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Peak Load Prediction Using Fuzzy Logic For The 150 kV Sulselrabar System

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Abstract. Prediction of electrical load on 150 kV Sulselrabar electrical system, analyzed using approach at night peak load using Fuzzy Logic based intelligent method. The peak load characteristics are certainly different from the load in normal time, therefore a special approach is needed to predict the peak night load. As input data will be used data of night peak load in 2010 until 2015, on the same day and date, each 4 days before day-H or day date which will be predicted load. For the data processing stage is divided into several stages, namely pre-processing, processing, and post-processing. The load data processing follows several procedures, ie computing WDmax, LDmax, TLDmax and VLDmax each year. Data processing is processed using excel software and then using Matlab software to run Fuzzy Logic. From the analysis results obtained, Error Prediction The peak evening load is very small that is equal to -0.039035754%. As comparison data used actual day-H data is April 2016. The graph of analysis result also shown in this paper.

1. Introduction

Sulselrabar electrical system studies previously been widely done, in order to review the electrical system sulselrabar [1-12]. Forecasting burden is one of the studies that need to be done in sulselrabar system, because it is growing. In this research will be conducted a study of electrical load prediction on sulselrabar system using intelligent fuzzy logic method. Previously smart methods have been widely applied to power system optimization, one of them forecasting the electrical load. Some research related techniques for forecasting the load conventionally to use smart methods such as, Regression [13], Support Machine [14], Fuzzy Logic [15, 16], Genetic Algorithm [17, 18], Neural Network [19, 20], Firefly [21].

Load forecasting is a study conducted in order to anticipate the development of load and operating system strategy in the future and also in evaluating the current system. Some of the above research shows that the application of load forecasting technique in sulselrabar electrical system still has not been done, and only using conventional method so that the resulting error is still relatively big. In this research we will use load data several years ago as input data for fuzzy logic. Fuzzy Logic is one of the smart methods that have been widely used in various fields. Therefore the authors use this method as a media forecasting techniques on the electrical load system Sulselrabar.

2. Load Forecasting

Forecasting is a phenomenon of the calculation or estimation of measurements in the period of time to come. In the operation of power system, load forecasting problem is a very important problem in the company. Both in terms of management and in operations, so the load forecasting has special attention. The time load forecasting is divided into several groups:

1. Long Term Load Forecasting is forecasting the load for a period of over five years. For long term load forecasting is commonly used for planning and development of a system (planning), the highest peak load on a power system is often used as a reference in system development. In addition, external factors such as macroeconomic factors also determine in forecasting long-term expenses.
2. Medium load forecasting (medium term load forecasting) is forecasting the load for a period of one month to five years. Forecasting medium-term expenses can not be separated from long-term forecasting of loads, so that long-term forecasting costs will not be much distorted from long-term forecasting expenses. In mid-term forecasting is used for the operational aspects of power systems such as the capacity of the Circuit Breaker (CB) or Transformator panel capacity, expanding the distribution network so that not much is done in medium-term forecasting loads.
3. Forecasting the short term load (for example loading forecasting) is forecasting the load for a period of several hours to a week. In short-term forecasting for forecasts there is a maximum load limit (Pmax) and a minimum load limit (Pmin) determined by medium-term forecasting loads. Short-term load forecasting is most widely used for the operation of a power system
4. Very short term forecasting forecasting (for example load forecasting for less than one hour (hour, minute, second). Very short term load forecasting is used for some special cases.

3. Fuzzy Logic

Fuzzy logic was first introduced by professor Zadeh (California University) in 1965 by describing the mathematical calculations based on set theory to describe vagueness in the form of linguistic variables, in other words fuzzy logic theory developed the theory of boolean set (0 and 1) into set which has an obscure membership value (between 0 and 1) so that fuzzy logic is also called fuzzy logic. Fuzzy inference is doing reasoning using fuzzy input and fuzzy rules that have been determined so as to produce fuzzy output. The main structure of type-1 fuzzy logic system is as follows:

