

# Predictive Model of Energy Cost in Steelmaking Process Based on BP Neural Network

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**Abstract**—China is a Steel superpower, with large production and high efficiency. But we need more research in Business energy cost control. This paper is oriented to cost flow of steel industry, Aim at solve the shorting of energy cost control in steel industry. Using the producing data in steel making, Basing on BP neural network, optimizing by Genetic algorithm, I build the Predictive Model which has a better predict result and provide predict function for steel industry. It make business management more convenient, support the task of energy-saving. Mean while, it has validate that Genetic algorithm has good function in BP neural network's optimizing problem and can be used in practical problems.

**Keywords**—component; Neural network; Genetic algorithm; Cost control; Steel making; BP optimizing; Energy cost

## I. INTRODUCTION

In recent years, China's economic has a sustained and rapid development, whose steel industry has also ushered in a good development opportunity. While the rapid development of the steel industry, the task of energy saving and environmental protection and the requirement of new energy development and utilization becoming more and more important. Since 2011, China is the world's first steel-producing country[1], but our energy utilization efficiency is still low. In order to improve the energy efficiency of the steel industry we should strengthen the steel industry's process optimization, adjust the energy consumption structure and recycle secondary energy. These are also energy lean operation mode's meaning. The main object of the mode is the steel industry material flow, energy flow, value flow and system operation. Based on current research, the material flow and energy flow have reached a certain degree of optimization[8], but there is a lack of in-depth study for the industry value flow. Value flow is built on the basis of cash flow, integrate material, energy, time, space, money and other elements' comprehensive economic problems. It has a significant impact on the enterprise's

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Therefore, carrying out the analysis of the steel industry energy cost forecast is now imminent, this article will focus on energy cost analysis in the steelmaking process.

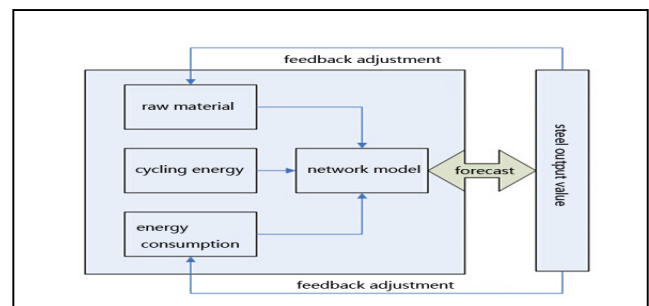


Figure 1. Analysis and prediction of the steel industry energy cost

Energy cost forecast in steelmaking process, using a variety of energy consumption costs and the cost of raw materials to determine the output value of cast steel production. This avoid the complex intermediate product data and excessive the circulating energy analysis, the problems turn to training and prediction of the total consumption[2]. Artificial neural network has the associative and reasoning for complex problem's functions, which has strong adaptive learning ability, strong fault tolerance and robustness. So it applies to steel-making process's complex information forecasting applications. As is shown in Fig 1. At present, among the application of neural networks, BP neural network has better results in training and prediction. Meanwhile it has its own shortcomings. This paper will use the genetic algorithm in BP network's optimizing, and perform the steel industry energy costs predictive analysis by optimizing BP neural network [3].

## II. THE BP NEURAL NETWORK MODEL'S ESTABLISHMENT

### A. the BP neural network model

Neural network's idea comes from human's neural synapses network which can process and determine complex information[4]. The Nature of neural network is achieving distributed information's learning and processing functions by network's transformed and computing and the dynamic behavior. Based on the above foundation, BP neural network's forward propagation is changing the input data through the hidden layer to the output layer and comparing with the actual value, then seeking the deviation to back propagation and modifying the neural network's thresholds. This cycle will continue until the deviation reach the

requirement. So BP neural network model has a stronger local search capability, can be well applied to control, optimize and predict problems. This mode will use the most widely used three layer BP neural network structure, transfer function use the linear function and S-functions, training functions use the gradient descent w/ momentum function.

