A COMPREHENSIVE SYSTEM FOR SHORT-TERM LOAD FORECASTING APPLIED IN SHANGHAI

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ABSTRACT

The level of load forecasting is one of the measures of modern power system management. So load forecasting, especially accurate short-term load forecasting (STLF) is of great importance to power system. The forecasting models of STLF and the development of load forecasting system are studied in the work.

This work studies several practical STLF models, such as time series, least mean squares, gray model and similar day. Integrated optimum model is studied for better utilization of each model, and it is more suitable in STLF.

A whole STLF system based on dispatching automation system for a certain district in Shanghai is successfully developed according to the practical demands of electric power company, with the advantages such as real-time, economy and practicality. Client/Server(C/S) mode is used in the system. Oracle 9i is employed as supporting database platform.

Total load, total load of each distribution voltage (10kV, 35kV and 110kV) can be forecasted in the SLTF system. Abundant forecasting models and methodologies are provided to validate different forecasting results. It has been proved by practical data that this system can commendably satisfy the demands of power dispatching department to forecast short-term load more effectively and can finely meet the required precision.

INTRODUCTION

Accurate load forecasting is an important job for electric power company. The result of load forecasting of a certain district is the foundation of the planning and development of the local power system network, and is also closely related to the economic development of the local district. Short-term load forecasting (STLF) is a significant component part of load forecasting. It is an important daily job for dispatching and operation department, and is a main foundation for making power generation plan and formulating transmission scheme.

The main research object in this work is the forecasting of daily load. According the actual situation of Shanghai, 96-point load of the next day should be forecasted on the basis of the history data saved in the load database, considering other factors such as holiday and weather. The key problem is to raise the precision of the forecasting job. Several practical STLF models are studied in the work, and a comprehensive system is developed upon the studied models.

SEVERAL PRACTICAL STLF MODELS

TIME SERIES MODEL

Time series method is a basic method to process random sequence, and is widely applied in STLF for power system. In this method, power load data is viewed as a fluctuant data sequence with time point, not considering the causal relationship between power load and other factors. Auto regressive model (AR model), moving average model (MA model) and auto regressive & moving average model (ARMA model) are three main models. Considering the calculating velocity in STLF, AR model is selected in the work.

WEIGHTED LEAST MEAN SQUARES MODEL

Least mean squares model is a traditional forecasting method. The history power load sequence is expressed by a certain equation and the future load data will be predicted using the equation based on least square method. [1]

GRAY MODEL

Grey forecasting method is a new nonlinear predicting technology introduced to power system. Compared with other traditional methods, grey forecasting method has some merits such as not needing large samples, not insuring the variation of load obeying normal distribution or not, convenient operation and good forecasting precision. GM(1,1) is a frequently used grey model. Detail derivation can be referred to document [1,2].

But gray model also has its limitations. When the discrete degree of the samples is very large, that is the gray level is very large, the forecasting precision will be badly influenced. Some improvement must be done to better use grey model. [2,3]

SIMILAR DAY MODEL

In actual prediction work, an experienced engineer can find out a similar history day to the forecasting one. The similar day model is based on this idea. It does not need to find out the functional relationship between power load and influencing factors directly. The basic method is based on finding out similar days and predicting upon the difference between the forecasting day and similar day. [4]

The basic procedure of the method includes: (a) Selecting similar days upon three factors. (b) Correction of the load data for similar day.

Similar day method is convenient for actual use and can be combined with the experience of forecasting engineers. It can also take temperature, sunlight intensity and other weather conditions into account. But the method is sensitive to weather forecasting. Bad weather forecasting can lead to inaccurate load predicting directly.

COMPREHENSIVE FORECASTING MODEL

Optimum model is used as a comprehensive model in this work. Let a raw sequence $x_t, t = 1, 2, ..., n$. By using m kinds of methods, we can get m forecasted result sequences $\hat{x}_{it}, i = 1, 2, ..., m; t = 1, 2, ..., N$. Then the integrated optimum model can be expressed as

$$\min \quad z = \sum_{t=1}^{n} (\hat{x}_{0t} - x_t)^2$$

$$s.t. \quad \sum_{i=1}^{m} w_i = 1 \qquad (1)$$

$$w_i \geq 0, i = 1, 2, ..., m$$

It is an optimization model with the decision variable w_i . Detailed solution method can be referred to document [1,5].

DEVELOPMENT OF THE STLF SYSTEM

SEVERAL DESIGNING PRINCIPLES

The STLF system is mainly serving for practical power operation, including some basic principles. (a) Comprehensive forecasting functions, abundant models and be suitable for needs of power operation and dispatching department. (b) Friendly man-machine interface, convenient operation and fast calculation speed. (c) Making full use the experience of forecasting engineers and trying to improve forecasting precision. (d) Adopting modular structure design, with strong extensibility and portability. (e) Emphasizing real time and keeping strong relation with the dispatching system.

