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Power System Short Term Load Forecasting Based on Markov Chain

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ABSTRACT

Power system load forecasting is basic aspect in planning of city power grid; it is a pre- requisite of ensuring reliable operation of power system, too. The key issue is to build proper mathematical models. A new method based on the combination of fuzzy clustering and Markov chain is presented. Status analysis of an object is carried out using the Markov chain, while fuzzy clustering is employed to the states of samples to suit the real case. According to state transfer, the load change is predicted. This algorithm is applied on power load forecasting in certain district of Qinghai province, and compared with real data. Simulation results show that the error can be limited to with- in 5%, which verify the high accuracy of application of Markov model to short—term load forecasting.

Keywords: Markov chain, fuzzy clustering, load forecasting

INTRODUCTION

The so-called power load prediction refers to the analysis of historical data of power load, the estimation of power system demand and the study of the influence of related factors on power load through specific mathematical methods or the establishment of mathematical models based on the change of power load and the change of external factors.

Load forecast includes two aspects: the meaning of power demand forecasting decided to power generation, transmission and distribution system the size of the new capacity; The forecast of electricity demand determines the type of power generation equipment, such as the basic load type of two units.

Load forecasting to meet both conditions is the reliability of the historical data information; Second, the effectiveness of prediction methods.

The core problem of load forecasting is how to use the existing historical data (historical load failure data and meteorological data, etc.) to estimate the power value and power quantity value in the future time or time period with appropriate prediction methods.

The purpose of load forecasting is to provide the load development status and level, and at the same time to determine the power supply area, the annual planning power supply and consumption, the maximum load for power supply and consumption and the overall load development level of the planning area, to determine the annual planning power load composition.

Power system load forecasting is related to power system dispatching operation and production planning. Accurate load forecasting is helpful to improve the security and stability of the system and reduce the cost of power generation.

Power system operation process, the power load forecasting problem for many power sector plays an important role, it relates to power system planning and design, economic safe operation of power system and electric power market transaction, and many other aspects.

BRIEF DESCRIPTION OF MAIN PREDICTION METHODS

Generally, there are two kinds of prediction methods: classical method and modern method. The classical methods include trend extrapolation, time series and regression analysis. Modern methods mainly include grey theory method, expert system method, neural network theory, fuzzy prediction method, support vector machine method, wavelet analysis method. No matter it is a classical method or a modern method, its mathematical model is the fitting of the historical load curve, and the prediction of future load is realized by setting parameters and parameters.

Model in terms of the commonly used model with regression analysis model, random event sequence model, artificial neural network model, grey prediction model and wavelet analysis forecast model and combined forecasting model, the neural network model, the wavelet analysis model is used in short-term, short-term prediction, gray prediction model, the regression analysis model, trend extrapolation model is more suitable for medium and long-term prediction.

With the continuous development of the power industry and the gradual entry into the market, load forecasting is playing an increasingly important role in the power industry. Well has become the core business of the marketing and trading department, which also puts forward higher requirements for the accuracy and stability of load forecasting.

CLASSIFICATION OF POWER SYSTEM LOAD FORECASTING

(1) ultra-short-term load forecasting refers to the future within 1h of the load forecasting, in the state of safety monitoring, need 5-10s or 1-5min of the predictive value, preventive control and emergency treatment need 10min to 1h of the predictive value.

(2) short-term load forecasting refers to the daily load pre-load and weekly load respectively used to arrange the daily and weekly scheduling plan, including determining the starting and stopping of the unit, water, fire and power coordination, contact line switching power, load economic distribution, reservoir operation and equipment maintenance, etc. For short-term forecasting, it is necessary to fully study the law of power grid load change, analyze the relevant factors of load change, especially the relationship between weather factors, daily type and short-term load change.

(3) medium-term load forecasting is to point to month to year of load forecasting, main is to determine the unit operation and equipment overhaul plan, etc.

(4) long-term load forecasting refers to the future 3-5 years based to a longer period of load forecasting, mainly based on the power grid planning department according to the development of the national economy and the demand for power load, the power grid transformation and expansion work of the vision plan. For medium - and long-term load forecasting, special study should be made on the impact of national economic development and national policy reform.