#### B. BP neural network's parameters of input layer and output layer

After processing and integration the data from energy costs for steelmaking processes, I sort the steelmaking raw material(iron) costs and energy consumption's corresponding energy costs in every steelmaking process, including gas (blast furnace gas, coke oven gas and converter gas, etc.), compressed air (oxygen, nitrogen, argon, steam, etc.), electrical and industrial water (soft water, clean circulating water and turbid circulating water, etc.). Sort steelmaking process's product cast steel's value as product value.Consolidation of the steel industry energy cost from the above data determine the input layer nodes as 13. The output layer is 1, the product of cast steel.

#### C. BP neural network's parameters of hidden layer

According to the above 13 inputs and one output, I use the empirical formula to get the initial hidden layer nodes as 4, then use different node number's hidden layers for training, through trial and error, I found the best results obtained in the 20 nodes hidden layer which has the least error and a better performance. the following Table I show the effect of the network model.

TABLE I. TRIAL AND ERROR

result	nodes			
	9	16	20	24
performance	0.267	0.0173	0.0129	0.0059
error	0.0188	0.0161	0.0151	0.0170

The Fig 2 shows neural network model structure

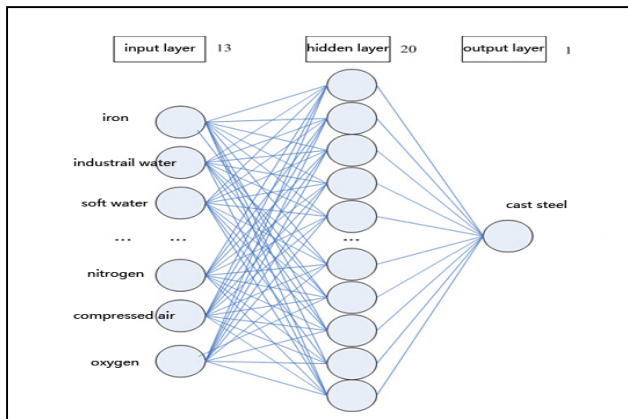


Figure 2. Structure of neural network model

#### D. BP neural network Genetic optimization

BP neural network is widely used in recent years, but it has its own shortcomings. Although there are some optimization methods[3] appears, but all of them can't solve the problem of BP itself fundamentally. The BP neural network prone to slow convergence rate when has too much data nodes, and as it is a nonlinear optimization process, it may leads into local minimum sometimes and fail to meet requirements[7]. In recent years, the genetic algorithm and BP neural network's combination is a hot topic, with a genetic algorithm to optimize BP neural network can complement the shortcomings[5]. This paper will using genetic algorithms to optimize the BP neural network.