GENERAL ARCHITECTURE DESIGN

Modular structure design is adopted in the STLF system, including five main modules: data management module, load forecasting module, error analysis module and results process model. The relationship of each module is as fig1.

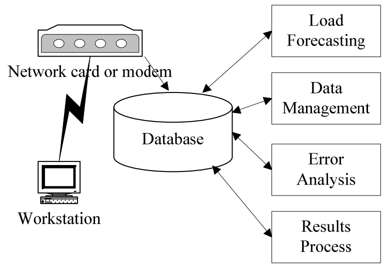

Fig1. Relationship of each module

Data management module

Data management module mainly includes three sub modules: data inputting, data preprocessing, data inquiry and data management. Data inputting module is responsible for data exchanging with the real time database and the input data (raw data) will be stored into the system database. Data preprocessing module is in charge of basic correction processing for the raw data such as bad data identification and correction. Data inquiry module includes inquiry of power load data, load curve and weather condition data. Data management module takes charge of adding and modifying weather condition data, parameters of model management and holiday management.

Load forecasting module

Load forecasting module is the core module of the overall system, including normal day load forecasting and holiday load forecasting. Normal day load forecasting module includes basic and comprehensive forecasting model. Basic practical model is composed of time series model, weighted least square model, gray model, and similar day model. Comprehensive forecasting model contains equal weighted method, integrated optimum model and user-defined method. The engineer can select the forecasting method flexibly upon the actual condition. The final results can be obtained after comparison an analysis of the forecasting results of each method.

Error analysis module

Error analysis module is responsible for error calculation and analysis of the forecasting results in a specified period, including absolute error analysis, relative error analysis and mean-square error analysis. The final analysis results should be output in the form of concise reports.

Results process model

Results process module is exploited for artificial modification of the forecasting results because of significant activities, interruption maintenance or other reasons. The model is also charge of saving, displaying (table or chart) and printing output for the forecasting results. Index and statistic analysis function based on given condition is also supplied in the model.

SYSTEM DATABASE DESIGN

Structure design of the database

The database is a key factor of the forecasting system. It is the foundation of data process and mathematical computation. The structure of the database is as follow.

(a) Weather condition data, including low temperature, high temperature, average temperature, rainfall capacity, wind power, wind speed, atmospheric pressure, air humidity and other weather conditions. It can be imported from the weather database of the local meteorological department with data exchanging interface.

(b) Power load data, including history load data, load forecasting results, forecasting error.

(c) System data, is related to the security of the system, like user type (administrator, senior or normal), user name and login password.

(d) Other data, including parameter data of user-defined comprehensive forecasting model, user-defined holiday information and other influencing factors like special events or significant activities.

Design of the database interface

The forecasting system realizes the real-time copy function from the mirror database of SCADA to the backend database of the system with the snapshot copy function of ORACLE. Snapshot is a subset of the query results of a data sheet. Snapshot function can be used to speed up data query speed. Data updating performance will be greatly improved using snapshot refreshing function.

The mirror database of SCADA is stored in *LoadData* sheet, created in a small workstation *rs600*, with the username *sffw*. *LoadData* sheet is a real time recording sheet, which is refreshed every five minutes. The backend database of the system is stored in another server *xf170*, with the username *dmtcx*. A snapshot *S_LoadData* of *LoadData* is created in the account *dmtcx* to realize the copy function and improve the query speed.

CASE ANALYSIS

The forecasting system has now been used for power dispatching department to predict short-term load. To display the effect of the system, an actual case is given. The power load of June, 2010 in a certain district of Shanghai will be forecasted using the system on the basis of the history data with multi-models developed in the system. The distribution system of the district is operated by a branch company of Shanghai Electric Power Company. The root-mean-square (RMS) error of the forecasting results for total load is showed in table1.

From the forecasting results listed in the table, we can see that in June, power load changes violently, the error of time series, gray and weighted least mean squares model is relatively large to others because the weather condition is not considered in these three models.

Fig2 and Fig3 show the forecasting and real curves of two days in June, 2010. The forecasting curves of weighted least squares and gray model deviate from the real curve obviously, especially for the gray model. So in some months of a certain year like January, June, July and so on (in Shanghai), temperature fluctuates largely, time series, gray and weighted least square model are not qualified to the forecasting job because these models are only deduced based on history data and weather conditions are not considered. Fig4 shows the curves of Nov 8, 2010. The forecasting results of the five models are close compared with the results of June 7 and June 19.

Similar day model is convenient for actual use and can be combined with the experience of forecasting engineers and weather condition. The average error of similar day model is less than 4.5% and can meet the forecasting precision. Optimum model makes full use of the results of each forecasting method effectively and can get better precision. So these two models can be used as main methods in actual forecasting work. In some months with the temperature fluctuating smoothly, time series, gray and weighted mean square model can also be finely utilized and can acquire relatively higher precision. These three models can be used as assist methods.

