PREDICTIONS FOR THE YIELD OF NATURAL GAS WITH THE GRAY MODEL AND THE GENETIC ALGORITHM

Lu Hongjie[a] **and Linda Zhang**[b]

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The gray model and the genetic algorithm for predicting natural gas yield have been introduced in the present article. Two new methods for forecasting the yield of natural gas in China have also been pointed out based on the gray model and the genetic algorithm. The experimental results show that both models can predict the yield of natural gas and the experimental data are in agreement with the quantitative analytical conclusions drawn from the calculated data. This proves that two types of new models can be used to predict the yield of natural gas. It results in good economic and social benefits in China.

* Corresponding Author
Fax: 86-24-56860869
E-Mail: lindazhang362@hotmail.com
[a] Liaoning Shihua University, Fushun, Liaoning, P.R. China.
[b] SAIT Polytechnic, Calgary AB, Canada.

Introduction

Natural gas has a lot of advantages such as being clean, highly efficient, abundant and easily storable. The global natural gas production and consumption in 2005 reached 2.763×10^{12} m^3 and 2.749×10^{12} m^3, respectively. The demands for natural gas had gradually increased to 3.3 % of the global natural gas production every year and were 25 % of total energy. Chinese natural gas consumption was only 1.7 % of total world natural gas consumption; however Chinese increment in natural gas consumption got 20.8 %. Natural gas as a clean energy is widely used in different areas such as electricity power, car market and residential fuel, etc.[1]

In the present paper, the gray model and the genetic algorithm have been discussed. Two new methods for predicting the yield of natural gas yield in China have also been explained based on the gray model and the genetic algorithm.

Discussion

The gray model (GM)[2]

GM (1,1) was one of the main and basic gray models. GM (1, 1) was described in details. The original sample in the sequence was listed as follows.

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

New sequence based on the above equation was written as follows.

$$X^{(1)} = \left\{x^{(1)}(1), x^{(1)}(2), \cdots, x^{(1)}(n)\right\} \quad (2).$$

$x^{(1)}$ was described as follows.

$$x^{(1)}(t) = \sum_{i=1}^{t} x^{(0)}(i), (i = 1, 2, \cdots, n) \quad (3)$$

or

$$x^{(1)}(t) = \theta x^{(1)}(t) + (1-\theta)x^{(1)}(t+1),$$
$$(t = 1, 2, \cdots, n \text{ and } 0<\theta<1) \quad (4)$$

It was supposed that:

$$x^{(0)}(t) + ax^{(1)}(t) = b \quad (5).$$

It was simply described as follows.

$$\frac{dx^{(1)}}{dt} + ax^{(1)} = b \quad (6)$$

.

Two parameters (a and b) were calculated with the least square method. $X^{(0)}(t)$ and $X^{(1)}(t+1)$ were obtained as follows.

$$X^{(0)}(t) = X^{(1)}(t) - X^{(1)}(t-1) = (1-e^{a})(x^{(0)}(1) - \frac{b}{a})e^{(-at)},$$
$$(t = 1, 2, \cdots, n-1) \quad (7)$$

$$X^{(1)}(t+1) = (x^{(0)}(1) - \frac{b}{a})e^{(-at)} + \frac{b}{a},$$
$$(t = 1, 2, \cdots, n-1) \quad (8)$$

The original $X^{(0)}$ was written as follows:

$$X^{(0)} = \begin{Bmatrix} 127.40,119.30,122.10,124.30,129.30,137.60, \\ 138.90,142.60,150.49,152.98,160.73 \end{Bmatrix}$$

$X^{(1)}$ obtained was listed as follows based on the above equation.

$$X^{(1)} = \begin{Bmatrix} 127.40,246.7,368.8,493.1,622.4,760,898.9, \\ 1041.5,1191.99,1344.97,1505.7 \end{Bmatrix}$$

The final gray model (GM(1,1)) was gotten and described as follows.

$$X^{(1)}(t+1) = (x^{(0)}(1) - \frac{b}{a})e^{(-at)} + \frac{b}{a} \approx 3449.875e^{0.033t} - 3322.475 \quad (9)$$

Table 1 showed the actual yield of natural gas and predicting the yield of natural gas based on the gray model. The experimental results presented that the actual yield of natural gas was close to predicting the yield of natural gas, so the gray model was a good model for predicting the yield of natural gas.

