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SHORT-TERM PEAK LOAD FORECASTING USING PSO-ANN METHODS: THE CASE OF INDONESIA

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Abstract

The purpose of this study was to investigate the model for predicting the electricity load and usage in Indonesia. This study combined two artificial intelligence methods, one is particle swarm optimization (PSO) and the other one is artificial neural network (ANN). The combination of PSO and ANN (known as hybrid particle swam optimization algorithm (HPSO-ANN)) is attempted to obtain better short-term load forecasting accuracy, especially in the case of daily peak electrical load forecasting. Daily peak loads were analyzed using data from Indonesian state electricity company for West Java area in Indonesia from 2005 to 2012. Data were analyzed for every 30 minutes and classified into the types of days (i.e., weekdays (Monday to Friday), weekend (Saturday to Sunday), and national holidays). To measure the level of accuracy of the prediction, the simulation results were compared with feed forward back propagation methods and actual data from Indonesian power company. The HPSO-ANN method provided the best results with an accuracy level above 98 percent. This analysis provided information on how much waste of electrical energy could be reduced by selecting the appropriate strategies in forecasting according to the load and day characteristics.

Keywords: Artificial neural network, Back propagation, MAPE, Particle swam optimization, Short-term peak load forecasting.

1. Introduction

Indonesia is one of the most populous countries and in the list for the most growing population in the world, making number of industries boosting every year. This condition makes the consideration for the generation of huge electrical energy and power system inevitable [1]. Therefore, planning steps in the operating power system in Indonesia is inevitable. The major step in this planning project is to make an estimation of the electrical load. However, problems in the understanding how to estimate electrical load are still persisted.

Theoretically, the estimation of electricity load are classified into three parts: i.e., short term load forecasting, medium term load forecasting, and long term load forecasting. Each load forecasting model uses different methods to meet its specific objectives. Among these models, short-term load forecasting is the most used method [2].

Short-term load forecasting is one of the important activities in electric power system operation [3]. Accurate forecasting results will provide optimal results in preparing power system operations, such as unit commitment, economic dispatch, and load flow analysis [4]. However, since the electrical load characteristics issued have a complex pattern, while this analysis can be manifested only if the load prediction model has a high accuracy (small errors), implementation of short-term load forecasting prediction is very difficult. Electrical load patterns are non-linear behavior and their characteristics are random and depending on weather, economic, and social factors as well as local activities [5].

In Indonesia, like in other developing countries, the characteristics of electricity usage are very unique and quite different from the behavior of electricity usage in the developed countries [2]. For example, while the change in the weather in the developed countries with four seasons creates great difference in the electrical usage, weather factors in Indonesia have almost no impact on the behavior of electricity usage. The most influencing factor in Indonesia for short-term load forecasting is local activities [6]. Local activities such as lucrative television broadcasts greatly affect the behavior of electricity usage in Indonesia, and the use of electricity for lighting purposes more than the electricity usage for industrial purposes [7]. Thus, based on these considerations, a special prediction model for electricity systems in Indonesia is required.

Understanding a model for electrical load forecasting in Indonesia to get more accurate predictions and less errors, is a mandatory and becomes great challenge for scientists and practitioners. To meet this demand, many methods have been suggested and the most widely used method is the artificial intelligent method. Some artificial intelligence methods have been proposed, such as Fuzzy Logic [8-10], Neural Network [3, 11, 12], and Genetic Algorithm [13, 14]. To get more effective analysis and prediction of electrical load, many researchers have combined the methods [6, 15, 16]. Although current electrical load forecasting methods continue to evolve along with the need for better electrical load forecasts, until now there is no information in detail how to predict the typical electrical load in a specific country such as Indonesia. In fact, this prediction is important for the comparison of electrical energy demand and electrical energy source.

