Development of High-precision Demand Forecasting Technology for Factories

KAZUYUKI WAKASUGI[*1] **KATSUAKI MORITA**[*2]

YUSUKE YASHIRO[*3] **RYUJI IKEDA**[*4]

TEPPEI TESHIMA[*5] **TOMOYUKI ENOMOTO**[*6]

By operation with an efficient combination of multiple utility facilities such as turbines, boilers and engines, distributed power supply using renewable energy and a power storage system such as ESS, effects such as a reduction of CO_2 emissions, a reduction of energy cost through the optimization of power contracts and a reduction of fuel cost and an increase in profits through the selling of power can be expected. There are many technologies required for the realization of such an operation, and one of the key elements is demand forecasting technology. In this report, the forecasting method and system that Mitsubishi Heavy Industries, Ltd. (MHI) developed with a focus on factory demand forecasting and a case example where the developed system was applied to forecast the power demand in its factory are described.

1. Introduction

Large consumers such as large-scale factories have been faced with the need for more efficient energy operations in order to correspond to the changes in the energy environment due to global environmental issues and electricity deregulation. But under the present situation, it is especially difficult for factories requiring multiple kinds of energy (electric power, heat, water, etc.) to pursue efficient energy operations because of the following issues:

(1) While forecasting various types of factory demand that change from moment to moment due to variable factors such as states of production and facilities and weather conditions and the amount of power generated by distributed power supply, the operation plan for the utility facilities must be reviewed according to needs and the supply of energy must be continued without interruption.

(2) Even if a method of making an operation plan is established, the state of operation changes with the degradation of facilities and change of products with the passage of time, resulting in obsolescence of the method.

(3) Since the labor force is declining due to declining birthrate, etc., the labor resources at the factory must be concentrated in the production section, which is the factory core. Therefore, it is difficult to continuously conduct the maintenance as described above.

To respond to these needs, we have been promoting the provision of an energy solution business called ENERGY CLOUD® Service[(1)]. This service allows the highly-accurate forecasting of various types of demand using our proprietary technology described in this report and can provide support for the planning of the efficient operation of utility facilities which leads to a reduction of energy costs (such as fuel cost and man-hours). This forecasting system has a function of relearning the model as appropriate, enabling continuous use of the system without obsolescence. In addition, since the adjustment of parameters is incorporated into the algorithm, manual adjustment is not required.

*1 EPI Department, ICT Solution Headquarters
*2 Chief Staff Manager, EPI Department, ICT Solution Headquarters
*3 CIS Department, ICT Solution Headquarters
*4 ICT Project Department, ICT Solution Headquarters
*5 Power & Energy Solution Business Planning Department, Power & Energy Solution Business Division, Power Systems
*6 Chief Staff Manager, Power & Energy Solution Business Planning Department, Power & Energy Solution Business Division, Power Systems

2. Developed method

2.1 Problems in the conventional method

The forecasting system using conventional methods suitable for demand forecasting using the linear regression method, such as the seasonal autoregressive integrated moving average (SARIMA) model, had the following problems:

(1) The forecasting accuracy is low. In the autoregressive method, for example, any data item other than demand cannot be set as an explanatory variable, and therefore, operation plans, weather information, etc., cannot be used as explanatory variables. In addition, there is the possibility that by using some explanatory variable values, a predicted value which differs significantly from the actual performance value will result. This low forecasting accuracy leads to a reduction of the effect of the solution using the forecast results. So, a high forecasting accuracy is desirable.

(2) Manual tuning is required. For example, parameters such as the number of dimensions need to be adjusted for each case. In addition, even if tuning is completed, a review is required when the number of explanatory variables is changed or the content is changed. When manual work is required, it may interfere with the development or make continuous operation difficult due to a delay in introduction, etc. Therefore, it is desirable to establish a forecasting model with the minimum amount of work

2.2 Characteristics of the developed method

(1) High forecasting accuracy

The method adopts an ensemble learning method in which our proprietary technology is incorporated. In this method, an effective number of features is automatically extracted from a large number of explanatory variables, and therefore, operation plans and weather information can be incorporated without issue. In addition, as shown in **Figure 1**, the target variables are divided into clusters before the forecasting is conducted, allowing appropriate forecasting values to be more easily obtained. The verification results for the actual data showed that the developed method can reduce errors by as much as 50% compared with the conventional method (Section 2.3), and as a result of the method being applied to five plants, it has been confirmed that it is effective because an average of about 90% accuracy was obtained (Section 4).

(2) No parameter adjustment required

In the developed method, parameter adjustment is not required in the entire model, except for the number of ensembles which is decided according to the computational resources. Concerning the number of divided clusters, for example, an optimal division number is automatically decided based on the verification using the past data. In addition, if any explanatory variable item is changed, the forecasting model can be automatically restudied according to the changed item. Thus, in this method, the parameters can be flexibly adapted to any change of input data (Section 3). With this function, in the verification example for 5 plants of our company, the operation could be started in about two weeks for each plant (Section 4).