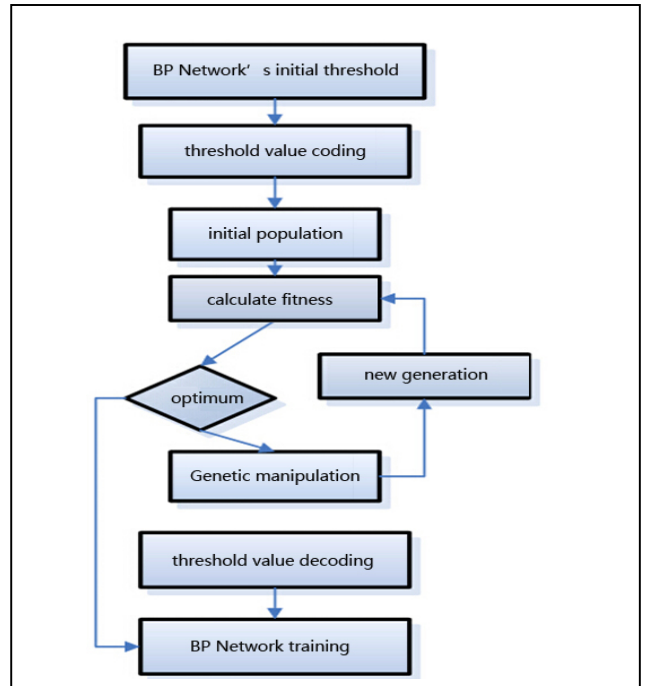


Figure 3. BP neural network Genetic optimization's procedures

Genetic algorithms was founded by the American scholar Holland at 1975, through the imitation of natural selection and genetic mechanism[8] to find the optimal solution. Depending on the genetic operators to copy, crossover and mutation, meanwhile gradually to optimize the population, finally achieve the optimal solution. It is a global-based heuristic search algorithm, which can find the optimal solution quickly and avoid trapped in local minimum effectively. This model is suitable for multi-function multi-parameter optimization problem. According to the characteristics of genetic algorithm, this article will use it in the optimization of each layer BP neural network's threshold value, the basic process as in Fig 3. After treatment of genetic algorithm, makes BP neural network model can avoid falling into local minimum point and accelerate the convergence speed model training. etc.

### III. BP NEURAL NETWORK MODEL'S TRAINING AND PREDICTION

#### A. Data normalization

To make data normalization must first ensure that the data in consistent magnitude. Since the steelmaking process data include raw data, output data and a variety of energy consumption data. In order to make the data into the same order of magnitude, I take an hundred thousand as unit and retain 4 decimals, and to facilitate the normalizing and training of the data. After data preprocessing, the model use Mapminmax function for data normalization (1)

$$y = \frac{(y_{\max} - y_{\min}) * (x - x_{\min})}{x_{\max} - x_{\min}} + y_{\min} \quad (1)$$

In Formula, ymax and ymin can be designated by demand, here use the default value 1 and -1, easy for data training.

#### B. Genetic optimizing initial threshold value

Traditional BP network initial threshold is determined by a random function, which sometimes resulting in fall into local minimum point, can't reach convergence effect and limit the convergence rate. Here I use genetic algorithm to optimize BP network initial threshold value. First, according to the network scale, population's coding is :  $S = R * S1 + S1 * S2 + S1 + S2$ , wherein R is the input layer data, S2 is the output layer data, S1 is set to 20, as the population coding parameters. Then, use Fitness as objective function. Set genetic algebra as 100, select function is NormGeomSelect, cross-function is arithXover, variogram is nonUnifMutation. Then, genetic selection will continue cycling variation, cross, replica and produce progeny until reach the targets. Finally, I get the best genetic, then according coding rules to decode get the optimized network weights parameter and assignment back to BP neural network.

#### C. Network model's transfer function

The model uses the S-function and linear function as the transfer function. Tansig function (2) as the input layer to the hidden layer's transfer function, it can accept any input value and the output value is from -1 to +1, in order to simplify the problem size, easy to model training.

$$\tan sig(n) = \frac{2}{(1 + e^{-2 * n}) - 1} \quad (2)$$

Purelin function as the hidden layer to output layer's transfer function, it can accept any input value, the output can contain any output value, which is suitable for complex data in cast steel production.

#### D. Network model's training function

The traditional method in BP neural network's optimization added in the previous accumulated experience

while revise network weights  $W(k)$ , reducing the threshold shocks, improving the convergence rate, so we can get a closer prediction. As is shown in (3)

$$\Delta W(k) = -\eta \nabla E(k) + \alpha \Delta W(k-1) \quad (3)$$

in the Formula,  $E()$  is the additional momentum,  $\eta$  is the learning rate,  $\alpha$  is the momentum factor.

This model is using the momentum gradient descent training function Traingdm for the model training. While correcting the network weights  $W(k)$ , it not only add in the previous accumulated experience, but also add a gradient to reduce on the adjustments, so it can make a further reduce the training shock tendency, effectively suppress fall into local minimum, as (4) below

$$W(k) = \eta[(1 - \alpha)D(k-1) + \alpha D(k-2)] + W(k-1) \quad (4)$$

in the Formula,  $D()$  is the gradient of momentum,  $\eta$  is learning rate,  $\alpha$  is the momentum factor.

