Energy 101 (2016) 366–379

Contents lists available at ScienceDirect

Energy

journal homepage: www.elsevier.com/locate/energy

Financial security evaluation of the electric power industry in China based on a back propagation neural network optimized by genetic algorithm

Wei Sun, Yanfeng Xu*

Department of Economics and Management, North China Electric Power University Baoding, 071003, China

ARTICLE INFO

Article history:
Received 4 June 2015
Received in revised form
9 January 2016
Accepted 7 February 2016
Available online 24 March 2016

Keywords:
Financial security evaluation
Power industry
Genetic algorithm
Back propagation neural network

ABSTRACT

Recently security issues like investment and financing in China's power industry have become increasingly prominent, bringing serious challenges to the financial security of the domestic power industry. Thus, it deserves to develop financial safety evaluation towards the Chinese power industry and is of practical significance. In this paper, the GA (genetic algorithm) is used to optimize the connection weights and thresholds of the traditional BPNN (back propagation neural network) so the new model of BPNN based on GA is established, hereinafter referred to as GA-BPNN (back propagation neural network based on genetic algorithm). Then, an empirical example of the electric power industry in China during the period 2003–2010 was selected to verify the proposed algorithm. By comparison with three other algorithms, the results indicate the model can be applied to evaluate the financial security of China's power industry effectively. Then index values of the financial security of China's power industry in 2011 were obtained according to the tested prediction model and the comprehensive safety scores and grades are calculated by the weighted algorithm. Finally, we analyzed the reasons and throw out suggestions based on the results. The work of this paper will provide a reference for the financial security evaluation of the energy industry in the future.

1. Introduction

Twenty-first Century is the era dominated by energy, which means that the mastery of the energy equals to the initiative and the discourse power. For decades, the demand for energy all over the world is expanding along with the rapid economic growth, which has inevitably triggered an investment boom in the energy industry. And the increasing status of the energy, which is the strategic material in various countries, has drawn the high attention of governments and scholars to the energy security issues.

At present, all countries have carried out the research on energy security issues. Francesco and Peter adopted the times integrated assessment model to develop a framework for a comprehensive and systemic assessment of energy security [1]. Jessica et al. proposed a framework to evaluate energy security under long-term energy scenarios generated by integrated assessment models [2]. Meanwhile, both the states and the international organizations have conducted researches related with energy security issues by selecting the appropriate evaluation index and establishing the scientific evaluation model according to their actual situation, including Singapore [3], Malaysia [4], Korea and Mongolia [5], Bangladesh [6], European Union [7,8], the ASEAN (Association of Southeast Asian Nations) [9] and the OCED (Organization for economic cooperation and development) [10]. From the research direction, the world's concerns about energy security nowadays are almost attached to the fields of the energy supply and demand problems and the changes in energy prices and so on. On the one hand, James et al. [11] studied the problem of oil supply in Ireland while Wu [12] studied the crude oil and natural gas supply in China. On the other hand, José et al. [13] and Hang and Tu [14] discussed the issues about energy prices in Brazil and China respectively.

Electric power industry is not only the most vital basic energy industry in the development of national economy, but also the basic supporting industry related to the national economy and the people's livelihood. It is in the natural monopoly position among the energy industry and has the priority in the development of the world economy, which plays an important role in promoting the national economy and social progress and is closely related to the

* Corresponding author.
E-mail address: ncepuxyf@163.com (Y. Xu).

http://dx.doi.org/10.1016/j.energy.2016.02.046
0360-5442/

national economic security strategy as well as people's daily life and social stability. And papers involved with the power industry are numerous. Bai et al. used the SBM-DEA (slack based measure data envelopment analysis) model and Tobit regression model to evaluate the emission reduction work of the power industry in 26 OCED and BRIC (Brazil, Russia, India and China) countries from 1996 to 2010 [15]. Li and Huang constructed a dynamic security assessment model of power system based on grey theory [16]. Duan and Zhang carried out the safety risk assessment using the method of fast probabilistic power flow under the condition of static power-frequency characteristics of power systems [17] and Amélia et al. conducted the safety assessment to the static and transient power system [18]. And Hanieh with Maryam [19] studied the voltage security of power system using principal component analysis and decision tree method.

However, in the existing macroeconomic background domestic and international, in addition to the above security and assessment problems about the operation and technical aspects of the power industry, the economic security issues of the electric power industry should not be ignored, namely how the enterprises ensure their financing demand and investment security issues [20]. The energy finance can be considered as a brand new research topic, not to mention the subdivision point about the energy financial security assessment. At present, related researches on the energy finance have not yet been commenced systematically and in depth worldwide, moreover it is even much rarer on the financial security assessment to the power industry in China. The outbreak and spread of the world financial crisis in 2008 along with the increasing complexity of the international political situations led to the financial security issues in China's power industry increasingly prominent, which caused severe challenges to the development of China. Since in the long cycle of the economic development in the future, the electric power will always occupy the dominant position in China's energy. We shall select the power industry as the study object and construct the reasonable index system to evaluate the financial security of this industry, which is quite necessary for the further research to evaluate the financial risk in the power sector.

