Available online at www.sciencedirect.com

SciVerse ScienceDirect

AASRI Procedia 1 (2012) 576 – 580

AASRI Procedia

www.elsevier.com/locate/procedia

2012 AASRI Conference on Computational Intelligence and Bioinformatics

Research on Power Load Prediction in the Intelligent Power Grid Environment based on MV Optimum Combined Model

Dongxiao Niu[a], Haochi Guo[a,b], Jinpeng Liu[a], Guanqing Wang[a,*]

[a]*School of Economics and Management, North China Electric Power University, No.2, BeiNong Road, Changping District ,Beijing ,102206,China*

[b]*State Grid Corporation of China, No. 86, West Chang'an Street, Xicheng District, Beijing, 100031,China*

Abstract

Along with China's construction of high voltage grid and the deepening of the reform in the power system, intelligent power grid will become a strategic direction for China's power grid development. In the intelligent power grid system, the power load has new change features due to the energy using change and the impact of the difference in price. This paper comparing the gray model, the trend fitting model and MV method, MV method is more accurate in forecasting than other methods, and can help to improve the power load forecasting management level in intelligent power grid construction.

Keywords: the Intelligent Power Grid; Power Load Forecasting; MV Optimum Combined Model

Along with China's construction of high voltage grid and the deepening of the reform in the power system, intelligent power grid will become a strategic direction for China's power grid development. In the current international environment that energy conservation and emission reduction, green energy, the sustainable development become the focus attention of the countries, the first challenge for human energy development is that to replace fossil fuels by renewable energy gradually， to build energy use innovation system, to transform the existing energy system using the information technology, and to maximize the grid system of

* Corresponding author. Tel.: +86-010-51963345.
E-mail address: wangguaner123@163.com.

doi:10.1016/j.aasri.2012.06.089

energy efficiency. And at present the strong intelligent power grid in planning and construction is just meet this demand.

From technology development and application perspective, Strong intelligent power grid is the network which makes the high-voltage electric network for the backbone network frame, all levels of the coordinate power grid network for the foundation, communication and information platform for the support, with information technology, automation, interactive features; and includes all aspects of power system generation, such as transmission, substation, power distribution, power and scheduling; and to achieve a high degree of integration of the power flow, information flow, business flow, "the fusion of modern power grid[1].

1. Power load forecasting under the background of intelligent power grid

In the intelligent power grid, the user will be an integral part of the power system, and it is an important feature for the intelligent power grid to encourage and facilitate participation in the power system operation and management. In the construction and management process of intelligent power grid, it is much more important and urgent to do the high quality power load forecasting, and the predictive accuracy is closely related to the interests for system operation and users.

Based on high quality power load forecasting results, the power supply enterprises work out a reasonable real-time pricing according to the grid load rate to manage users to guide their electricity consumption to balance the relationship of power supply and demand, making load shifting to improve the system load rate, and to ensure power quality and reliability of power supply and improve the security and stability of the grid. In addition to provide more accurate, timely variable electricity price information to intelligent power grid users, to provide them sufficient power consumption cost and power network operation state information, then the users could have many schemes to arrange their reasonable and economic power consumption[2].

2. MV optimum combined model

Power load forecasting is to make the demand prediction for electricity in the future based on the known requirement, considering the political, economic, climate, energy alternative factors, etc. The power system load forecasting is more complicated due to changes in energy used in the intelligent power grid environment. Therefore it needs to choose a better precision prediction method to complete the work.

In a long period, the prediction precision is difficult to meet the requirements which used single forecasting method. Relatively, combination forecast model has a higher predictive performance and a smaller risk of extreme prediction errors.

（1）the Gray Model

The Grey Model is an effective prediction model, constituted only by the first order differential equation which contains a single variable. The theory has been proved that this method has many advantages, such as required less sample data, high prediction precision, simple calculation and verifiable, when the basic data is strictly index increase [3].