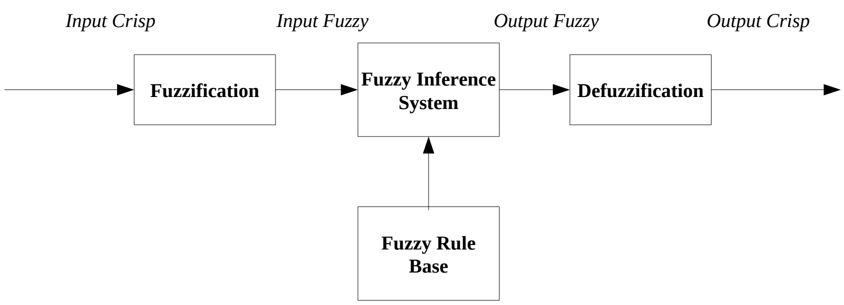

Fig. 1. Fuzzy Type-1 Structure

The fuzzy rule method was first introduced by Ebrahim Mamdani in 1975 known as the mamdani or Max-Min method where there are five stages to get the output:

a. The establishment of the Fuzzy set (input and output variables)
b. *Membership function operation*

c. Application function implications (Commonly used Min function)
d. Agregation
e. Defuzzification

4. Fuzzy Logic Implementation for Sulselrabar Load Forecasting

Forecasting the electrical load on the electrical system of 150 kV Sulselrabar analyzed using 24 hours short-term forecasting approach. As data input used data load of electricity year 2010 until 2015, the data obtained from UPB PT. PLN Region Sulselrabar. For the data processing stage is divided into several stages, namely pre-processing, processing, and post-processing. as described in the previous chapter. Software used in this research using Microsoft Excel to process load data and Matlab Software to perform load forecasting optimization using Fuzzy Logic.

Calculation of Input Variables Fuzzy Logic X, Y, Z

The first step is to calculate the value of MaxWD, LDMax, TLDMax, and VLDmax. Calculates MaxWD for each input data, 2011, 2012, 2013, 2014, 2015 and 2016 for forecasting in 2016 and 2017, using the following equation (n is the forecasting year):

Calculating MaxWD Value

$$MaxWD_{(T-n)} = \frac{MaxWD_{H-4} + MaxWD_{H-3} + MaxWD_{H-2} + MaxWD_{H-1}}{4} \quad (1)$$

Calculating LD Max Value

$$LD_{MAX\,(T-n)} = \frac{MaxSD_{(T-n)} - MaxWD_{(T-n)}}{MaxWD_{(T-n)}} x100 \quad (2)$$

Calculating TLDMax Value (1 Year Before Forecast)

$$TLD_{MAX\,(T-n)} = \frac{LD_{MAX\,(2011)} + LD_{MAX\,(2012)} + LD_{MAX\,(2013)} + LD_{MAX\,(2014)} + LD_{MAX\,(2015)}}{5} \quad (3)$$

Calculating VLDMax Value (1 Year Before Forecast)

$$VLD_{MAX\,(T-n)} = LD_{MAX\,(T-n)} - TLD_{MAX\,(T-n)} \quad (4)$$

VLD value max 1 year before forecasting year become input variable X, and VLD value max year forecasting become input variable Y and Z. After obtained value of input variable X, Y, Z Fuzzy, next make Fuzzy Logic design (Membership Function & Fuzzy Rule) using M-File and Matlab toolbox. Here's a picture of Fuzzy Logic input-output design.

