Application of Big Data Analysis for Energy Consumption Standards Establishment of Oil Wells

Yun Liu[1](✉), Tingting Liu[1], Xingping Cheng[2], Weiyi Xie[1], Runfang Miao[3], Shan Gao[1], Fengjiao Qu[1], Zhiyong Liu[4], Fei Zhao[1], and Lihong Du[1]

[1] Engineering Technology Research Institute of Huabei Oilfield Company, Huaibei, China
{yjy_liuyun,cyy_liutt,cyy_xiewy,yjy_qfj,hzkf_zf,
cyy_dlh}@petrochina.com.cn, cyy_gaos@petrochina.com
[2] Economic and Technical Research Institute of Huabei Oilfield Company, Huaibei, China
hse_cxp@petrochina.com.cn
[3] Sales Department of Huabei Oilfield Company, Huaibei, China
cy4_mrf@petrochina.com.cn
[4] The Fifth Factory of Huabei Oilfield Company, Huaibei, China
cy5_liuzy@petrochina.com.cn

Abstract. The big data analysis of oil wells uses the historical production data of the oilfield to find out the internal relationship between the data, to guide on-site production and to realize energy consumption reduction. Due to the huge of wells' historical data the big data analysis methods such as descriptive analysis, matrix correlation, grouping analysis and gray correlation analysis have been used to analyse influencing factors and get the key indicators affecting energy consumption. The key influence factors of energy consumption have been determined by the big data analysis, which provides scientific data support for measure wells selection and effect prediction. At the same time, according to the threshold and energy consumption conditions, the pumping parameters and working conditions have been optimized. At present, this method has been applied to 340 oil wells in Huabei oilfield and achieved a remarkable energy conservation effect.

Keywords: Big data analysis · Gray correlation analysis · Energy consumption

1 Introduction

The Huabei Oilfield belongs to the late stage of high water cut development, the oil wells' annual power consumption is as high as $4.7\% \times 10^8$ kW·h which accounts 95% of the total consumption [1]. With the increasing of energy consumption in order to improve energy utilization and economic benefits, the big data analysis is carried out based on the intelligent Oilfield monitoring system[2]. The research has deeply mined the internal meaning and correlation of development and production data by big data analysis method to find the laws contained in massive data. Then the energy consumption quota standard system has been established based on the big data analysis. It provides a reliable foundation for scientific management of oil wells in the future.

G. Guan et al. (Eds.): ICBDSS 2022, AHCS 8, pp. 883–890, 2023.
https://doi.org/10.2991/978-94-6463-064-0_90

2 Data Analysis Methods and Key Indicator Selection

The common big data analysis methods include descriptive analysis, matrix correlation analysis, grouping analysis, gray correlation analysis and etc. Through the big data analysis can completely understand the whole characteristics of samples and energy consumption situation in specific area [3].

2.1 Gray Correlation Analysis

The correlation is the measure of factors' correlation between two systems which is vary with time or different objects. In the process of system development if the change trend of the two factors is consistent which is highly synchronous change. The correlation between the two factors is high, otherwise it is low [4]. For the energy consumption sensitive factors of oil wells each influence factor is not a determined value, but a variation range. Gray correlation analysis is used for analysis and discussion. It used to describe the correlation order between different information and to get the influence and contribution extent to the main factor. And measure the correlation between factors [5]. The calculation formulas of correlation coefficient and gray correlation are as follows.

The parent sequence is {x0, (k)}, and the sub-sequence is {Xi, (k)}, and N is the length of time series, and M is the number of influencing factors. (k = 1, 2,…,N; i = 1, 2, …,m)

$$\Delta_i(k) = \left| x_0^{'}(k) - x_i^{'}(k) \right|$$

$$\Delta_i = (\Delta_i(1), \Delta_{\mathrm{i}}(2), \ldots \Delta_{\mathrm{i}}(n)); \; ; \; (i = 1, 2, \ldots \mathrm{m})$$

$$\mathrm{M} = \max_{\mathrm{i}} \max_{\mathrm{k}} \Delta_{\mathrm{i}}(\mathrm{k})$$

$$m = \min_{i} \min_{k} \Delta_i(k)$$

$$\gamma_{oi}(k) = \frac{m + \xi M}{\Delta_{i(k)} + \xi M}$$

$$\xi \in (0, 1); \; \mathrm{k} = 1, 2 \ldots \mathrm{n}; \; i = 1, 2, \ldots, m$$

$$\gamma_{\mathrm{oi}} = \frac{1}{\mathrm{n}} \Sigma_{\mathrm{k}=1}^{\mathrm{n}} \gamma_{\mathrm{oi}}(\mathrm{k}); i = 1, 2, ..., m$$