Under the inevitable trend of power system marketization, short-term load forecasting has become an indispensable part of power planning and development. In practical applications, the different part of electric power system short-term impact on the scope and accuracy of load forecasting is different, so the short-term load change inherent law and load characteristics, related factors that affect the short-term load change and various related factors in predicting how to normalize the process, to improve the prediction accuracy and is of important significance for the development of load forecasting.

CHARACTERISTICS OF POWER LOAD FORECASTING

Since load forecasting is based on the past and present of power load to predict its future value, the object of load forecasting is uncertain events. Only uncertain events and random events require people to use appropriate prediction techniques to deduce the development trend and possible state of load. This makes the load forecasting has the following obvious characteristics: inaccuracy, conditionality, timeliness and multi-scheme.

4.1 Uncertainty

Because the future development of power load is uncertain, it will be affected by a variety of complex factors, and the various impact factors are also the development of change. These developments, some of which can be anticipated, some of which are difficult to foresee in advance, coupled with the effects of temporary changes, determine the inaccuracy or incomplete accuracy of the forecast results.

4.2 Conditional

Various load forecasts are made under certain conditions. For conditions, they can be divided into necessary conditions and assumed conditions, if the load operator is to grasp the nature of the law of power load, then the prediction conditions are necessary conditions, the prediction is often more reliable. In many cases, due to the uncertainty of future load development, some assumptions are required.

4.3 Timing

Each kind of load forecast all has the certain time scope, because the load forecast belongs to the science forecast category, therefore, requests to have the quite definite quantity concept, often needs to specify the forecast time definitely.

4.4 Multiple solutions

Due to the uncertainty and conditionality of the prediction, sometimes it is necessary to predict the possible development of the load under various conditions, and different load prediction schemes will be obtained under various conditions.

EXISTING PROBLEMS IN CURRENT PREDICTION WORK

5.1 Theoretical research is divorced from practical application

In the past, the main direction of domestic theoretical research was the prediction method theory, model and optimization, algorithm and optimization, etc., and a lot of studies were conducted. However, few cases were widely promoted and applied. Due to the lack of effective and practical technical support, most of the methods used in the application field are still empirical methods, such as "dividing pork from the top to the bottom" or "assembling plates from the bottom to the top", which are not highly theoretical and have low prediction level.

5.2 Insufficient ability to predict the response to changes

Depending on the huge inertia of the whole society, the prediction based on the empirical method usually does not have a big deviation. But since the 2008 financial crisis, the power load experienced a sharp wave process, engaged in before the sign to the subsequent development of load forecasting work faces many difficulties, lack of effective tools to make scientific analysis and judgement, basically follow the government's caliber, predicted results always slow half racket reality problem is relatively common, had to frequent revision.

5.3 Power load research has not received sufficient attention for a long time

Electric power is a special commodity, its application scope permeates and covers all aspects of social production and life. Therefore, it is conceivable that there are many factors affecting electric power load, and the mechanism of these factors is complicated. As deepening the reform of electric power system, with new energy technology, energy technology, energy storage technology as a representative of advanced science and technology to accelerate the popularization and application, with the emergence of various new type electric appliances, over the years the load side had profound changes, the diversity of power load, crosslinking, randomness and other issues become more prominent.

Different from other commodity producers, the main concerns of the power system are power supply security, overall load control, etc., while the user segmentation needs to be strengthened, such as user segmentation classification, electricity information tracking and accumulation, data mining and analysis, etc. Especially need to point out that for a variety of factors influencing power load and the mechanism of the lack of in-depth study, such as all kinds of economic/environmental/energy policies, industry and industry structure, the boom of industry/industry development, domestic and international political and economic environment, the primary energy supply and prices, the user power consumption habits, new technology development and meteorological factors such as climate and mechanism, and the effect of electric power market under the condition of electricity price information feedback.