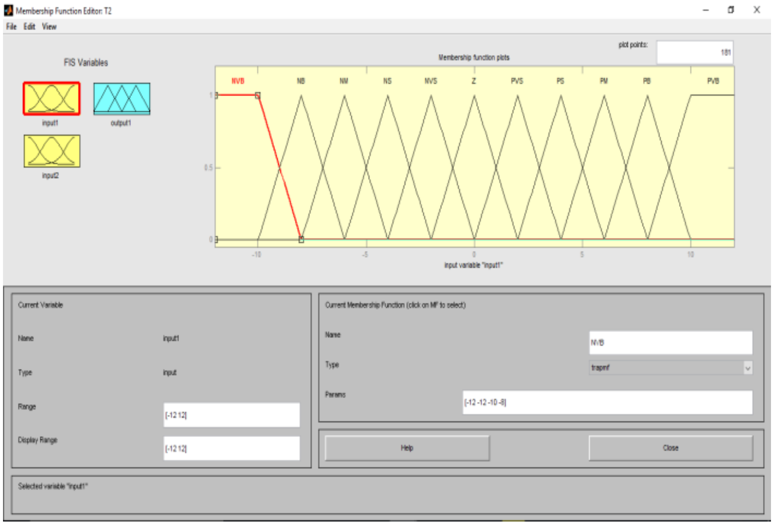

Fig. 2. X Input Design of Fuzzy Logic

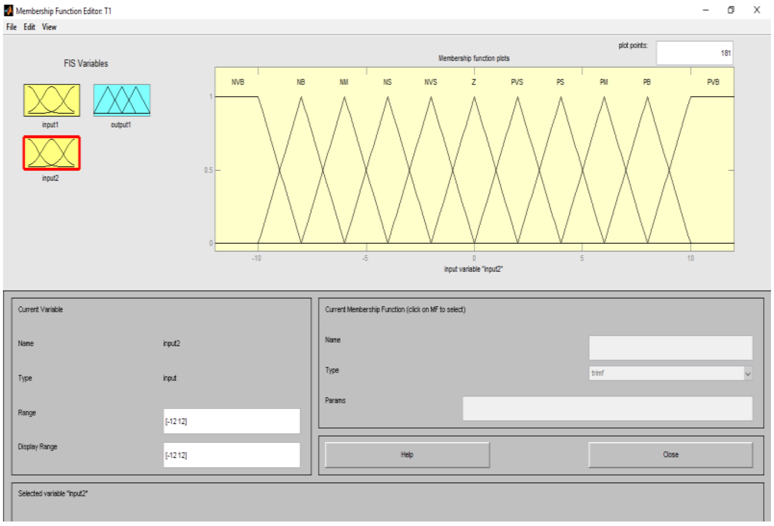

Fig. 3. Y Input Design of Fuzzy Logic

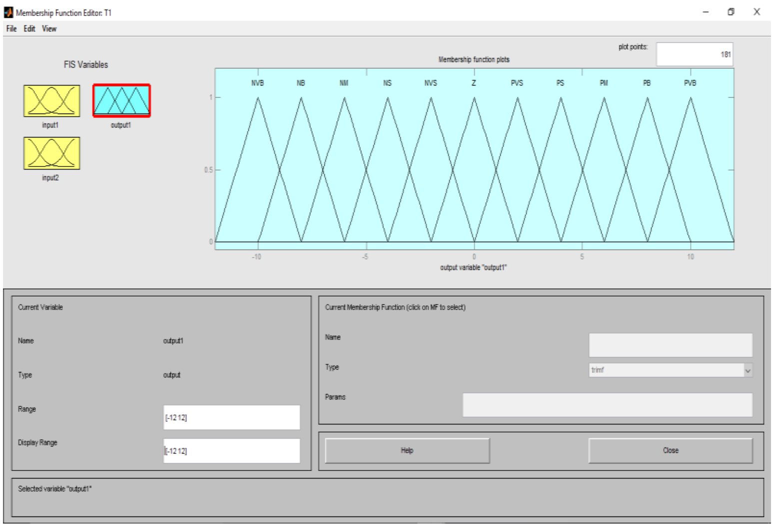

Fig. 4. Z Input Design of Fuzzy Logic

Membership Function Fuzzy Design

Function membership design uses 11 Fuzzy sets.

1. Negative Very Big (NVB) range : -12 s/d -8
2. Negative Big (NB) range : -10 s/d -6
3. Negative Medium (NM) range : -8 s/d -4
4. Negative Small (NS) range : -6 s/d -2
5. Negative Very Small (NVS) range : -4 s/d 0
6. Zero (ZE) range : -2 s/d 2
7. Positive Very Small (PVS) range : 0 s/d 4
8. Positive Small (PS) range : 2 s/d 6
9. Positive Medium (PM) range : 4 s/d 8
10. Positive Big (PB) range : 6 s/d 10
11. Positive Very Big (PVB) range : 8 s/d 12