Table 1. The relationship between the actual yield of natural gas and predicting the yield of natural gas based on the gray model

Actual yield of natural gas (billion m^3)	Predicting the yield of natural gas (billion m^3)	Relative error (%)
127.40		
119.30	117.92	1.16
122.10	121.95	0.12
124.30	126.12	-1.46
129.30	130.43	-0.87
137.60	134.89	1.97
138.90	137.50	1.01
142.60	144.26	-1.16
150.49	149.19	0.86
152.98	154.29	-0.86
160.73	159.57	0.72
157.88	165.02	-4.52
167.65	170.66	-1.80
175.59	176.50	-0.52

The genetic algorithm for forecasting the yield of natural gas.[3]

The generalized Wengshi model was a model for predicting the yield of natural gas [4]. Chen Yuanqian explained more details about the generalized Wengshi model. Its model was written as follows.

$$Q = at^b e^{-\frac{t}{c}}, t = y - y_0 \quad (10).$$

where

a - constant; a > 0

b - constant, b $\geq$ 0.

c- constant; c > 0

y- prediction for the year

y_0 - the beginning of the year

Yang Shuzi[5] introduced an exponential smoothing model which could forecast the yield of natural gas. The exponential smoothing model meant that a predicted value at the time (t+1) weighted average with an experimental value. The exponential smoothing model was listed as follows.

$$\bar{x}t+1 = a_0 x_t + (1 - a_0)\bar{x}t, 0 \leq a_0 \leq 1 \quad (11).$$

when a_0 equals 1, $\bar{x}_{t+1} = x_t$. It means the predicted value equals the experimental value at the time (t). When a_0 equals 0, the predicted value does not change.

Shuai Xunbo pointed out the optimal group model about predicting the yield of natural gas. The optimal group model meant that the generalized Wengshi model connected with the exponential smoothing model together. It was written as follows.

$$Q = \beta at^b e^{-\frac{t}{c}} + (1-\beta)[a_0 x_t + (1-a_0)\bar{x}t];$$
$$0 \leq a_0 \leq 1; 0 \leq \beta \leq 1 \quad (12)$$

where

a_0- constant

β- weight average

Q- the optimal group model

The optimal group model was calculated based on the genetic algorithm. There were four steps described as follows.

(1) It made sure population size (S), crossover probability (ν_c), mutation probability (p_m) and iteration condition. N types of beginning populations were determined.

(2) Each fitness function value was computed.

(3) Its reproduction probability was calculated based on the above fitness function value. It was supposed that crossover probability (ν_c) and mutation probability (ν_m) were known during the genetic process. Finally N types of new populations were gotten.

(4) Steps (2) and (3) did not redo until its result was convergence. The final optimal group model was listed as follows.

$$Q_{calc.}(a,b,c,a_0,\beta) = \beta at^b e^{-\frac{t}{c}} + (1-\beta)[a_0 x_t + (1-a_0)\bar{x}t];$$
$$a > 0; b \geq 0; c > 0; 0 \leq a_0 \leq 1; 0 \leq \beta \leq 1 \quad (13)$$

Small pieces of natural gas field in Liaohe oilfield were forecasted. It was supposed that population size (s), crossover probability (p_c), mutation probability (p_m) and iteration number were 80, 0.60, 0.001 and 800, respectively. Table 2 showed the relationship between predicting the yield of natural gas and the optimal group model with the genetic algorithm. Experimental results showed that relative errors of the optimal group model were very low, so the optimal group model was used to predict the yield of natural gas.

Table 2. The relationship between predicting the yield of natural gas and the optimal group model with the genetic algorithm

Actual yield of natural gas (10^4 m^3)	Predicting the yield of natural gas (10^4 m^3)	Relative error, %
16.30	15.87	2.63
33.80	33.80	0
47.90	46.15	3.65
55.30	55.30	0
79.30	72.55	8.51
81.10	78.30	3.45
59.30	58.39	1.53
41.30	41.29	0.02
45.30	42.35	6.51

Conclusion

In this paper, the author has introduced that the gray model and the genetic algorithm lead to and are closely in accordance with predicting the practical experimental values. The yield of natural gas in China can be accurately estimated. The gray model and the genetic algorithm point out that predicting the yield of natural gas not only has a very important significance, but also provides a theoretical reference for chemical plants or oil companies.

It is important for Chinese government to design and utilize rightly and optimize natural resources and may increase Chinese government’s benefits. This mathematical method is effective, economic, simple and convenient and thus it is suitable for chemical plants or oil companies in China.

References

[1]Wang, B., Liu, S. W., Luo, S., Fang, J. and Suo, L., *Natural Gas and Oil*, **2008**, *26(5)*, 30-32.

[2]Chen, X. D. and Xie, C. Y., *J. Guizhou Educ. Coll*., **2005**, *16(4)*, 4-6.

[3]Shuai, X. B., Zhou, X. G., Guan, X., Wu, B. and Zhao, S. R., *Comput. Appl. Petr*., *2007*, *15(4)*, 23-25.

[4]Chen, Y. Q., *Reservoir Engineering Practical Methods*, Beijing, Petroleum Industry Press. **1999**.

[5]Yang, S. Z. *Time series analysis of engineering application*, Wuhan, Huazhong University of Science and Technology Press. **1992**.

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