Table 1 RMS error of the forecasting results for June, 2010

Date	Time series	Gray	Similar day	Weighted least mean squares	Optimum model
6-1	2.89	4.17	2.86	1.33	2.69
6-2	4.35	7.11	3.59	3.53	3.01
6-3	9.72	9.48	8.28	6.73	7.21
6-4	4.67	2.61	4.45	3.96	4.19
6-5	7.16	3.72	1.33	5.93	2.08
6-6	7.22	8.14	3.65	7.40	2.66
6-7	4.47	3.77	2.02	4.54	1.44
6-8	4.8	3.41	3.65	2.63	3.54
6-9	2.97	1.81	1.23	2.36	1.18
6-10	5.21	4.26	4.78	4.71	4.76
6-11	4.61	9.4	2.89	6.28	2.46
6-12	12.8	10.4	2.35	4.61	5.29
…	…	…	…	…	…
6-19	2.52	10.78	2.18	4.8	2.11

6-20	3.28	5.44	3.22	6.24	2.94
6-21	4.21	5.29	2.12	5.70	5.08
6-22	9.2	7.31	4.63	5.55	4.55
…	…	…	…	…	…
6-29	4.4	4.46	8.24	2.77	6.31
6-30	4.63	9.7	6.46	5.12	4.46
Average	5.98%	6.40%	4.02%	4.82%	3.86%

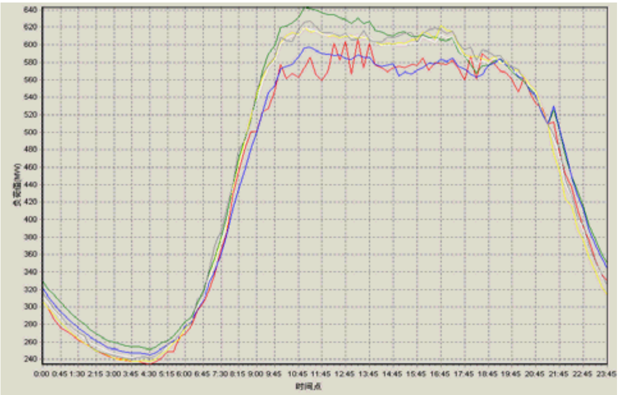

Fig2. Forecasting and real curves of June 7, 2010 (Monday) (red-time series, green-gray, yellow-similar day, bule-weighted least square, white-optimum model, gray-real cure)

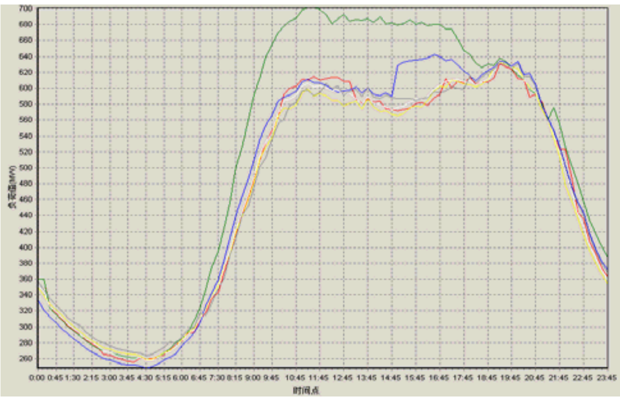

Fig3. Forecasting and real curves of June 19,2010 (Saturday)

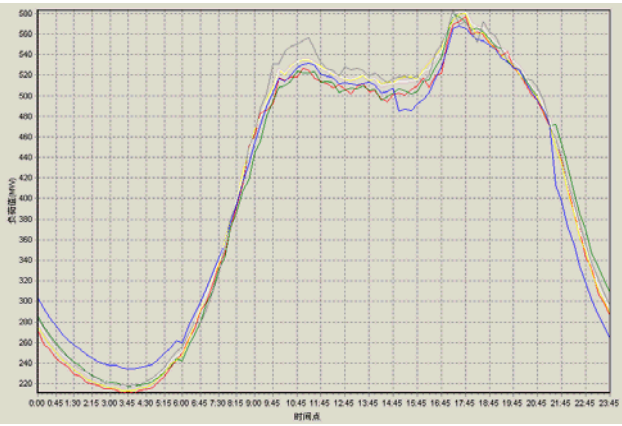

Fig4. Forecasting and real curves of Nov 8,2010 (Monday)

CONCLUSIONS AND PROSPECTS

The forecasting system introduced in this paper is now used in the power supply companies in Shanghai Electric Power Company. It is developed based on SCADA system and is mainly designed for power dispatching department for short -term load forecasting, with the merits such as friendly man-machine interfaces, high work efficiency and good forecasting precision.

The forecasting system mainly works for daily power load prediction, divided into normal day load forecasting and holiday load forecasting. Five models are integrated into the system. Similar day model and optimum model can obtain better precision compared with the other three models, and they are selected as the two main methods. Time series, gray and weighted least square model are selected as the assist methods for weather condition cannot be fully considered in these three models.

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