Thus, the purpose of this study was to investigate the model on how to predict the electricity load and usage in Indonesia. We combined two artificial intelligence

methods; one is particle swarm optimization (PSO) and artificial neural network (ANN). This methods are then used to predict the daily peak electrical load based on the types of days (i.e., weekdays (Monday to Friday), weekend (Saturday and Sunday), and national holidays).

The combination of PSO and ANN (known as hybrid particle swam optimization algorithm (HPSO-ANN)) is attempted to obtain better short-term load forecasting accuracy, especially in the case of electrical load forecasting at peak load times [6]. To measure the level of accuracy of the prediction, the simulation results are compared with feed forward back propagation methods and actual data from Indonesian power company. As a model of condition of power consumption in Indonesia, data was obtained from State Electricity Company (known as Perusahaan Listrik Negara (PLN)) in West Java area. PLN was selected because this company is an Indonesian government-owned corporation that has a monopoly on electricity generation and distribution. West Java was selected because this province is classified as the most populous resident in Indonesia.

2. Method

To predict short-term load forecasting, daily peak loads was analyzed using data from PLN. The study was conducted in West Java (one of the most populous and the busiest areas in Indonesia; 6.91°S, 107.60°E; see Fig. 1. Map in the figure was taken from reference [17]

The data had been analyzed from 2005 to 2012. To get precise condition, data were obtained and analyzed for every 30 minutes. The data were grouped into three clusters of days: weekdays (Monday to Friday), weekends (Saturday and Sunday), and national holidays. These data were used and analyzed using the PSO-ANN algorithm. ANN algorithm was used as a back-propagation (BP) algorithm. We also used a MATLAB software to ensure the analysis precisely. In addition, to get information about the accuracy of the algorithm, the Mean Absolute Percentage Error (MAPE) formula was conducted, according to Hyndman and Koehler [18].

3. Results and Discussion

Figure 2 shows the daily peak electrical load pattern in West Java area, Indonesia from 2005 to 2012. The figure was classified based on different time clusters, i.e., weekdays (Monday to Friday), weekends (Saturday and Sunday), and national holidays. This figure represents the electrical load (in MW) against the amount of data in the time series (days).

Different analysis results of electrical load among three types of days are obtained, and the electrical energy increases as the time does. The most used energy is in the weekdays.

As shown in the figure, there is a substantial difference in power consumption, especially in 2012 among three time series (weekdays, weekends, and national holidays). The average costs on working days, weekends, and national holidays give values of 3191.53; 2899.71; and 2761.51 MW, respectively. This phenomenon is in a good agreement with literature [6, 19].

There is a peak load grown every year on weekdays and weekends. For the working days, data at 2006, 2007, 2008, 2009, 2010, 2011, and 2012 had percentages

of load growth of 16.64%; 8.27%; 3.83%; 8.07%; 5.42%; and 8.66%, respectively. For the weekend, the growth values for 2006, 2007, 2008, 2009, 2010, 2011, and 2012 were 17.11%; 5.52%; 5.15%; 8.41%; 5.54%; and 4.69%, respectively. However, for national holiday there seems to be so much growing value compared to other types of days. The results inform that people productively use power when they have to work or study on weekdays; however, due to the internet growth of gadget use, the power consumption does not decrease significantly since people keep in touch with each other through social media on weekends. On national holidays, some people seem to go out for holiday so there is a decrease in the power consumption.

Analysing the detailed result in the peak load, this study finds out that the peak one always occurs at around 19:00, meaning that the use of electricity is for lighting purposes and social activities in society. In fact, this time has no relation with the energy used for industrial purposes.

Analysis of MAPE for weekdays (Monday to Friday), weekends (Saturday and Sunday), and national holiday is shown in Table 1. Average value for weekdays (Monday to Friday), weekends (Saturday and Sunday), and national holiday were 1.56; 1.67; and 1.40, respectively. This replied that HPSO-BP has high accuracy and relatively stable in analysis. The results have no more than 2% of error.