2.2 Regression Analysis

The regression analysis is to select any two attributes from the many factors as the analysis basis, solve the regression equation, and to intuitively show the correlation between the two attributes [6].

2.3 Selection of Key Indicator

According to the exist energy consumption quota index system of oilfield company, the energy consumption per ton of liquid pumping hundred meters is an important index to evaluate the level of energy consumption, so it is selected as the target parameter of energy consumption evaluation [7].

$$E_{dybm} = \frac{E_{jcd}}{\sum(Q_{jc} \cdot H_{jc})} \times 100$$

E_{dybm}—Energy consumption per ton of liquid pumping hundred meters, kW·H / (t·100m);

E_{jcd}—Energy consumption of oil production in the statistical period, kW·h;

Q_{jc}—Liquid production per well in the Oilfield during the statistical period, t;

H_{jc}—Effective delivery lift per well in the statistical period, m.

3 Big Data Analysis

3.1 Data Acquisition

Collect the production and test data of 3496 oil wells in six oil production plants in Huabei Oilfield, then analysis and research the data combined with basic oil wells information. According to the previous research results choose twenty influence factors affecting the energy consumption including ten parameters of equipment and management (pumping types, motor types, motor capacity, balance index, input power, polished-rod power, effective power, ground efficiency, underground efficiency and daily power consumption) and ten swabbing related parameters (daily liquid production, daily oil production, water cut, submergence depth, pump diameter, pump depth, pump efficiency, dynamic liquid level height, stroke, stroke times and system efficiency).

3.2 Data Pretreatment

3.2.1 Data Cleaning

The data is the foundation and source of analysis, and the integrity and reliability of data is the premise of accurate analysis results. Therefore, data pretreatment plays an important role in big data analysis. It is necessary to clean the collected data by eliminating abnormal and missing values (for example, the surface efficiency and underground efficiency are negative or some values are more than 100%) to ensure the completeness and reliability of the analysis data.

3.2.2 Data Standard Pretreatment

Since different evaluation indicators often have different dimensions and dimensional units, data standard pretreatment is required to eliminate the influence of dimension between evaluation indicators and to solve the comparability between data indicators. After the standard process of the original data, all indicators are in the same order

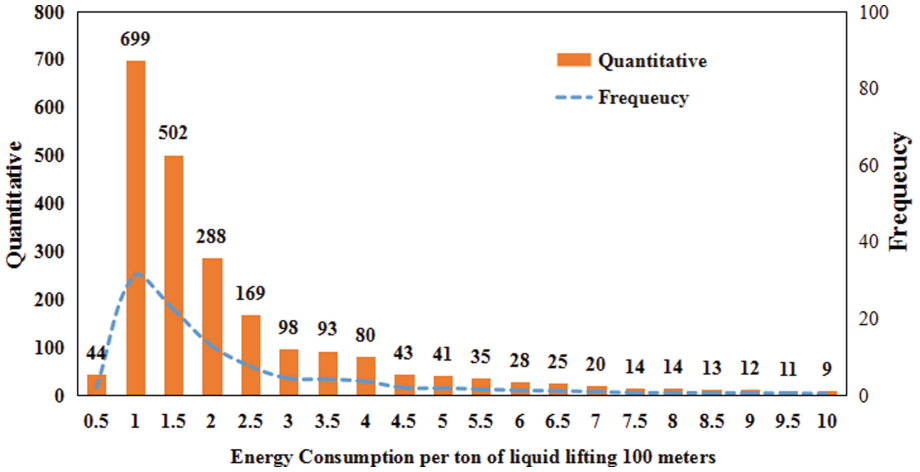

Fig. 1. The Distribution Diagram of Energy Consumption per ton of Liquid Pumping 100 m

of magnitude, which is suitable for analysis and comparison. The min-max deviation standardization is used to linearly transform the original data, so that the result value is mapped between zero and one. Finally, a completed data volume can be obtained for big data analysis including 2236 effective data points.