Fuzzy Rules Design

The set of Fuzzy input variables (X, Y) of VLDmax national holidays for each linguistic degree membership membership fuzzy input variable (X, Y) is mathematically described as follows:

$$\mu_{X_{NVB}}[n]=\begin{cases}0 & ;\ n\geq -8\\ \frac{-8-n}{2} & ;\ -10\leq n\leq -8\\ 1 & ;\ n\leq -10\end{cases} \quad (5)$$

$$\mu_{X_{NB}}[n]=\begin{cases}0 & ;\ n\leq -10 \text{ atau } n\geq -6\\ \frac{n+10}{2} & ;\ -10\leq n\leq -8\\ \frac{-6-n}{2} & ;\ -8\leq n\leq -6\end{cases} \quad (6)$$

$$\mu_{X_{NM}}[n]=\begin{cases}0 & ;\ n\leq -8 \text{ atau } n\geq -4\\ \frac{n+8}{2} & ;\ -8\leq n\leq -6\\ \frac{-4-n}{2} & ;\ -6\leq n\leq -4\end{cases} \quad (7)$$

$$\mu_{X_{NS}}[n]=\begin{cases}0 & ;\ n\leq -6 \text{ atau } n\geq -2\\ \frac{n+6}{2} & ;\ -6\leq n\leq -4\\ \frac{-2-n}{2} & ;\ -4\leq n\leq -2\end{cases} \quad (8)$$

$$\mu_{X_{NVS}}[n]=\begin{cases}0 & ;\ n\leq -4 \text{ atau } n\geq 0\\ \frac{n+4}{2} & ;\ -4\leq n\leq -2\\ \frac{-n}{2} & ;\ -2\leq n\leq 0\end{cases} \quad (9)$$

$$\mu_{X_{ZE}}[n]=\begin{cases}0 & ;\ n\leq -2 \text{ atau } n\geq 2\\ \frac{n+2}{2} & ;\ -2\leq n\leq 0\\ \frac{2-n}{2} & ;\ 0\leq n\leq 2\end{cases} \quad (10)$$

$$\mu_{X_{PVS}}[n]=\begin{cases}0 & ;\ n\leq 0 \text{ atau } n\geq 4\\ \frac{n}{2} & ;\ 0\leq n\leq 2\\ \frac{4-n}{2} & ;\ 2\leq n\leq 4\end{cases} \quad (11)$$

$$\mu_{X_{PS}}[n]=\begin{cases}0 & ;\ n\leq 2 \text{ atau } n\geq 6\\ \frac{n-2}{2} & ;\ 2\leq n\leq 4\\ \frac{6-n}{2} & ;\ 4\leq n\leq 6\end{cases} \quad (12)$$

$$\mu_{X_{PM}}[n]=\begin{cases}0 & ;\ n\leq 4 \text{ atau } n\geq 8\\ \frac{n-4}{2} & ;\ 4\leq n\leq 6\\ \frac{8-n}{2} & ;\ 6\leq n\leq 8\end{cases} \quad (13)$$

$$\mu_{X_{PB}}[n]=\begin{cases}0 & ;\ n\leq 6 \text{ atau } n\geq 10\\ \frac{n-6}{2} & ;\ 6\leq n\leq 8\\ \frac{10-n}{2} & ;\ 8\leq n\leq 10\end{cases} \quad (14)$$

$$\mu_{X_{PVB}}[n]=\begin{cases}0 & ;\ n\leq 8\\ \frac{n-8}{2} & ;\ 8\leq n\leq 10\\ 1 & ;\ n\geq 10\end{cases} \quad (15)$$