5.4 The degree of informatization in the prediction field needs to be improved

Power load forecasting needs to analyze and process a lot of information, which requires not only reliable data sources, but also comprehensive and detailed data. However, the reality is that both the academic research field and the practical application field are faced with the problem of data acquisition, which is mainly reflected in the lack of data acquisition channels. Even if there are channels, there are also problems such as numerous data records, incomplete data recorded, discontinuous statistical caliber and so on.

The rapid development of information technology, the scope of application is expanding, its role has been widely recognized. However, the informatization work in the field of power load prediction mainly remains on the lower level applications such as paperless office and intermediate information interaction.

At present, there are systematic researches on short-term load forecasting models at home and abroad. The main existing power load prediction technologies include artificial neural network, fuzzy neural network, etc. The latest research trend is to use wavelet decomposition to analyze the quasi-periodicity and non-linearity of time series and establish mathematical models respectively. None of these analysis techniques take into account the influence of meteorological factors. In practical application, the power load data itself is greatly affected by meteorological factors, and the fluctuation of the sequence itself is also large, so the prediction accuracy of random terms becomes a problem. In fact, demonstrated the randomness of the item due to random sequence is formed by the interference of meteorological factors, but each month and there is a certain correlation between meteorological factors, therefore, can make use of Markov chain to describe a system, the random change of it according to the state transition probability between to speculate the future development of a system change, therefore, Markov chain is suitable to describe the prediction problem of random volatile.

Electric power load data of the chaos characteristics, pure randomness and strict, so from the viewpoint of stochastic process with Markov chain model for data processing can make up for the loss of information.

MATHEMATICAL MODELS IN LOAD FORECASTING

6.1 Markov chain

Markov chain is a special stochastic process which has no aftereffect. This no-aftereffect is defined as: the probabilistic property of the state of the process at t_m time t is only related to the state of the process at time, and has nothing to do with the state of the process before time. Time - discrete and state - discrete Markov processes become Markov chains. Its mathematical expression is:

Defined in the probability space of (ξ, F, P) the random sequence on $\{X_{(t)}, t \in T\}$, including $T=\{0,1,2......\}$, state space $I=\{......\}$, called the Markov chain. If for any positive integer l, m, k and any nonnegative integer $j_l > j_2 > j_1 (m > j_l)$, j_{m+k}, j_m, j_l, ... j_2, j_1

$$P\{X(m+k)=i_{m+k}|X_{(m+k)}=i_m, |X_{(j_l)}=i_{j_2}, X_{(j_l)}=i_{j_l}\}=P\{X(m+k)=i_{m+k}|X_{(m)}=i_m\} \quad (1)$$

Was established. If for any $k,\ n \in N^+$, which have

$$P_{i,j}(n,k)=P_{i,j}(k),\ i,\ j=0,1,2,\ ...... \quad (2)$$

Among which $P_{i,j}(n,k)$ represents "the probability that the state of the system at time n is i and that it is transferred to state j through k steps", and $P_{i,j}(k)$ represents "the probability that it is transferred from state to state through steps". In this case, Markov chain is said to be homogeneous.

In power load forecasting, set $X^{(0)}=[X^{(0)}(1), X^{(0)}(2), \ldots X^{(0)}(n)]$ for the load of the observation sequence, $\hat{x}^{(0)}(1),\ \hat{x}^{(0)}(2), \ldots \hat{x}^{(0)}(n)$ for observation sequence simulation values, the value reflects the change tendency of the observation sequence. When $k>n$, $\hat{x}^{(0)}(k)$ to predict the true value. For an accord with the characteristics of Markov chain are non-stationary random sequence $X^{(0)}$, with m+1 the parallel to the trend line $\hat{x}^{(0)}$ of the curve can be divided into m range, represents a kind of state of each interval. Its arbitrary state E_j can be expressed as:

$$E_j \in [\otimes_{1j},\ \otimes_{2j}],\ j=1,2, \ldots m \quad (3)$$

The $\otimes_{1j}=\hat{x}^{(0)}+\varepsilon_{1j}\overline{x^0}$ÿ$\otimes_{2j}=\hat{x}^{(0)}+\varepsilon_{2j}\overline{x^0}$ÿ$\varepsilon_{1j}$ and ε_{2j} constant for translation, the regulating effect to the interval. Because $\hat{x}^{(0)}$ is the change over time, so $\otimes_{1j}$ and $\otimes_{2j}$ also order at any time to change, namely E_j dynamic. The number of states m can be determined according to the specific research object and the characteristics of the original data.