3.3 Frequency Histogram Analysis of Energy Consumption

The energy consumption distribution diagram shows that the average energy consumption per ton of liquid pumping hundred meters in Huabei Oilfield is 3.06kw·h. The energy consume of 95.7% oil wells is less than 10kW·h which is concentrated in 1kw·h belonged to the normal level of energy consumption. In addition, energy consumption of 22.6% oil wells is over the normal level, and they have big differences in energy consumption and wide distribution. So this type of oil wells has been focused on energy conservation and consumption reduction.

3.4 Gray Correlation Analysis

The energy consumption factors of oil wells are comprehensively analyzed by the gray correlation analysis method, then the gray correlation model affecting the energy consumption of oil wells is established. After data pretreatment the extreme conditions data affecting the fitting is eliminated, then the gray correlation analysis method is used to analyze the pretreatment data. After sequencing the influencing factors the daily liquid, balance index and dynamic liquid level are the three important factors related energy consumption shown in Fig. 2.

The influencing factors according to the correlation have been sorted in Fig. 2. From the gray correlation analysis the correlation of all influencing factors is greater than 0.7 indicated that the correlation between these evaluation factors is high. The correlation of three top influencing factors is more than 0.8 including daily liquid production, balance

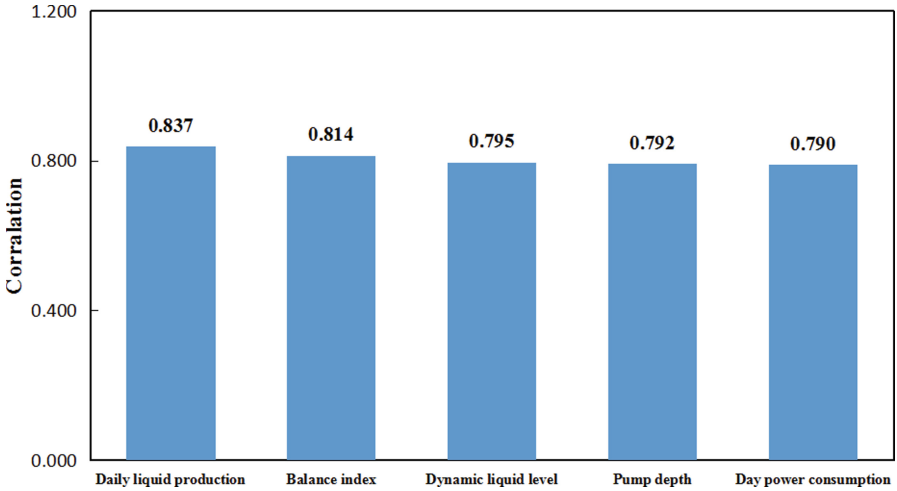

Fig. 2. Gray Correlation Analysis Results of Energy Consumption per ton Liquid Pumping 100m

index and dynamic liquid level. According to the correlation and the relationship of influencing factors, three factors including daily liquid production, balance index and dynamic liquid level have been selected as key indicators to carry out the next single factor sensitivity analysis and research and establish the energy consumption quota index system model.

3.5 Establishment of Energy Consumption Quota Standard System

The mathematical statistics has been used to sort and analyze relevant statistical material, focus on the main factors affecting quota, establish energy consumption quota index system, and determine energy consumption quota index according to different types of oil well parameters and production conditions. Since types of motor and pumping unit which is the key energy consuming equipment belong to non numerical data, it is necessary to classify and study those parameters before establishing the index system. Based on the classification of data samples, different types of energy consuming equipment have been analyzed and studied, the energy consumption quota index model has been refined, and the energy consumption index system has been established.