Table 1. Processing Results of Load Data

April 2011		**April 2012**		**April 2013**		**April 2014**		**April 2015**				**April 2016**			
WD Max	**LD Max**	**WD Max**	**LD Max**	**WD Max**	**LD Max**	**WD Max**	**LD Max**	**WD Max**	**LD Max**	**TLDmax**	**VLDmax**	**WD Max**	**LD Max**	**TLDmax**	**VLDmax**
564.435	-3.52299202	619.41	-2.72517396	714.9125	-0.34724529	798	2.380952381	872.225	-2.62833558	-1.05361	-1.57472	914.35	-1.0882	-1.36856	0.280354
560.0325	-2.19853312	612.9325	3.670469424	712.465	5.996785807	802.6	2.354846748	862.95	-1.57019526	2.455892	-4.02609	910.275	-5.52306	1.650675	-7.17373
553.17	-4.9116908	616.305	4.375268739	721.4125	1.103044375	808.3	0.296919461	864.8	-6.47548566	0.215885	-6.69137	896.475	-1.15731	-1.12239	-0.03492
542.4175	2.601778151	622.5225	1.080683831	724.19	-0.08975545	813.075	-3.99409649	845.325	-0.3696803	-0.10035	-0.26933	893.05	2.96176	-0.15421	3.115974
543.7	4.305683281	627.62	-0.59112202	730.1325	2.834759444	807.45	-4.98482878	837.425	-0.60005374	0.391123	-0.99118	892.5	6.106443	0.192888	5.913555
549.34	4.405286344	632.965	-6.43084531	739.7325	1.243354861	795	-0.93081761	833.2	0.624099856	-0.42826	1.052355	903.15	3.493329	-0.21778	3.711113
555.795	3.421225452	622.1725	-1.12870627	738.1675	-2.52076934	786.525	1.649661486	830.45	3.690770064	0.355353	3.335417	921.825	0.149161	1.022436	-0.87328
567.9975	3.977570324	615.1425	0.601080238	735.715	-5.61698484	783.725	1.208969983	843.525	6.481728461	0.042659	6.43907	931.1	-8.07647	1.330473	-9.40694
576.5125	-2.44617419	612.54	1.859470402	728.4275	-3.54016014	786.875	-11.3836378	857.525	4.591702866	-3.87763	8.469328	915.2	-5.79108	-2.18376	-3.60732
575.3375	-3.12642579	612.545	6.196279457	716.38	-2.02546135	769.4	5.861710424	873.65	-3.76008699	1.726526	-5.48661	894	3.053691	0.629203	2.424488
571.29	-0.0997742	627.105	0.538187385	704.615	3.277676462	776.125	4.738283137	874.25	-4.39805548	2.113593	-6.51165	890.65	1.936788	0.811263	1.125524
570.2675	1.01575138	630.9375	1.807231303	706.6525	7.237998875	779.475	4.095705443	867.925	-9.9807011	3.539172	-13.5199	886.825	6.740338	0.835197	5.905141
566.635	0.507381295	636.8125	1.675139857	722.505	0.753628003	784.025	-4.41631326	838.7	-2.76618576	-0.37004	-2.39614	909.5	1.682243	-0.84927	2.531513
568.41	1.282524938	642.7	-3.61288315	728.8325	-2.23405241	797.05	-3.97089267	818.35	1.264740026	-2.13383	3.398566	925.15	-0.96741	-1.45411	0.486702
572.9975	2.935876684	634.945	-4.28462308	731.5025	3.517076155	784.775	-5.06833169	815.325	9.575935976	-0.725	10.30094	923.875	-5.95048	1.335187	-7.28567
577.7725	0.513610461	629.26	4.1016432	738.8825	2.572465852	767.8	6.095337327	829.725	4.685287294	3.320764	1.364523	914.125	-4.60823	3.593669	-8.2019
578.9425	-3.87991899	632.4425	5.147898821	738.905	0.895243638	768.6	1.678376269	851.55	-2.6011391	0.9604	-3.56154	895.475	3.743823	0.248092	3.495731
575.685	-2.01933349	636.8225	3.711787822	743.2975	2.494626983	776.625	3.190085305	855.025	-3.1256396	1.844292	-4.96993	896.525	3.298848	0.850305	2.448543
572.775	3.843568592	647.0675	-1.90358811	755.62	-10.2353035	785.625	1.677008751	854.925	-5.82799661	-1.65458	-4.17342	899	1.957731	-2.48926	4.446993
574.0175	3.362702357	653.82	-4.7031293	735.8825	-1.16221	799.075	1.442292651	832.85	3.379960377	-0.26509	3.645046	910.925	-0.34306	0.463923	-0.80698
577.1625	1.390856128	645.82	-4.92552104	728.2425	-1.9955578	798.075	6.468690286	830.95	1.84728323	0.234617	1.612666	919.875	-2.09539	0.55715	-2.65254
584.34	-4.18078516	633.0725	-1.10769304	720.29	2.017243055	815.125	-0.00306701	835.175	4.445176161	-0.81858	5.263752	912.775	0.561475	0.234175	0.3273
583.3025	-4.19036435	624.4725	2.707485117	713.535	-1.50448121	818.55	1.386598253	846.175	2.910154519	-0.40019	3.310345	910.725	-1.40822	0.261878	-1.6701
574.32	-2.44811255	626.13	0.977432801	719.665	0.339741407	826.325	1.437085892	862.6	0.023185718	0.076537	-0.05335	906.05	1.638982	0.065867	1.573116
566.055	0.175777972	628.425	4.461152882	718.36	1.792972883	833.225	0.249032374	863.05	-5.59063785	1.669734	-7.26037	909.325	3.285404	0.21766	3.067744
561.52	-0.67851546	639.0375	1.102048002	722.7425	-2.5005448	829.625	-0.37667621	855.175	-7.29382875	-0.61342	-6.68041	918.975	-5.84075	-1.9495	-3.89124
560.97	2.50102501	644.0425	1.224686259	715.205	-1.46741144	832.475	-1.00603622	835.3	1.316892135	0.313066	1.003826	905.825	-0.89697	0.513831	-1.4108
565.005	1.020344953	646.68	0.282983856	715.6825	-1.67148142	831.025	2.23519148	829.175	3.934633823	0.46676	3.467874	905.775	0.676216	1.160335	-0.48412
567.6325	0.700717454	650.745	-1.33616086	711.085	5.171674272	833.875	3.132963574	828.925	4.810447266	1.917299	2.893149	903.525	3.240087	2.495928	0.744159
568.7725	-6.19799656	647.1425	-0.04674396	715.24	8.567753481	840.05	-0.35116957	842.425	3.938036027	0.492961	3.445075	901.925	1.959697	1.181976	0.777721

