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China's Energy Consumption Demand Forecasting and Analysis

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Abstract: This study analyzes the advantages of Support Vector Regression (SVR) in the prediction of energy demand, decides the set of input vectors and output vectors and then establishes the model of prediction of Energy demand by SVR based on Matlab technology Modeling and Simulation of Energy demand from 1985 to 2009. At last, we apply this method to predict the demand for energy of china in 2010 and 2020. The article drew following conclusions: On the one hand, with the development of economy of china, the demand of energy will gradually increase from 31.553 million tons in 2010 to 45.30 million tons in 2020, with an annual increase of about 2.39 %. On the other hand, the SVR better than bp neural network about forecast accuracy, the long existing problem with the small sample¡¢non-linear and pattern recognition of energy system will be soon solved.

Key words: Support vector regression, energy demand, forecast

INTRODUCTION

Energy is not only an important material base for human survival and development but also the major strategic materials for lifeline of the national economy and the national security. Since the reform and opening-up, china's energy demand has showed a rising trend year by year with the rapid growth of economy and the adjustment of industrial structure. According to statistics, China's total energy consumption was 3.066 billion tons of standard coal in 2009. And according to international experience in the mid-term of industrialization and re-industrialization stage, China's growth situation of energy consumption is on the left of the "climbing" stage in the "environmental Kuznets curve", the demand for energy will also be increasing. It is expected that China's industrialization and urbanization advance-ement would come to an end around 2020 (He *et al*., 2009; Lin and Liu, 2010). It can be said that energy demand will continue to grow rapidly for a relatively long time in the future and the situation of energy supply and demand is still very serious. Therefore, this study seeks the scientific forecasting method, do a good job in the future energy demand analysis, it has important practical significance.

In the 1970s, the outbreak of the "oil crisis" made the scholars from various countries pay attention to energy issues. With China's growing demand for energy, it is of more urgent concern. Many domestic and overseas energy agencies or related institutions, mainly from the two angles of economic theory and engineering theory, did a lot of research on the factors influencing energy demand, energy demand forecast and forecasting methodologies. About energy demand forecast and forecasting methodologies. The representative prediction methodologies that have been widely used in research and prediction of energy demand include MARKAL (Market allocation) model, scenario analysis, elastic coefficient, static or dynamic input-output analysis, time series and so on (Khazzoom, 1980; Capros and Mantzos, 2000; Liang and Wei, 2004; Han, 2004; Suganthi and Samuel, 2012). In the interpretation of long-run equilibrium between economic development and energy consumption and the relations of short-term fluctuations, the standard Granger causality test, cointegration and Error Correction Model (ECM) were frequently used (Bentzen and Engsted, 1993; Bentzen and Engsted, 1993; Lin and Liu, 2010; Han, 2011).

However, the energy system is a nonlinear. The forecasting accuracy of the above prediction methods is not high. As the traditional linear prediction method had not the learning process on the data sample, it is difficult to accurately characterize the nonlinear relationship between energy systems, resulting in low prediction accuracy (Murat and Ceylan, 2006; Hu and Zhao, 2008). Although the artificial neural network is relatively well recognized method of energy system that is very suitable for such a complex nonlinear system, the prediction with neural network usually gains deficient training in small samples, allowing the instability of properties and other shortcomings (Moody, 1992; Lawrence *et al*., 1997). However, Support vector machines (Vapnik, 1995; Deng and Tian, 2004) is a specialized case of a limited

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sample of non-parametric estimation of machine learning methods which had the performance of many special advantages in solving the small sample, nonlinear and high dimensional pattern recognition problem. It is favored by scholars and have been successfully applied to time series prediction (Zhang *et al*., 2013). Support vector machines have become one of the research fields in machine learning.

Therefore, the method of support vector regression is utilized to establish nonlinear math model of energy consumption and economic growth. Based on the model, it will make China's energy demand forecast and recommendations are given.

SVR MODEL FOR PREDICTING THE ENERGY DEMAND

In machine learning, support vector machines (SVMs, also support vector networks) are supervised learning models with associated learning algorithms that analyze data and recognize patterns, used for classification and regression analysis. A version of SVM for regression was proposed (Vapnik *et al*., 1997). This method is called Support Vector Regression (SVR). At present, whether in the country or abroad, theoretical and applied researches related to support vector machine have been widely concerned.

SVR model for analyzing and forecasting: Energy system is a very big and complex nonlinear system and energy demand is influenced by economy, social factors and so on which are of mutual infiltration and interactions. Generally speaking, the relationship between the energy demand influence factors and energy demand is so complex that it is difficult to use a specific model to describe. This study adopts SVR to map the relationship between input (energy demand influence factors) and output (energy demand).

In this study, we analysis of the energy demand for 1985-2008 as well as the factors affecting and establishing a forecasting model of the multi-input, single-output support vector regression machine, as is shown in Fig. 1.