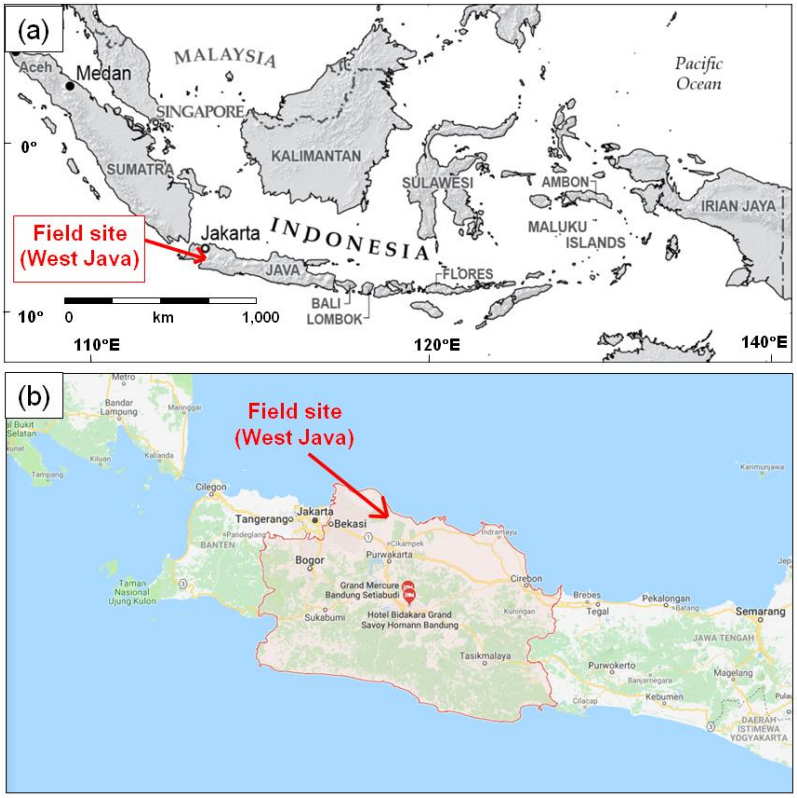

Fig. 1. The field of the measurement site. Figure (a) is the location of the field site in Indonesia. Figure (b) is the exact area that is evaluated. Figure (a) is adopted from reference [17], whereas Fig. (b) is taken from Google Map on March 2018.

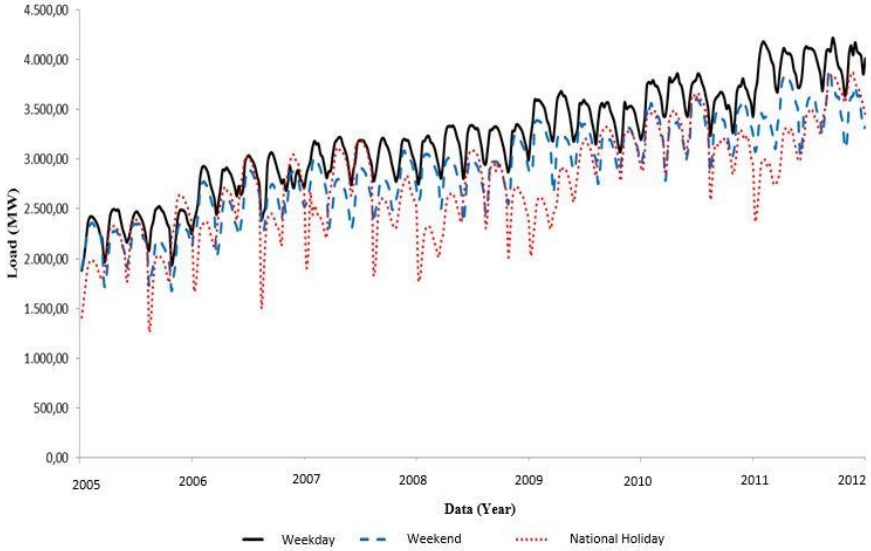

Fig. 2. Daily peak electrical load in West Java, Indonesia.

