A Two-Tier Forecasting Power Generation Model in Smart Grids

Yen-Wen Wang, San-Jung Peng, and Meng-Hui Chen

Abstract—Smart Grid means the integration of power, electricity transmission, power transmission and its usage in the client side, combine with automation and information technology superiority. It can achieve self-monitoring, diagnosis, repair, and other functions. The power company can use the remote monitoring system to find out the electricity consumption in order to adjust the amount of power needs to be deployed. The clients can also grasp their own power consumption to adjust power usage to achieve energy saving and money saving policy. The main idea in this study is to use cluster approach to cluster the villages and towns as different zones and cluster the data of each zone again to enhance the performance of electricity demand forecasting. If we could predict the electricity demand effective, we would decrease the power consumption. So we use the K-means to cluster the electricity substation, and collect the demand of electricity by each villages and towns to develop the forecasting model. According to the experimental result, the prediction of electricity demand is effective.

Keywords—Power forecasting, K-means, Self-organizing map, Support vector regression.

I. INTRODUCTION

In order to have an ideal Smart Grid deployment, the first is to understand the national and regional power trend, with the development of the basic infrastructure to integrate a complete project. In the recent years, many big countries have begun to conduct major research and construct basis in this area. Since 2001, United States have funded about 20 million in Intelligrid project. The emphasis is on the development of the software architecture and distributed control system interface maintenance and improvement of Smart Grid. From 2002 to 2006, 50 million has been funded for the research. Japan focus is to integrate power supply for a district with the new power system. The new energy system provides technological management to import power for large number of distributed power to conduct research and data analysis. The project is demonstrated in the regional power grid. The total amount of investment is more than 14.7 billion yen. In Europe, European Union has been the major region for renewable energy in the world. It is expected to continually invest 500 billion euros in the transmission and distribution upgrade and update. Therefore, the promotion of Smart Grid requires a long-term planning and investment. Under these conditions, the demand on the control of the resources required and the energy needed to be accurately forecasted has become an important task.

In this paper, we develop a model for electricity demand forecasting of villages and towns in Taiwan. The main idea is to using K-means [7] to cluster all cities in Taiwan and the electricity substation as the central of each cluster. By this way, we can find the cities with high similarity habits of electricity demand.

II. LITERATURE REVIEW

A. Smart grid

In the development of smart grid related fields, the power load forecasting has a very important role. The predicted results can serve as a future basis for national power development plan, electricity demand-side management (DSM, Demand Side Management), and energy procurement. If we distinguish the power load forecasting based on the size of the region, it can be divided into large regional and small regional forecasts. Small regional forecasting problems contain considerable uncertainties especially in short-term load forecasting. Therefore, the majority of small regional forecasting studies have mainly focused on the long-term forecasting. The previous literature indicates that there are many problems when performing load forecasting. The regional development and land use situation has a significant influence on the region's future growth in electricity consumption. Therefore the use of geographic information systems (GIS, Geographic Information System) for analysis of land use in a small regional load forecasting related research is fairly often [14] [17]. Most of the studies only focus on the region overall electricity load demand for forecasting. It cannot focus on individual demand and provide forecasting based on each unit [5]. Lo [8] has pointed out that a good predictive model needs to have the following five characteristics:

1) In different load problems, choose the best predictive models.
2) In different models, choose the best combination of parameters.
III. METHODOLOGY

The effects of electricity demand are various, and the geographical location is one of that. Therefore, the electricity substation is used to be as the central of clusters in this study and adopts the K-means [7] to cluster all the villages and towns. Next step is to select a cluster and use SOM to cluster the data of the clusters again, and using PCA (principal component analysis) [9] to do the feature selection to enhance the accuracy of proposed model. Finally, we adopt the multi factor line regression method to forecast the electricity demand. As following, the proposed model is shown in Fig. 1.

A. Data collection

This study is considered load balancing in Taiwan national power plant to subdivide into regions. Our target is all levels of Taiwan's current power plants (such as: nuclear, fire, water, wind et al.) and investigate its ability to provide power supply. The data for regional demand for electricity across the country also needs to be collected.