2.1 Fuzzy ordered clustering

The purpose of applying fuzzy ordered clustering method is to divide the variation interval of load on the basis of fully considering the data structure of load sequence. Let a category of variable $x_1,\ x_2,\ \ldots,\ x_n$ be $\{x_i,\ \ldots x_j\},\ j \geq i$, and its mean vector is defined as:

$$\bar{x}_{ij}=\frac{1}{j-i+1}\sum_{l=i}^{j} x_l \quad (4)$$

The diameter of $x_i,\ \ldots x_j\},\ j \geq i$ is:

$$D(i,j)=\sum_{l=i}^{j}(x_l-\bar{x}_{ij})'(x_l-\bar{x}_{ij}) \quad (5)$$

It represents the difference between variables within the variable segment. The smaller $D(i,j)$ is, the smaller the difference between variables in this section is. Conversely, the greater the difference between variables in the paragraph.

The n ordered variables are divided into k categories: $P(n,K)$:{ i_1=1, …, i_2-1}; { i_2, …, i_3-1}; …{ i_k, …, n}

The error function defining this classification is:

$$e[P(n,K)]=\sum_{j=l}^{K} D(i_j,\ i_{j+1}-1) \quad (6)$$

Calculate the curve of min{$P(n, K)$]} and K, the corner of the K value is the optimal classification tree, according to the min{$P(n,K)$]} the recursion formula to calculate the corresponding optimal classification criteria.

In the ideal state, each kind of influence or interference produces a type of load change, but the actual situation is more complex, such as the power supply system is restricted by a variety of comprehensive factors, so the simple division of the change result will increase the error rate. After the initial value is set, the algorithm converges and the clustering result is obtained.

Set the first k days of load and the load of interpolation for x_k k-1 day, clustering number is c, the current clustering center, according

$$\mathrm{to}\tau_{(x_i)}=\frac{\left(\frac{1}{||x_i-m_i||^{(2)}}\right)}{\sum_{k=1}^{c}\left(\frac{1}{||x_i-m_i||^{(2)}}\right)} \quad (7)$$

The membership degree is calculated, and the current membership degree is used to update the clustering centers according to formula (8).

$$\mathrm{m}_j=\frac{\sum_{j=1}^{n}[\tau_j(\mathrm{x}_i)]^2}{\sum_{i=1}^{n}[\tau_j(\mathrm{x}_i)]^2} \quad (8)$$

According to Bayes' principle, the sample sequence is divided into different class sequences, which meets the following conditions (X is the sample space):

$$P(\omega)p(X|\omega_i) > P(\omega)p\big(X\big|\omega_j\big),\ (i \neq j) \quad (9)$$

Because we're talking about Markov chains, then

$$P(\omega_i)= P(\mu_{i1},\ \mu_{i2},\ \ldots\mu_{in})= P(\mu_{il})\prod_{k=2}^{n} P(\mu_{ik}|\mu_{i(k-1)}) \quad (10)$$

Judge the category of the last sample of the sequence, that is, the sample before the prediction time, and get the predicted value from the mathematical model established by this category.

EXAMPLE ANALYSIS

The following is the monthly electricity sales data of a region in Qinghai province to illustrate the Markov chain's prediction of power load. Figure 1 is the daily peak load value for 20 consecutive days in August. There was a jump on the 7th day, indicating that there was a change in climatic factors on that day (in fact, there was a rainstorm on that day), and other conditions were similar. It can be seen that load changes can be divided into various categories, and there is indeed a trend for each category to be transferred to other categories, which is determined by its transfer probability.