Table 1. Analysis of MAPE in the HPSO-BP algorithm.

Hour	MAPE (%) Weekday	MAPE (%) Weekend	MAPE (%) National Holiday
17.00	3.21	0.87	1.67
17.30	2.61	1.8	1.46
18.00	0.06	2.82	0.53
18.30	1.17	1.19	1.06
19.00	0.64	0.82	1.58
19.30	2.78	3.16	0.97
20.00	0.68	0.58	1.6
20.30	0.48	1.22	1.52
21.00	0.75	2.73	2.56
21.30	2.54	2.68	1.25
22.00	2.23	0.5	1.18
MAPE	1.56	1.67	1.4

To ensure the analysis of short-term load forecasting, Figures 3, 4, and 5, along with Tables 2, 3, and 4, present the prediction of electrical load between 17.00 and 22.00 on weekdays, weekends, and national holidays, respectively. We compared several methods to estimate how much power is used. The results showed that HPSO-BP is the best result with high accuracy, compared with other methods such as RBS-PLN and BP-JST.

Prior to the discussion of each method displayed in the three figures, it is shown that the in general, the power consumption has an increase starting from 17.00. This pattern consistently comes up on weekdays, weekends, and national holidays. This is due to the fact that most people start turning on the lights since the sun is about

to set. Another consistent pattern occurs at around 21.00 on weekdays and weekend where there is a decrease of the power consumption most people switch the lights off to go to bed. However, this decrease does not happen on national holidays since the decrease already occurs before.

The highest error was obtained for HPSO-BP and BP-JST at 17.00. This is because there is a significant change in the electricity load in this time. Most of the people start to use lamp, lighting, and electricity due to the change weather from evening to night. Then, for RBS-PLN, the highest error was obtained at 18.00, in which this is due to the improvement of maximum electricity load.

Based on the above results, prediction of power supply is one of the crucial references for the power operating system. The actual electricity load occurring in the system is not the same with the prediction analysis. However, this electricity load can be used and implemented to the system. If the actual load occurring in the system is less than the predicted load, savings or reduction of the planned power generation can be made. On the contrary, when the actual load is greater than the predicted load, the increases in the power generation is a mandatory. Thus, implementation of the power reserve is required, which can be either spinning [20] or cold reserve [21].

Among three types of methods, the error value generated by HPSO-BP is the smallest. The average of errors can reach value of less than 5%. This gives ideas that this method is reliable to maintain the economic factor of the power system. Further, prediction gained by HPSO-BP brings advantages in the unnecessary condition for the intervention from expert operators. HPSO-BP can directly generate predictive load value after completing the optimization process.

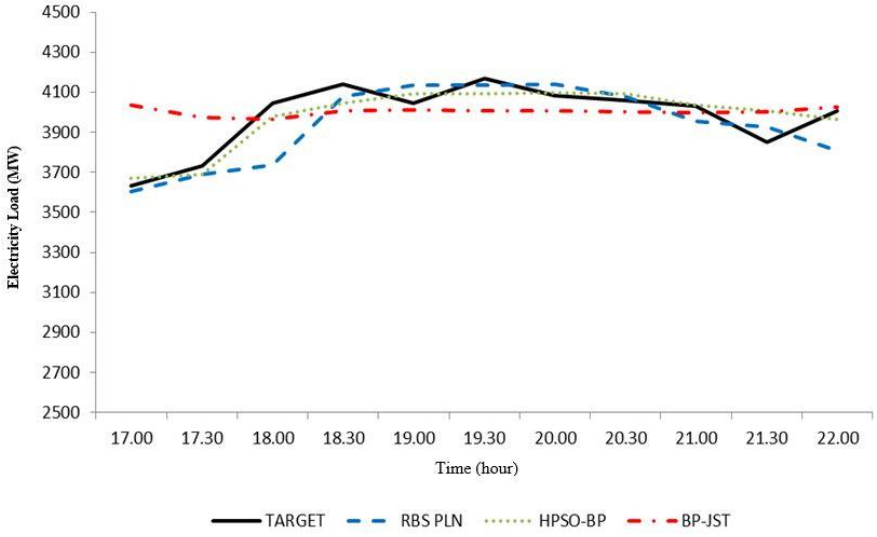

Fig. 3. Prediction of electricity load on weekdays.