B. Cluster the data

After getting the data, the study is hybrid the two cluster approaches to cluster the data. The first stage is to set the electricity substation as the cluster central and using K-means to cluster the villages and towns. The second stage is to select one...
zone and calculate the total electricity demand of each month in the zone. Then we adopt SOM to cluster the electricity demand of each month, where SOM analysis process continues until all input vectors are processed. Convergence criterion utilized here is in terms of epochs, which defines how many times all input vectors should be fed to the SOM for analysis.

C. Forecasting of electricity demand

Multiple regression analysis is applied to learn about the relationship between the independent or predictor variables. For example, the census data has many factors affecting the electricity demand. Therefore, we collect various variables about the electricity demand in this study. Thus, multiple regression analysis is adopted to predict electricity demand. Furthermore, the data include many parameters relative to electricity demand, but there may be several noises to reduce the performance of prediction. So we adopt PCA to do feature selection to enhance the accuracy.

In addition, we also hybrid simple genetic algorithm (GA) and support vector regression (SVR) to construct a simple forecasting model to compare with the proposed forecasting model. In this model, GA is adopted to evolve effective parameters to enhance the performance.

IV. EXPERIMENTAL RESULTS

The data are the electrical load of each electrical substation within 4 years and there are 271 substations in Taiwan area. From the data, there are many variables might influence the electrical load include: Metal/Machinery Industry production Index, Industrial production index, Chemical Industry production index, Traditional industries production index, electricity and gas supply production index, Water supply production index, Buildings construction production index, Composite leading index, Industrial production index, Electric power consumption, Index of Producer’s Shipment for Manufacturing and the last year power supply of 271 electrical substation. As following, we represent the results of the substation clusters and electricity demand.

A. The substation clusters

According to the regional electricity supply and demand data, we used 15 clusters in this study, and the distribution figure is shown in Fig. 2.

B. Forecasting of electricity demand

In this study, we select one zone from the 15 cluster, and set the cluster number 3, 4 and 5 of SOM to cluster the data of the zone again. In addition, we also compare the origin data and the data adopted PCA to do the feature selection.

The data is collected from the villages and towns during 2009/1 to 2012/12 in Taiwan. Therefore, we select the data during 2009/1 to 2011/12 as the training data, and the data during 2012/1 to 2012/12 as the testing data.

Fig. 2 A distribution of 15 clusters of K-means

Fig. 3 3 Clusters Forecasting Results
The result as shown in Table I is represented different cluster number in SOM compared. The measure is adopted mean absolute percentage error (MAPE) given as following:

$$\text{MAPE} = \frac{1}{n} \sum_{i=1}^{n} \frac{|ED_i - ED'|}{ED_i} \times 100\%$$  \hspace{1cm} (1)$$

Where n is the total numbers of testing months.

<table>
<thead>
<tr>
<th>Table I</th>
<th>THE FORECASTING RESULT COMPARED WITH DIFFERENT FORECASTING MODEL</th>
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<td>SOM+MRA</td>
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<td># clusters of SOM</td>
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<td>MAPE</td>
<td>w/o  feature selection</td>
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<td>with feature selection</td>
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As mentioned, according to the results shown in Fig. 3, Fig. 4, Fig. 5 and Table I, it is represented that when using the cluster number-3 by SOM to cluster the data and adopting PCA to do feature selection can get the best result.

V. CONCLUSION AND FURTHER WORKS

In this study, we use two-stage cluster mechanism and multiple regression analysis to develop the electricity demand forecasting model. According to different purpose, we adopt different cluster approaches. Finally, in order to find the key parameters of electricity demand, PCA is adopted for feature selection mechanism. According to results, the best MAPE which is 13.75% represents the performance is effective.

Finally, we select one zone of the 15 cluster to test the performance of proposed forecasting model. Thus the further works suggested is to collect more data to verify the robust of proposed forecasting model and try to hybrid different cluster approaches or feature selection methods to enhance the forecasting accuracy.

ACKNOWLEDGMENT

This research work was supported by the National Science of Council in Taiwan with the contract No. NSC 101-2221-E-231-007-MY3.

REFERENCE


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