Although the relationship among the energy investment, financing and the development of energy industry in China was studied by Li et al. [21] from a qualitative point of view, it solved neither the investment and financial security issues in China's energy enterprises from a quantitative analysis angle rigorously nor the economic security issues from the perspective of safety economics. Literature [22] and [23] introduced the concept of energy finance into China's coal industry and Li Kaifeng proposed a back propagation neural network based on genetic algorithm to make a quantitative study of China's energy financial security issues for the first time in his book [24]. But the lack of the algorithm comparisons caused some deficiencies when the scholar got the final results. Therefore, a new evaluation index will be added and three other methods are selected in this paper to improve the model on this basis.

The genetic algorithm chosen in this paper is a kind of typical artificial intelligence bionic algorithm and has been widely used in many fields, including the portfolio optimization problem in financial field [25], the operation planning problem of thermal power plants [26] and power dispatch problem [27] in power industry, as well as the multi-objective optimization of an underwater compressed air energy storage system [28] and the prediction problem of spray characteristics of diesel engine [29] in engineering field.

And the GA-BPNN (back propagation neural network based on genetic algorithm) was put forward by V. Petridis et al. in 1992 and it was a combination of the genetic algorithm and a variant of back propagation. The model both had the characteristics of the wide mapping ability and reinforced learning performance of the neural network and the fast global convergence of the genetic algorithm [30]. Later, scholars from various countries developed more and deeper studies towards this GA-BPNN model. For instance, Liu et al. applied the algorithm for the forecast model of electricity industry loan research [31]. Yu and Xu used an optimized genetic algorithm and improved BP neural network to predict the short-term load of natural gas [32]. And Liu et al. combined the mind evolutionary algorithm and fast ensemble empirical model decomposition with the GA-BPNN model to forecast the wind speed [33a].

In summary, we utilize the good global search capability of the GA (genetic algorithm) to train the connection weights and thresholds of the BPNN (back propagation neural network), then establish the model of BPNN optimized by the GA, hereinafter referred to as the GA-BPNN. The proposed model can not only maximize the local search ability of BPNN but also effectively compensate for the shortcomings among the learning process such as slow convergence speed, vulnerability of falling into local minimum and poor robustness. In the empirical analysis, we select important macroeconomic and industry financial indicators related with the financial security of China's power industry from 2003 to 2010 and establish the scientific and reasonable evaluation system to assess the financial security of electric power industry in China. Then the traditional BPNN, GM (1,1) model and the SVM (support vector machine) are compared with the proposed model in order to verify the practicability and validity of the GA-BPNN model in the financial security evaluation of the China's power industry. Then index values of the financial security of China's electric power industry in 2011 are obtained according to the tested prediction model and the comprehensive safety scores with grades are calculated by the weighted algorithm. Finally, we analyze the reasons and throw out suggestions on the basis of the results. Through the work of this paper, we can acknowledge the financial security situation of China's electric power industry, and provide strong theoretical support for the Chinese government and other relevant organizations to develop the policies and measures to improve the financial security as well as other energy industry in the future.

2. Introduction of the algorithms

2.1. Genetic algorithm

The GA (genetic algorithm) [33b,34] was put forward by John Henry Holland, an American professor, in the 1970s for the first time. It is a random search algorithm inspired by the biological natural selection and the natural genetic mechanism, which belongs to one of the classical artificial intelligence algorithms. The GA simulates the phenomenon of reproduction, crossover and mutation in the process of natural selection and genetic mechanism. In the GA, the solution of the optimized problem is an individual, namely the genetic string or chromosome. Usually, the GA can be defined as an eight tuple [35]: $GA = \{C, E, P_0, M, \Phi, \Gamma, \Psi, T\}$. In the tuple, C is the coding method for the individual; E is individual fitness evaluation function; P_0 is the initial population namely the initial solution; M is the size of the population; Φ, Γ and Ψ is the selection, crossover and mutation operator respectively; and T is the termination condition of the GA.

During the optimal solution search process of the GA, a set of candidate solutions are reserved in each iteration, and the better individual from the solution group is selected according to a certain rule. Then these individuals are recombined to produce a new generation of candidate solution group using three genetic operators—selection, crossover and mutation operator. Repeat this procedure until the iteration meets the termination condition.