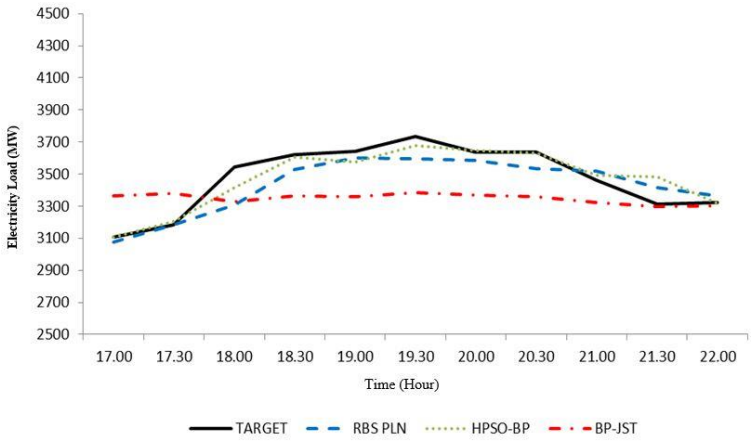

Fig. 4. Prediction of electricity load on weekend.

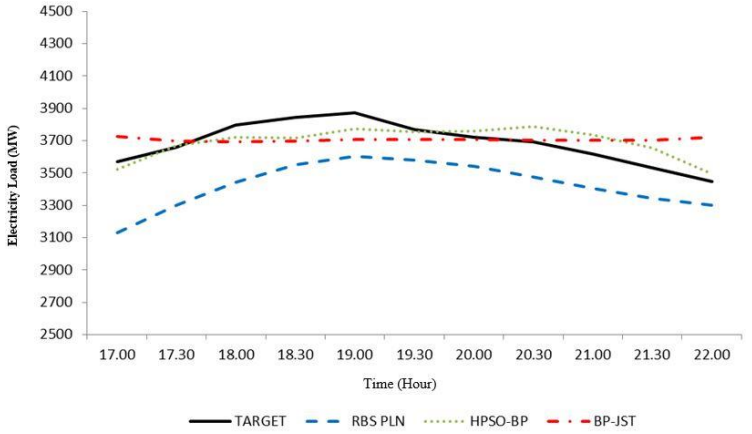

Fig. 5. Prediction of electricity load on national holiday.

Table 2. Comparison of the peak load prediction on Weekdays

hour	**Electricity Load**				**Prediction *Error* (%)**		
	Actual Load (Target)	**Prediction HPSO-BP**	**Prediction RBS-PLN**	**Prediction BP-JST**	***Error* HPSO-BP**	***Error* RBS-PLN**	***Error* BP-JST**
17.00	3633.27	3671.42	3602	4036.79	3.21	12.32	11.11
17.30	3732.66	3690.48	3689	3974.28	2.61	9.83	6.47
18.00	4047.36	3977.34	3738	3963.07	0.06	9.37	2.08
18.30	4140.02	4043.97	4077	4009.46	1.17	7.59	3.15
19.00	4045.48	4093.62	4135	4012.14	0.64	6.91	0.82
19.30	4170.8	4091.14	4135	4007.54	2.78	5.10	3.91
20.00	4083.8	4096.05	4138	4008.06	0.68	4.88	1.85
20.30	4060.27	4090.72	4079	4004.34	0.48	5.91	1.38
21.00	4031.19	4036.43	3955	3996.63	0.75	5.92	0.86
21.30	3851.74	4005.04	3928	4001.22	2.54	5.43	3.88
22.00	4009.41	3962.90	3809	4028.44	2.23	4.33	0.47
		MAPE			1.56	2.27	3.27
		***Error* Minimum**			0.06	0.46	0.47
		***Error* Maximum**			3.21	7.64	11.11