The variables affecting energy demand is taken as input, the energy demand as output which are represented by ($x^1, x^2,\ldots, x^d$) and y, respectively. Overall, the national income is one of the main factors that affect energy demand. In addition, since China is in transformation, the change of industrial structure, especially the change of heavy industrial structure in energy consumption will have a greater impact on energy demand (Wu *et al*., 2005; Guo *et al*., 2008); At the same time, China's large

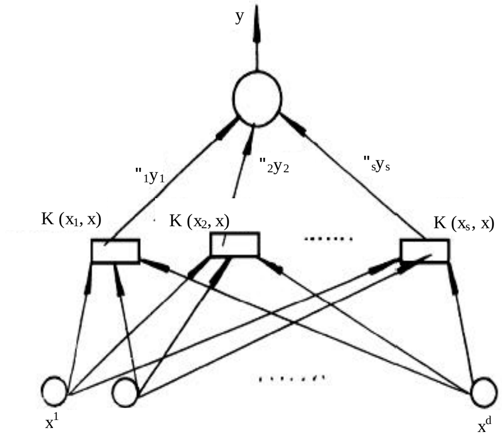

Fig. 1: Structure of support vector regression machine

population has a direct impact on the total energy consumption but also has a direct impact on per capita consumption of energy resources and ways of use. Because of the large difference in energy utilization patterns and consumption levels between urban and rural residents, energy demand will also increase with the accelerated pace of urbanization in China which is more obvious especially in developing country, so the population and urbanization are also the important factors of energy demand (Lin, 2001). So, this article uses four variables of economic growth (GDP), urbanization (the proportion of urban population accounting for the total population), the industry structure (the proportion of secondary industry accounting for the whole industry) and the total population to be as the input.

According to the historical data as time series $\{X(t), t = 1, 2,\ldots n\}$, the forecasting model can be described as:

$$X(t) = \Phi[X(t-1), X(t-2), \cdots X(t-d)]$$

where, Φ is the non-linear function and d is the dimension of input vector.

When forecasting the energy demand, we use the Support Vector Regression machine (SVR) to do regression and prediction, that is, we map the input factors $x^1, x^2,\ldots, x^d$ into a high dimensional feature space and then do linear regression in this space which will transform the nonlinear regression problems of feature space into the linear regression problems of high-dimensional feature space. So it is very effective on some complex or nonlinear problems. Based on the statistical learning theory (Vapnik, 1995; Deng and Tian, 2004),

Table 1: Prediction result analysis of energy demand

		BP		SVR	
Year	Actual value (1×108ton of standard coal)	Predicted value (1×10^8ton of standard coal)	Error (%)	Predicted value (1×10^8ton of standard coal)	Error (%)
2006	24.6270	25.144	2.10	24.727	0.41
2007	26.5583	28.063	5.67	27.305	2.81
2008	28.5000	28.416	0.29	29.214	2.50
2009	30.6578	28.094	8.37	29.159	4.89

Table 2: Simulation of long-term demand of energy in China Units(1¡Á108ton of standard coal)

Year	Forecasted result	Year	Forecasted result	Year	Forecasted result
2010	31.553	2014	38.325	2018	43.978
2011	33.221	2015	39.957	2019	44.820
2012	34.923	2016	41.483	2020	45.300
2013	36.634	2017	42.844		

Test and verify of methods: Firstly, we handle the energy demand data from year 1985 to 2005(training sample) as the SVR's input meanwhile China's energy consumption as output to do the imitation and simulation. Secondly, we use trained model to forecast for China's energy demand (test sample) from year 2006 to 2008. Lastly, we compare the result according to the forecast with the actual value to proof the effectively and the feasibility. During the training and forecast, it needs insure normalization parameter c and RBF kernel function parameter σ^2. This will put the error produced by the forecast result as the evaluation criterion and then we confirm the appropriate parameters value according to the performance of the test. After going through the test over and over again, we finally confirm that when C equals 100, σ^2 equals 50, the forecasting energy demand from year 2006 to 2009 is 2.4727, 2.7305, 2.9214 and 2.9159 billion ton of standard coal, the errors of which are 0.41%, 2.81% and 4.89% compared with the actual. In order to test the feasibility, we compare the test result with the true value and the BP neural network predicted value, as is shown in the Table 1.

The result indicates that the prediction error ranges in SVR is smaller than in BP neural network, shows SVR have better prediction accuracy. Therefore, the selected influencing factor and establish model is well provided with feasibility and reliability. The programming and forecasting of all above models are accomplished on the basis of Matlab 8.0.

Energy demand forecasting: According to the prediction model and the process, carried on the forecast to the future in China in 2010 and 2020, energy demand is obtained as shown in Table 2.

From Table 1 and 2 shows, increasing amount of energy consumption in China, especially since 2004, the annual growth of energy demand was faster. The demand for energy increased to 45.30 Million tons of standard coal in 2020, an average annual growth rate about 2.41%. Therefore, within the next ten years the growth rate of energy demand is great and the challenge is still serious.

CONCLUSION

This study uses the support vector regression based on Matlab, established the energy demand forecast model. We put industrial structure and percentage of urbanization, population and GDP as the input data set, energy demand as the output data set. The simulation results show;

In this study, Prediction method of SVR is good methods which have practical characteristics. it overcomes the lack of small sample and the learning defects of BP neural networks. And avoid the influence of human factors. It had better prediction ability than the other methods. And the prediction accuracy better, the future planning is more reasonable, the economic benefit is more obvious.

Therefore, these studies indicate that, in dealing with small samples, nonlinear and high dimensional pattern recognition problem of energy system, SVR exhibit many special advantages, very suitable for China's energy demand forecasting research. At the same time also can be extended to other fields of study, for decision-making people provide scientific support.

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