#### E. Display of BP neural network's predict

The model use an iron and steel enterprise's actual operation data as data sources. By analyze and consolidate the companies' monthly reports in steel-making process from 2009.11 to 2013.10, including raw material iron, various energy consumption, steel production and other data, screen out of the 47 monthly data set as the model's input. This set of data after pretreatment as 47 samples randomly selected 10 sets of data as predictive data, and the remaining 37 groups as training data.

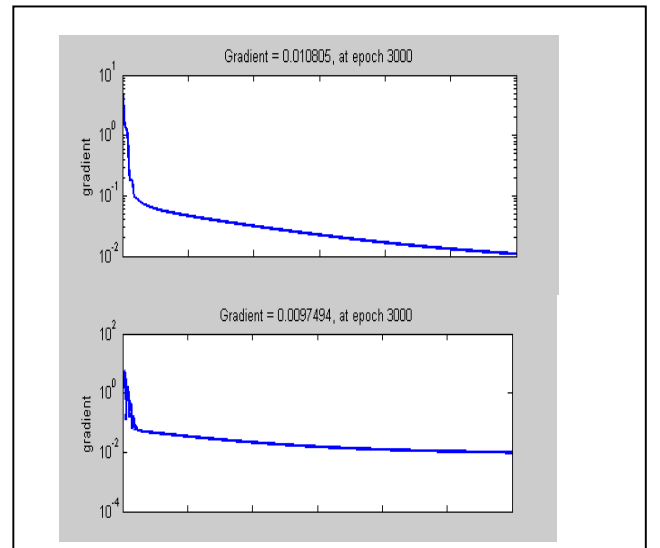


Figure 4. BP neural network model and optimization model's training

Fig 4 is BP neural network's training results and the genetic optimization BP's training results, respectively. By contrast can be seen, after 3000 training, the optimized BP

neural network approaching faster to 10<sup>-2</sup>'s errors, obvious it's converges speed is faster than usual BP neural network.

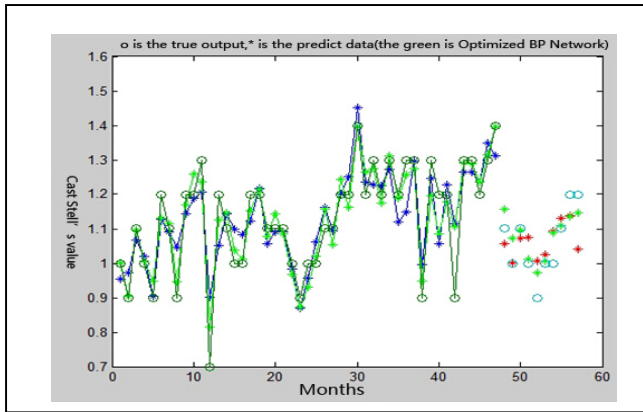


Figure 5. Prediction of BP neural network model

Fig 5 is optimized BP neural network in the steelmaking process energy cost forecast results. Among them, the blue color is the BP neural network's prediction, the green is optimization BP's predict results. The solid line is a prediction of training data, the point is result of predictive data. By contrast can be seen the genetic algorithm optimization neural network has a better result in the training data's prediction, especially in the prediction of predictive data. This reflection that the genetic algorithm optimized BP neural network can effectively avoid falling into local minimum point. Meanwhile, as the steelmaking process energy cost prediction model, it can effectively predict the trend of steel output in different amount of materials, various energy consumption conditions. At last the model can help adjusting energy ratio, cost optimization and other related decisions.

#### IV. CONCLUSION

Steel industry contains a large amount of data information, which contains a wealth of data regularity. Among them, excavate the data from energy costs in the steel industry can provide forecasting for industry's energy cost management, which can effectively improve the enterprise's operating profit and improve energy efficiency and steel output rate. To sum up, According the results of the experiment, the genetic algorithm optimized BP neural network can carry out the relevant data analysis and forecasting quickly and efficiently. Able to provide convincing data service to support the steel industry energy cost management. The model will further promote the steel industry's energy saving task and improve their energy efficiency.

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