Table 3. Comparison of the peak load on weekends

hour	Electricity Load				Prediction *Error* (%)		
	Actual Load (Target)	Prediction HPSO-BP	Prediction RBS-PLN	Prediction BP-JST	*Error* HPSO-BP	*Error* RBS-PLN	*Error* BP-JST
17.00	3107.12	3105.88	3077	3362.26	0.87	0.97	8.21
17.30	3181.45	3206.27	3183	3380.37	1.80	0.05	6.25
18.00	3542.5	3417.10	3309	3327.04	2.82	6.59	6.08
18.30	3618.67	3604.56	3529	3362.3	1.19	2.48	7.08
19.00	3639.17	3577.30	3603	3359.42	0.82	0.99	7.69
19.30	3736.73	3677.32	3596	3382.98	3.16	3.77	9.47
20.00	3635.23	3644.68	3585	3368.83	0.58	1.38	7.33
20.30	3634.37	3633.28	3534	3358.79	1.22	2.76	7.58
21.00	3462.03	3493.53	3520	3324.66	2.73	1.67	3.97
21.30	3310.34	3483.80	3415	3296.4	2.68	3.16	0.42
22.00	3323.61	3318.96	3362	3304.31	0.50	1.16	0.58
		MAPE			1.67	2.27	5.88
		***Error* Minimum**			0.5	0.05	0.42
		***Error* Maximum**			3.16	6.59	9.47

Table 4. Comparison of the peak load prediction on national holidays.

hour	Electricity Load				Prediction *Error* (%)		
	Actual Load (Target)	Prediction HPSO-BP	Prediction RBS-PLN	Prediction BP-JST	*Error* HPSO-BP	*Error* RBS-PLN	*Error* BP-JST
17.00	3568.5	3523.89	3129	3726.47	1.67	12.32	4.43
17.30	3658.5	3670.94	3299	3699.2	1.46	9.83	1.11
18.00	3798.06	3722.48	3442	3692.7	0.53	9.37	2.77
18.30	3841.46	3717.00	3550	3698.78	1.06	7.59	3.71
19.00	3870.57	3773.42	3603	3704.33	1.58	6.91	4.29
19.30	3770.46	3754.62	3578	3705.46	0.97	5.10	1.72
20.00	3722.57	3756.45	3541	3705.84	1.60	4.88	0.45
20.30	3693.32	3788.24	3475	3703.84	1.52	5.91	0.28
21.00	3616.07	3736.12	3402	3699.76	2.56	5.92	2.31
21.30	3534.05	3654.21	3342	3701.68	1.25	5.43	4.74
22.00	3448.44	3494.30	3299	3721.95	1.18	4.33	7.93
		MAPE			1.4	7.05	3.07
		***Error* Minimum**			0.53	4.33	0.28
		***Error* Maximum**			2.56	12.32	7.93

4. Conclusion

This study has compared and analyzed the power consumption (calculated as an electrical load) on weekdays, weekends, and national holidays. HPSO-BP algorithm was used for determining the daily peak load. The results showed that the accuracy of the prediction electrical load using HPSO-BP is the best, compared to other types of methods such as RBS-PLN and back-propagation. The average of errors obtained can reach value of less than 5%. This gives ideas that this method is reliable to maintain the economic factor of the power system. Further, prediction gained by HPSO-BP brings advantages in the unnecessary condition for the intervention from expert operators. HPSO-BP can directly generate predictive load value after completing the optimization process. This analysis provides information

of how much waste of electrical energy can be reduced by selecting the appropriate strategies in forecasting according to the load and day characteristics.

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