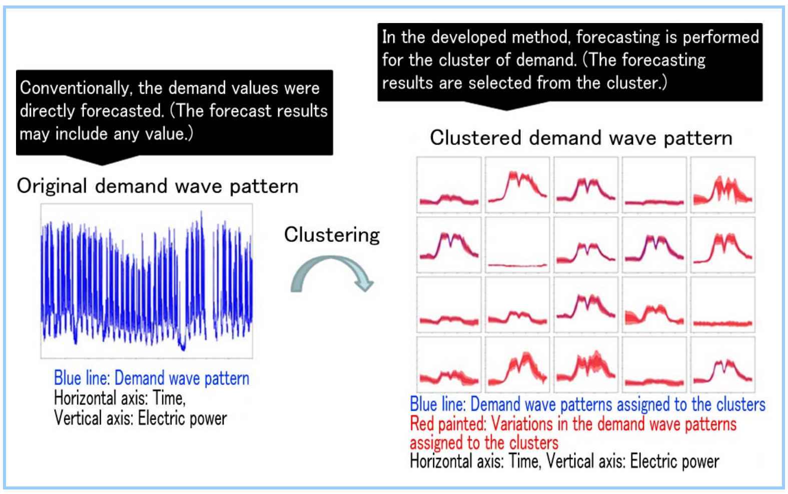

Figure 1 Forecasting in combination with clustering

2.3 Comparison with conventional method

In order to verify the effectiveness of the developed method, we performed a comparison of the accuracy between the developed method and the SARIMA at two sites of our company (Site K, Site O) as one example.

(1) Verification conditions

The verification conditions are depicted in the upper part of **Table 1**. The learning data, verification data, and forecasting conditions are common. For explanatory variables, in the SARIMA which is an autoregressive model, only the past demand data can be used in principle, while in this developed method, calendar data and weather data are also used.

Table 1 Verification conditions and verification results

Item	Site K		Site O	
	Developed method	Conventional method	Developed method	Conventional method
Learning data	2015/7/1 to 2016/2/23			
Verification data	2016/2/24 to 2016/3/31			
Forecasting condition	Forecasting the demand for the period from 12:00 a.m. to 12:00 p.m. of the next day at 11:00 a.m. on the previous day (every 30 minutes, in 48 segments)			
Explanatory variable	- Past demand - Calendar information - Weather information	- Past demand	- Past demand - Calendar information - Weather information	- Past demand

(2) Verification results

The verification results can be found in **Figure 2**. The average number of errors in the conventional method is evaluated as 100% at each site. The error value is calculated from the minimum root mean square error (RMSE). The results showed that the number of errors was substantially reduced by about 50% at Site K and by as much as 30% at Site O. Thus, the effectiveness of this developed method was proved. For reference, the forecasting waveform of the developed method is presented in **Figure 3**. It is considered that the reasons why the developed method has such a large effect compared with the SARIMA are that the explanatory variables such as calendar data and weather data can be freely added, and that clustering reduces the number of days with extreme deviations. From this result, it can be expected that the developed method allows forecasting with higher accuracy than the conventional method.

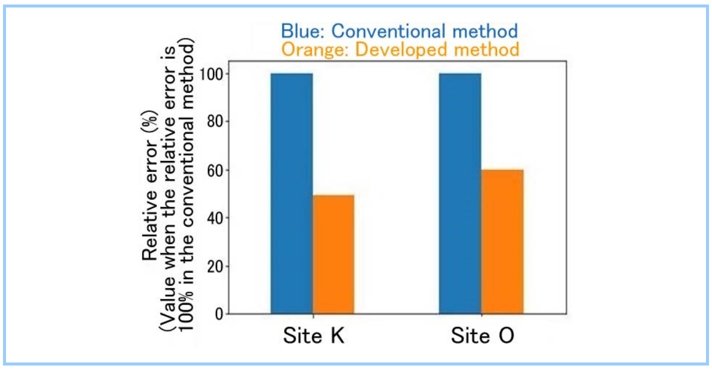

Figure 2 Comparison between the conventional method and the developed method

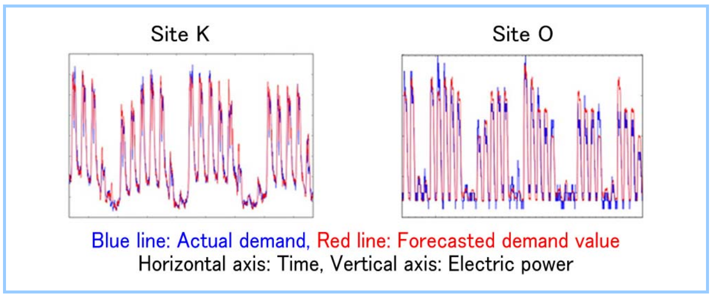

Figure 3 Results of forecasting using the developed method

3. Forecasting system

Next, the forecasting system using the developed method is described. An outline of the typical system configuration of the demand forecasting system is given in **Figure 4**. This system is constructed on the cloud and automatically collects the facility operational data and time-series data such as open information according to the settings and uses them in forecasting. In addition, the setting of off-days and the facility operation plans can be input in a web browser by users as appropriate.