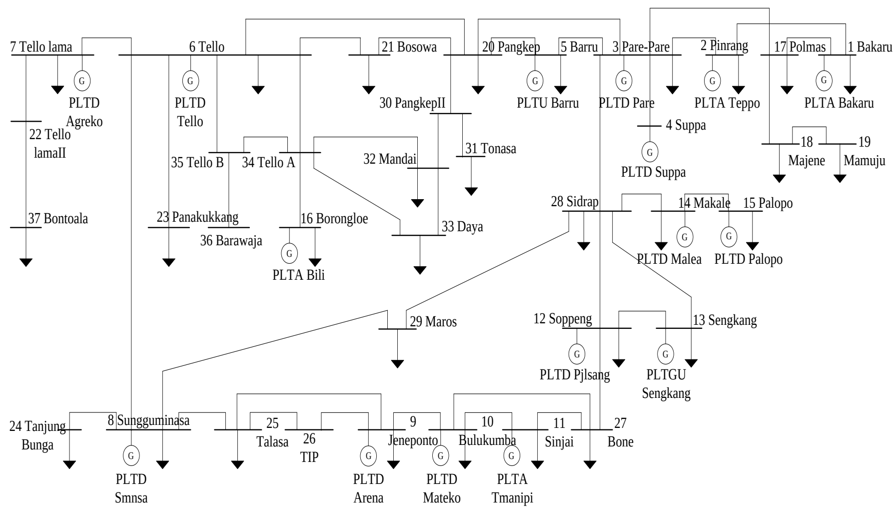

Fig. 5. Single Line Diagram of Sulselrabar System [1-3]

5. Result and Analysis

For example the result of calculation of input variable Fuzzy Logic, can be seen in table 2 below, by using sample of calculation of Input X variable on load forecasting for load on april 2016.

Table 2. Results Calculation of Input Variables X, Y, Z April 2016

Day	Input			Set		
	X	Y	Z	X	Y	Z
1	-1.57472	0.280354	0.280354	ZE	ZE	ZE
2	-4.02609	-7.17373	-7.17373	NVS	NS	NS
3	-6.69137	-0.03492	-0.03492	NS	ZE	ZE
4	-0.26933	3.115974	3.115974	ZE	PVS	PVS
5	-0.99118	5.913555	5.913555	ZE	PVS	PVS
6	1.052355	3.711113	3.711113	ZE	PVS	PVS
7	3.335417	-0.87328	-0.87328	PVS	ZE	ZE
8	6.43907	-9.40694	-9.40694	PS	NS	NS
9	8.469328	-3.60732	-3.60732	NVS	NVS	NVS
10	-5.48661	2.424488	2.424488	NS	PVS	PVS
11	-6.51165	1.125524	1.125524	NS	ZE	ZE
12	-13.5199	5.905141	5.905141	NM	PVS	PVS
13	-2.39614	2.531513	2.531513	NVS	PVS	PVS
14	3.398566	0.486702	0.486702	PVS	ZE	ZE
15	10.30094	-7.28567	-7.28567	PM	NS	NS
16	1.364523	-8.2019	-8.2019	ZE	NS	NS
17	-3.56154	3.495731	3.495731	NVS	PVS	PVS
18	-4.96993	2.448543	2.448543	NVS	PVS	PVS
19	-4.17342	4.446993	4.446993	NVS	PVS	PVS
20	3.645046	-0.80698	-0.80698	PVS	ZE	ZE
21	1.612666	-2.65254	-2.65254	ZE	NVS	NVS
22	5.263752	0.3273	0.3273	PVS	ZE	ZE
23	3.310345	-1.6701	-1.6701	PVS	ZE	ZE
24	-0.05335	1.573116	1.573116	ZE	ZE	ZE
25	-7.26037	3.067744	3.067744	NS	PVS	PVS
26	-6.68041	-3.89124	-3.89124	NS	NVS	NVS

