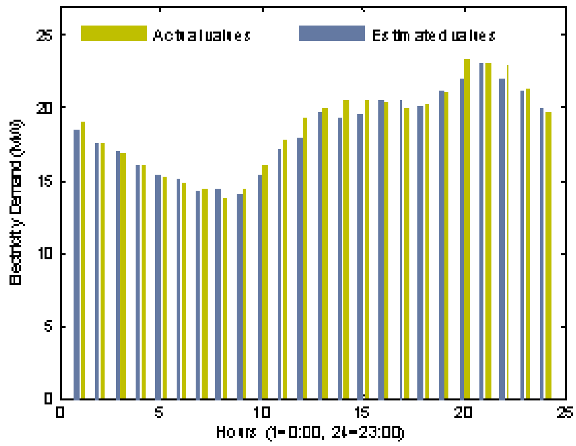
Forecasting Case	Fuzzy Model for Rainy Season Load		
	MAPE	MAE	MPE
Non-Holiday: 14/03/2014	2.74%	0.54	-0.16%
Holiday: 15/03/2014	2.37%	0.44	-1.27%

C. *Forecasting Comparison*

Comparedbetween seasonal forecasting results, obtained MAPE and MAE values in rainy season are slightly lower than MAPE and MAE values in dry season for similar day classification in terms of non-holiday or holiday as seen in Tables 1 and 2. These indicate forecasting results in rainy season are slightly better than in dry season. However, as MAPE values for both seasons are below 2.95%, the seasonal fuzzy models have good accuracy. From paper of [14], a forecasting study is categorized in well forecasted level if MAPE is ≤ 5%. Thus, both seasonal models are capable to be used for STLF task. The relatively good performance of models implies used fuzzy sets are able to follow sufficiently variation of the observed seasonal electricity demands.



(a) Load demand for a non-holiday (Friday, 14/03/2014)



(b) Load demand for a holiday (Saturday, 15/03/2014)

Figure 9: Actual load demand dan fuzzy estimated values in rainy season.

V. Conclusion

Short-term electricity demand forecasting under tropical environment using fuzzy approach is presented in this paper. Two different demand models for dry season (DS) and rainy season (RS) are proposed to forecast a total load demand in Makassar, Indonesia for 24 hours ahead in related seasons. Three different inputs are used to model DS load, and four inputs to model RS load which are based on the characteristic of demand in each season. From tested cases, both models have good results with MAPE values below 2.95%. Estimated load demand values when non-holidays and holidays which are relatively close to the actual values for both seasons shown effectiveness of the fuzzy based models. Further work is needed to introduce other variables such as humidity and previous temperature values in models and to test other forecasting scenarios for providing more optimal model under tropical condition.

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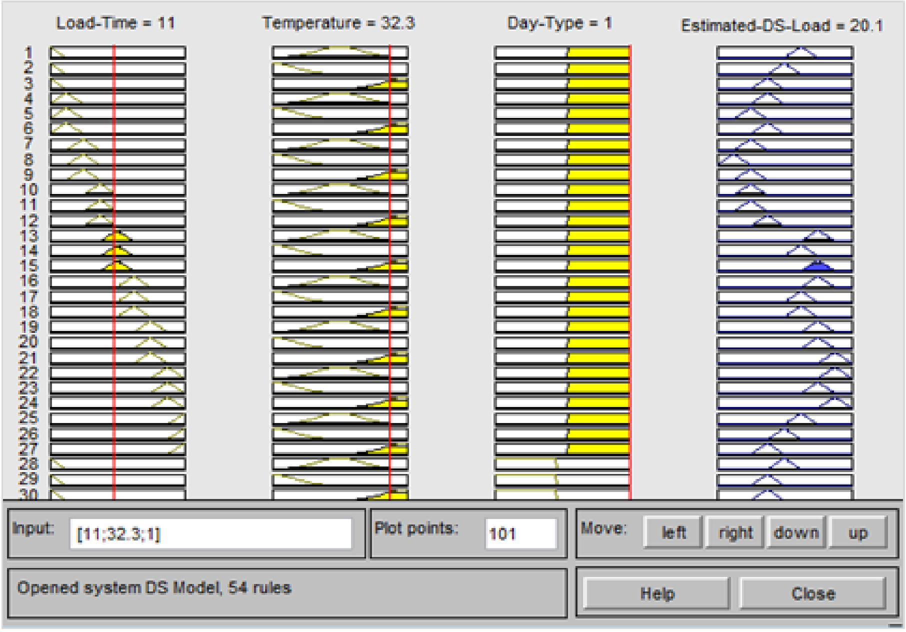

Figure 6: Rule base for dry season load demand forecasting on 22/08/2014

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