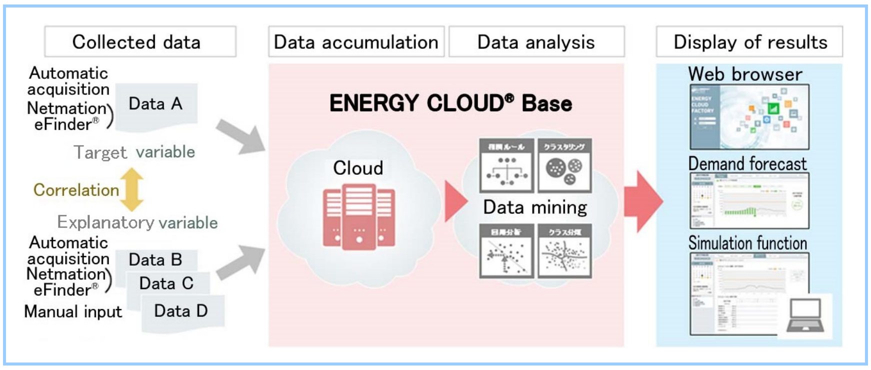

Figure 4 Outline of the demand forecasting system

With these data, the demand forecasting system conducts demand forecasting for a maximum of one year. Because the long-term, medium-term and short-term concepts can be used together as shown in **Figure 5**, the system is available in varied applications to meet each purpose of the users. If the user changes the operation plan, etc., the system detects the changes and updates the forecasting results. Specifically, as an annual operation plan is refined monthly or weekly, the forecasting results are changed and the accuracy is increased accordingly. The system also allows updating of the day's demand forecasting based on the latest operational data once an hour. Therefore, even if the operation is not conducted according to the plan, the forecasting results can follow the operation. Furthermore, this system has a simulation function as previously described. Therefore, when the facility operation plan is changed, the demand according to the plan can be simulated. Thus, the system is also used as a study tool for operation adjustment based on the demand forecasting results.

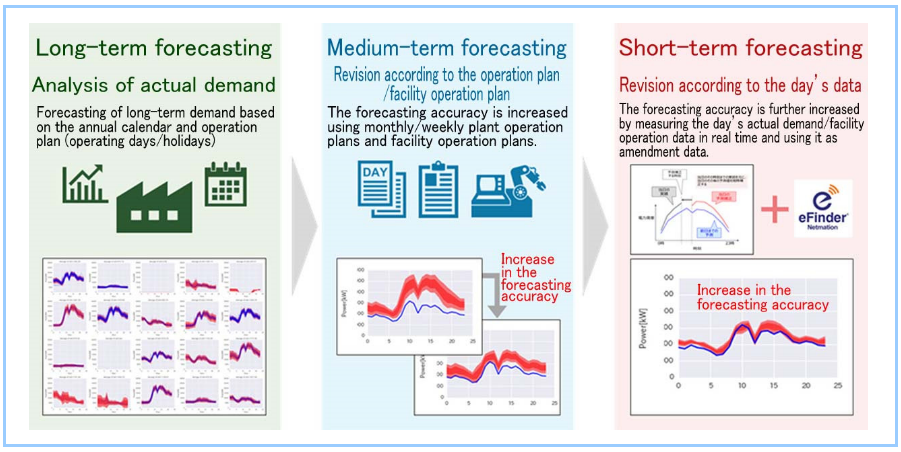

Figure 5 Forecasting period of the demand forecasting system

4. Demonstration example

The results of the application of the developed forecasting system to seven factories in our company are given in **Table 2**. The accuracy is defined as the difference from 100% after the RMSE is standardized by the average value of true values. As a representative example, the accuracy value for the day's 24-hour power demand forecasting at 12:00 a.m. is indicated. The results showed that the average accuracy for the seven factories was high at about 90%, although there were some differences by factory.

Table 2 Demonstration results at in-house factories

Target	System Period of introduction	Accuracy (to December 2017)
Plant A	12 days	87.8%
Plant B	10 days	90.1%
Plant C	9 days	89.8%
Plant D	16 days	92.0%
Plant E	12 days	93.7%

The system has started a short-period operation of about 2 weeks including the field adjustment, and the standardization has been fully developed through the in-house demonstration. This system has also been applied to the forecasting of steam and water demand in addition to power demand, and the application to factories of other companies has also been promoted.

5. Conclusion

In this report, our proprietary method that allows a higher level of forecasting accuracy than the conventional method, the forecasting system using the method and the demonstration example were described.

Through the development of this system, the high-accuracy forecasting of various types of power demand and the amount of power generated by distributed power supply, etc., which was one of bottlenecks in the implementation of an efficient energy operation method at large factories, can be provided through the ENERGY CLOUD® Service. At present, the application of this system to internal and external projects is being promoted.

This system can be applied to demand forecasting for engineering utilities such as steam and water, in addition to electric power. Through demonstrations, we continuously conduct verification of the forecasting accuracy of the system, and in the future, we will develop a technology that enables the creation of an optimal system operation plan from the perspective of operation and maintenance by combining the system with the abnormality detecting technology which has been simultaneously demonstrated.

References

1. News Release from Mitsubishi Heavy Industries, Ltd.
http://www.mhi.co.jp/news/story/1703015844.html