27	1.003826	-1.4108	-1.4108	ZE	ZE	ZE
28	3.467874	-0.48412	-0.48412	PVS	ZE	ZE
29	2.893149	0.744159	0.744159	PVS	ZE	ZE
30	3.445075	0.777721	0.777721	PVS	ZE	ZE

After calculating input variables X, Y, Z for Fuzzy Logic, optimizing the prediction of electrical load can be done, and the analysis results are shown in the following figure.

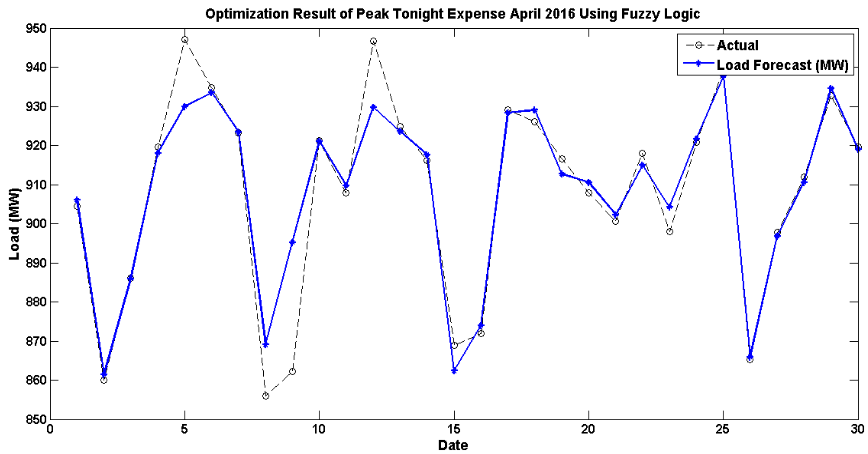

Fig.6. Peak Night Expense Prediction April 2016

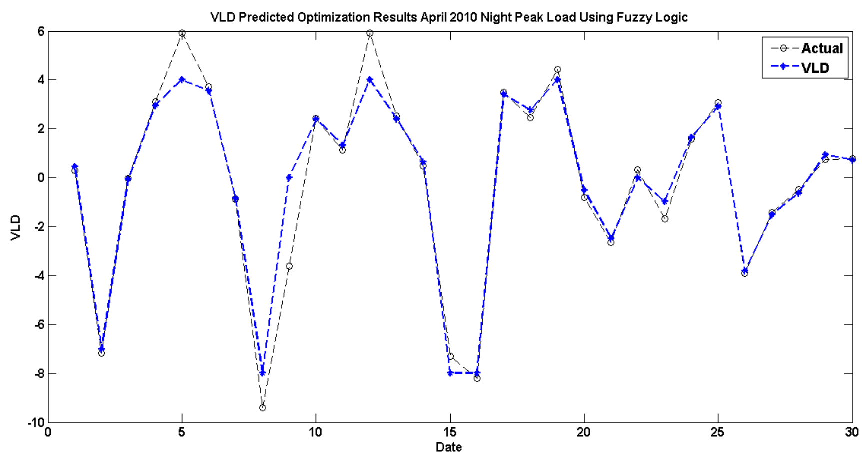

Fig. 7. VLD Prediction of August 2010 Peak Night Burden

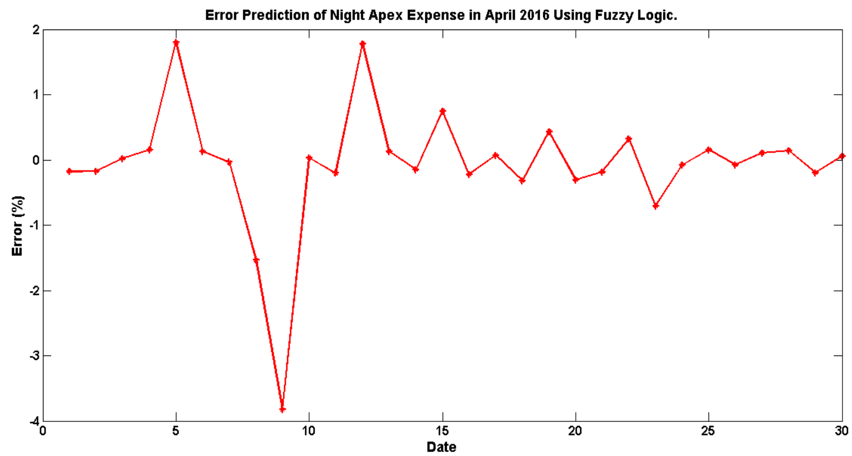

Fig. 8. Error Prediction of Peak Night Burden in April 2016

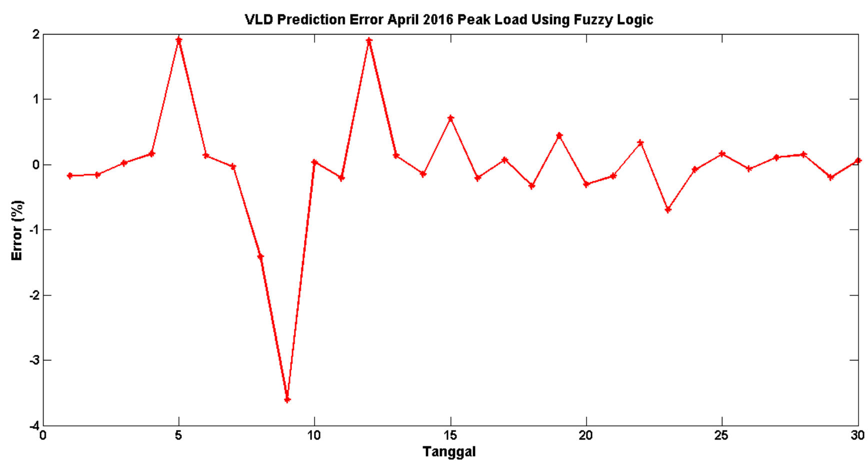

Fig. 9. VLD Error Peak Night Load Month in April 2016

Discussion

Prediction of electrical load on 150 kV Sulselrabar electrical system, analyzed using approach at night peak load using Fuzzy Logic based intelligent method. The peak load characteristics are certainly different from the load in normal time, therefore a special approach is needed to predict the peak night load. As input data will be used data of night peak load in 2010 until 2015, on the same day and date, each 4 days before day-H or day date which will be predicted load. For the data processing stage is divided into several stages, namely pre-processing, processing, and post-processing. The load data processing follows several procedures, ie computing WDmax, LDmax, TLDmax and VLDmax each year. Data processing is processed using excel software and then using Matlab software to run Fuzzy Logic. From the analysis results obtained, Error Prediction The peak evening load is very small that is equal to -0.039035754%. As comparison data used actual day-H data is April 2016.

Figure 6-9. Shows the prediction results of power load on april 2016. From the results of the analysis of the above electrical load prediction, obtained a very small load forecasting error of -0.039035754%. Based on Fig. 6-9 it can be seen that, the biggest error occurs in forecasting the 5th, 8th, 9th, and 12th load date.

Electric load prediction using Fuzzy Logic's intelligent method of optimization is highly accurate and is recommended for use in long-term forecasting studies. In addition, other input variables for Fuzzy Logic can be added to optimize for more complex electrical load forecasts. As a method development, it also proposed another combination of intelligent algortms with fuzzy logic.

6. Conclusion

Prediction of load sulselrabar system on april 2016 by using the data burden of 2010-2015 for Fuzzy Logic input, obtained Error forecasting the load is very small that is equal to -0.039035754%. The biggest error occurs in forecasting the 5th, 8th, 9th, and 12th load date. Electric load prediction using Fuzzy Logic's intelligent method of optimization is highly accurate and is recommended for use in long-term load forecasting studies.

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