The basic modeling process is as follows:

1）Assuming a raw data sequence with the variable $x^{(0)}$

$$x^{(0)} = \left[x^{(0)}(1), x^{(0)}(2), \cdots, x^{(0)}(n) \right] \quad (1)$$

2）Generating first-order accumulation sequence by 1-AGO (Accumulated Generating Operation):

$$x^{(1)} = \left[x^{(1)}(1), x^{(1)}(2), \cdots, x^{(1)}(n) \right]; \text{ In which: } x^{(1)}(k) = \sum_{j=1}^{k} x^{(0)}(j); k = (1, 2, \cdots, n) \quad (2)$$

3）Calculating the background value {z(k)}，k=(1,2,⋯,n)：

$$z(k)=\frac{1}{2}\left(x^{(1)}(k-1)+x^{(1)}(k)\right) \tag{3}$$

4）The sequence of x(1) satisfies the following first order linear differential equations model:

$$\frac{dx^{(1)}}{dt}+ax^{(1)}=u \tag{4}$$

5）Using least square method to solve the two parameters $\hat{a}$ and $\hat{u}$:

$$\begin{pmatrix}\hat{a}\\ \hat{u}\end{pmatrix}=\left(B^TB\right)^{-1}B^TY_n\ ;\ In\ which:\ Y_n=\left(x^{(0)}(2),x^{(0)}(3),...,x^{(0)}(n)\right)^T,\quad B=\begin{pmatrix}-z(2) & 1\\ -z(3) & 1\\ \cdots & \cdots\\ -z(n) & 1\end{pmatrix} \tag{5}$$

6）Calculating the gray predictive value $\hat{x}^{(1)}(k+1)$ of $x^{(1)}(k)$,

$$\hat{x}^{(1)}(k+1)=\left(x^{(0)}(1)-\frac{u}{a}\right)e^{-ak}+\frac{u}{a},\quad k=1,2,\cdots,n \tag{6}$$

7）Calculating the gray predictive value $\hat{x}^{(0)}(k+1)$ of $x^{(0)}$ by IAGO (Inverse Accumulated Generating Operation):

$$\hat{x}^{(0)}(k+1)=\left(1-e^{a}\right)\left(x^{(0)}(1)-\frac{u}{a}\right)e^{-ak},\quad k=1,2,\cdots,n \tag{7}$$

（2）The trend fitting model

The trend fitting model is fitting one curve according to the known historical material, which reflects growing trend in original data itself. Then according to the simulation trend curve, it can estimate the corresponding moment predictive value for the future requirement.

（3）the MV optimum combined model

Optimal combination forecast is the method which selects appropriate weight for some results by other methods to make the weighted average. This paper mainly determines the weights for different prediction method based on Variance-covariance method（MV）[4]，and the principle are as follows:

Assuming f_1、f_2 is two unbiased prediction of f, f_c is the predicted of weighted average, Prediction errors are e_1、e_2 and e_c respectively.

Take ω_1 and ω_2 as the corresponding weight coefficient, and ensure $\omega_1+\omega_2=1$:

$$f_c=\omega_1f_1+\omega_2f_2 \tag{8}$$

Require f_c is unbiased and their errors are:

$$e_c=\omega_1e_1+\omega_2e_2 \tag{9}$$

Making $Var(e_1)=\sigma_{11}$，$Var(e_2)=\sigma_{22}$，$\mathrm{cov}(e_1,e_2)=\sigma_{12}$.

The combination forecast weight coefficients of the two forecast methods were:

$$\omega_1=\frac{\sigma_{22}-\sigma_{12}}{\sigma_{11}+\sigma_{22}-2\sigma_{12}},\quad \omega_2=\frac{\sigma_{11}-\sigma_{12}}{\sigma_{11}+\sigma_{22}-2\sigma_{12}} \tag{10}$$

e_1 and e_2 are mutual independence, so $\sigma_{12} = 0$, and:

$$\omega_1 = \frac{\sigma_{22}}{\sigma_{11} + \sigma_{22}}, \quad \omega_2 = \frac{\sigma_{11}}{\sigma_{11} + \sigma_{22}} \tag{11}$$

（4）The Average Relative Error Inspection

In practical applications, the average relative error e_{MAPE} are often used as the basis for comparison.

$$e_{\mathrm{MAPE}} = \frac{1}{n}\sum_{i=1}^{n}\left|\frac{x(i) - \hat{x}(i)}{x(i)}\right| \times 100\% \tag{12}$$

In which, $x(i)$ expresses the original data; $\hat{x}(i)$ expresses the simulation results by using models and original data.