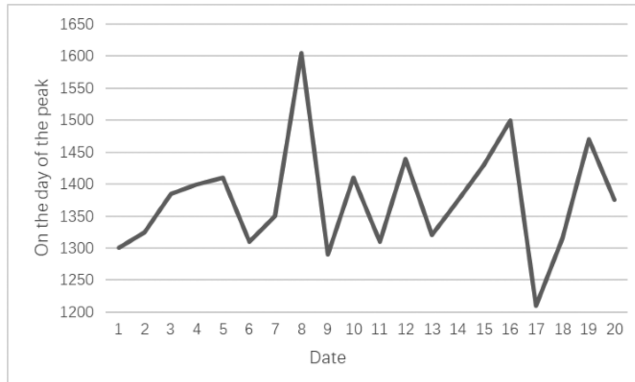

Fig.1 The diagram of peak value of daily load

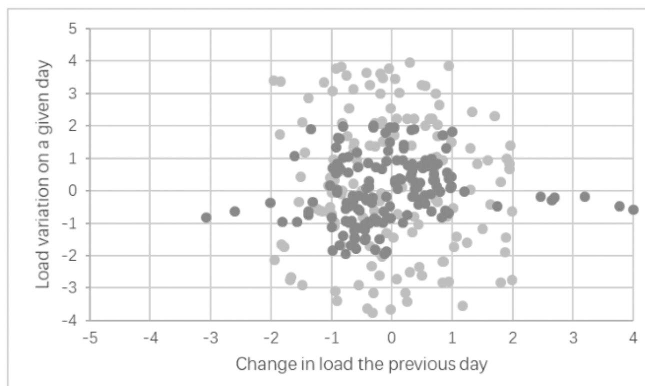

Fig.2 The result of load change clustering

As can be seen from figure 2, the samples are divided into 6 categories, which basically represent the possible change trend. After clustering, the calculated sample of Markov chain transition probability belongs to the category with the largest membership degree.

In the case that the sample is not greatly disturbed, the load value changes very little, so the probability of category transfer to itself is very high. However, this kind of transfer can only provide repeated information, so part of the samples in this category should be deleted when calculating the transfer probability. The probability that a sample belongs to a category is set as the inverse square of its distance from the center of that category.

The effects of different disturbances on the load are often the same, such as an increase in temperature that increases the load. And after heavy rain or the next day after rain, the load drops dramatically. Therefore, two consecutive load differences were selected as samples for classification. After the calculation of all samples, the error between the actual value and the predicted value is shown in table 1.

Tab. 1 The error of power load forecasting in Aug. 2004. Qinghai province

Date	The actual value	Predictive value	Error
2	3.274	3.121	4.67
8	3.556	3.518	1.07
10	3.247	3.163	2.59
15	3.565	3.523	1.18
17	3.474	3.456	0.52
20	3.899	3.952	-1.36
22	4.621	4.552	1.49
26	3.741	3.752	0.43

The results of the above numerical simulation are shown in figure 3. According to the results in table 1 and figure 3, the prediction accuracy is basically accurate.

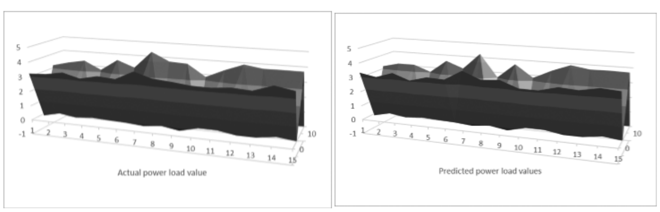

Fig.3 The comparison between read value and forecasting value, Aug 2004. Qinghai province

CORE ISSUES OF POWER LOAD FORECASTING RESEARCH

What is the core problem of power load forecasting? There is no unified answer to this question in the existing literature, and no authoritative explanation. Is it a prediction method or a mathematical model based on various mathematical theories? Or optimization algorithms? After all, most of the existing academic research focuses on these two fields. Unfortunately, both the current situation that theoretical research is out of line with the actual application, and the embarrassing reality that electric power prediction is led by the actual load, all these evidences tell us that the current research direction of electric power load prediction is greatly biased.