3. Example Analysis

The history data of power load in certain city from 1995 to 2010 was used in the following part to check the accuracy of the established combined model.

（1）the grey model

Based on the data of power load in certain city from 1995 to 2007 and the theory of grey model, the predicted installed capacity from 2008 to 2010 is shown in Table 1.

（2）Trend fitting model

The prediction using trend fitting model was performed based on the data of power load in certain city from 1995 to 2007. The steps were shown as follow:

First, the category of data should be analyzed, as Fig.1 shows.

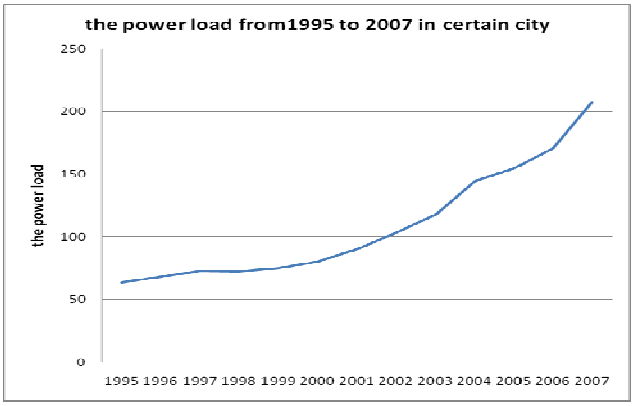

Fig.1 the power load change trend chart in 1995-2007

Then, the trend fitting was performed based on the trend of the cave in Fig.1 and the statistics from 1995 to 2007. A quadratic function was used to perform the fitting test based on the result that was got through many modal of fitting and the principle that the closer the R2 to 1, the better the result is. The result of prediction through trend fitting was shown as follow:

$$y = 1.197x^2 - 5.638x + 73.05$$

The range of R2 was from 0 to 1, it represented the fitting degree between prediction and reality. When R2 was very close to or equal to 1, its reliability was high, and it was called the coefficient of determination. In this case, R2=0.990, which meant that the fitting degree was good. Finally, the prediction of data from 2008 to 2010 was given in Table 1.

（3）MV optimization combinatorial model

The weights of grey model and trend fitting were calculated based on the theory above:

$$\omega_1 = 0.21528\ ,\quad \omega_2 = 0.78472$$

Results got through MV optimization combinatorial prediction were shown in Table 1:

（4）Precise inspection of model

The average error inspection was introduced to perform the precise inspection of the three models above, and results were shown in Table 1:

Table 1 the average error inspection result (Unit: 100 million kWh)

year	actual value	predictive results of Grey Model	predictive results of the trend fitting model	predictive results of MV model
2008	232.51	217.63	228.73	226.34
2009	252.80	244.45	257.81	254.93
2010	261.55	274.57	289.27	286.11
e_{MAPE}		4.89%	4.74%	4.30%

As shown in the Table 1, in terms of e_{MAPE}, the precise of MV optimization combinatorial prediction model was higher than the others. Thus, under the new situation of intelligent power grid construction, the MV optimum combined model can get the more excellent power load forecast management.

4. Conclusion

By comparing the gray model, the trend fitting model and MV method, MV method is more accurate in forecasting than other methods used only one method. Under the new situation of the deepening intelligent power grid construction, the high accuracy of the prediction model could guide load forecasting management and enhance comprehensive benefits.

References

[1] CHEN Shu-yong,SONG Shu-fang,LI Lan-xin,SHEN Jie. Survey on Smart Grid Technology. Power System Technology, 2009,33(8):1-7.

[2]WANG Jian-Jun. Research on Adaptive Interactive Intelligent Load Forecasting in Smart Grid Environment. SHANXI ELECTRIC POWER,2010(5):11-15.

[3]GAO Qing-min,MENG Fan-wei,WANG Li-ping,CAI Yu-fei. Electrical Load Forecast of Data Mining Model in Smart Grid. Journal of North China Institute of Water Conservancy and Hydroelectric Power, 2011,32(3):43-45.

[4]Dongxiao Niu, Shuhua Cao, Jianchang Lu, Lei Zhao. Electric power load forecasting technology and its application. Beijing: China Electric Power Press, 2009.