So, what is the core problem of power load forecasting research? Combined with the current research status, this bold proposal is the power load, this should be early research but long-term not enough attention to the object. It must be pointed out that the study of the power load is not confined to the daily load current, load, annual load historical data analysis and curve fitting, and the error analysis and data mining, need further to develop in the direction of segmentation, and to establish a long-term continuous tracking was studied for the various influence factors and mechanism of mechanism. Only to clear up we can see the history behind the curve is composed, which segment content clear how they are under the influence of the related function, maybe we can truly effective prediction method is put forward, which can be put in more close to the real load mathematical model, and according to the strength of the effect factors, speed, and proportion of theory of complex method and the precise mathematical model is simplified, practical, academic research to practical application of the transformation of the transition.

DISCUSSION ON FUTURE LOAD FORECASTING RESEARCH

(1) change the understanding and return to the problem itself

The research of power load prediction is the research of power load in the final analysis. Both the proposal of prediction theory method and the construction of specific model algorithm should come from and serve for these. There is no doubt that the fundamental and the complexity of power load research, giant quantification is a great challenge, the multi-factor electricity monitoring information acquisition, time-consuming tedious sample accumulation and huge data processing analysis problem is obvious, but it is the nature of power load property, is also a debt load for many years research in the field of history.

(2) prediction work should be “more emphasis on pre-testing and less testing”

The essence of power load forecasting is still a forecasting problem. The key problem to be solved first is “pre-forecasting”, which is to judge the future trend of change, including the overall trend and the possibility of the development process under the influence of various factors. “Test” is to give the future load value, “light test” does not mean that the load value is not important, but that the load value should not be unique, static, should be based on the judgment of the trend of change on the basis of the continuous band load interval, and combined with the trend of the development of the recommended curve of the dynamic process.

(3) practical application of theoretical research should be strengthened

The research in the field of power load prediction should focus on the practicality. Unrealistic models or overly complicated mathematical theories will not help solve the problem, and the academic attitude of research for research's sake is even less desirable. At present, the realistic demand of power load forecasting is more and more urgent. The application fields of planning and design, operation scheduling and power market transaction are eager to obtain practical and effective forecasting tools.

(4) promote the application of information technology

Power load prediction research is bound to face a large number of data collection, transmission, storage, extraction, analysis and decision-making, relying on manpower to complete the efficiency is low, in fact, can not deal with. The application of information technology means can greatly reduce the difficulty and work intensity of data processing, and can also be used to establish long-term continuous tracking and monitoring, to provide effective support for user segmentation and classification, influencing factors sorting and mechanism research, so as to give play to the advantages of rapid response to information technology and greatly improve efficiency.

CONCLUSION

When short-term power load changes, it is a stationary stochastic process. How to comprehensively consider various factors influencing load changes is a difficult point. After the load is affected by weather factors, there is a certain change trend. The trend is classified by fuzzy clustering method, and then markov chain is used to predict. The experiment shows that the error range is controlled within 5%, and the short-term power load can be predicted accurately.

The general public and a host of other interested parties regarding the enactment of sustainable initiatives in corporations as they seek to make more informed decisions regarding sustainable initiatives.

BIOGRAPHICAL NOTES

Yidong Fang is a student majoring in electrical engineering and automation at the school of engineering technology, Beijing normal university, Zhuhai. Major in electrical engineering and automation, second degree in finance (financial investment). During my college years, the course design of power plants is to carry out load prediction in the next ten years, so I have some experience in this aspect.

Bowei Wu is a student of electrical engineering and automation at the school of engineering and technology, Beijing normal university, Zhuhai. He has many opinions on the simulation of electric load.

Yuqing Huang is a student majoring in electrical engineering and automation at the school of engineering technology, Beijing normal university, Zhuhai. She has dabbled in various aspects and has a deep understanding of software and hardware.

Shengbo Chen is a student majoring in electrical engineering and automation at the school of engineering technology, Beijing normal university, Zhuhai. He has a better understanding of wind-solar complementary power generation.

Dongchu Zhao is a student majoring in electrical engineering and automation at the school of engineering and technology, Beijing normal university, Zhuhai. He has a comprehensive understanding of the photovoltaic power generation of DAMS.

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