Through big data analysis, daily liquid production, balance index and dynamic liquid level are main influence factors. Then the multiple linear regression has been applied to main controlling factors of energy consumption to obtain the energy consumption quota calculation model of oil wells. The average error between the model calculated quota value and the actual test value is 4.85%.

$$\text{Edybm} = \text{k1} * \text{Q} + \text{k2} * \eta + \text{k3} * \text{H} + \text{k4}$$

E_{dybm}—energy consumption per ton of liquid per hundred meters;
Q—Average daily liquid production; η—Average balance index;
H—Average dynamic liquid level; k_1, k_2, k_3, k_4—Correction factors.

Table 1. Energy Consumption Quota Evaluation System List in Huabei Oilfield

Pumping Type	Motor capacity (kW)	Daily liquid Production (t/d)	K_1	K_2	K_3	K_4	Quota value of Energy consumption per ton of liquid pumping hundred meters (kw.h)	Practical value of Energy consumption per ton of liquid pumping hundred meters (kw.h)	Tolerance
8	< 30	< 6	– 1.2325	0.0096	– 0.0702	6.2795	3.500	3.6100	3.14
		6—20	– 0.0624	0.0026	– 0.0080	1.5482	0.840	0.9412	12.05
		> 20	– 0.0089	0.0012	– 0.0015	1.1254	0.670	0.7065	5.45
10	< 30	< 6	– 2.3370	0.0633	0.0108	20.6093	0.850	0.8933	5.09
		6—20	– 0.0607	0.0021	– 0.0085	1.9270	1.640	1.6411	0.07
		> 20	– 0.0067	0.0014	– 0.0094	0.9116	0.970	1.0542	8.68
	30	< 6	– 4.4581	0.0158	– 0.1608	19.1692	0.610	0.7234	18.59
		6—20	– 0.0173	0.0034	– 0.0167	1.2673	2.290	2.3410	2.23
		> 20	– 0.0028	0.0011	– 0.0006	1.1946	1.430	1.5263	6.73
	> 37	< 6	– 3.0234	0.0048	– 0.1461	13.5025	0.690	0.7312	5.97
		6—20	– 0.0446	0.0023	– 0.0139	1.2549	4.570	4.6312	1.34
		> 20	0.0027	0.0031	– 0.0529	–1.3011	1.200	1.1553	3.73

Through the classification of key energy consuming equipment and the evaluation of energy consumption quota standard system, the operation parameters and equipment status of oil wells have been completed mastered, which is the foundation for the scientific and rational established energy consumption quota index system. The energy consumption quota evaluation method has been used to analyze and evaluate the oil wells to screen high energy consumption wells. It has been built a foundation for carrying out energy consumption reduction measures.

4 Field Application

Through the establishment of quota evaluation system, the reasonable threshold of energy consumption of oil wells with different pumping equipment and operation conditions is defined. By setting parameters through on-line control technology, the balance point of benefit and efficiency can be achieved. At the same time, it changes the previous thinking model of carrying out energy consumption reduction measures according to experience, and provides an accurate scientific basis to select wells for energy conservation measures.

According to the statistics results, 340 oil wells of high energy consumption have been selected by comparison of the energy consumption quota standard. The selected oil wells have been adopted the adequate energy conservation measures. The workload Statistics of different measures are shown in the Table 2.

Table 2. The Measure Workload Statistics List

Measure Types	Deepen pump hanging	Lifting pump hanger	Increase pump diameter	Decrease pump diameter	Increase stroke	Decrease stroke	Increase stroke times	Decrease stroke times	Interval Pumping	Total
Measure times	22	16	26	44	10	82	39	144	42	425

Table 3. The Measure Effect Statistics

	System Efficiency %	Pumping Efficiency %	Daily power consumption kW·h	Energy consumption for per ton of liquid pumping 100 m kW·h
Before Adjusting parameters	20.482	37.133	176.091	1.115
After Adjusting parameters	21.784	42.946	160.070	0.994
Value Change	1.303	5.813	–16.021	–0.121

As shown in Table 3 the oil well system efficiency has increased by 1.3%, the pump efficiency has increased by 5.81%, and the daily power consumption has decreased by 16kw·h for single well after adopting the measures.

5 Conclusion

Based on the results and discussions presented above, the conclusions are obtained as below:

(1) The big data analysis of oil well pumping system has combined the massive data of production and development with data analysis technology which facilitates the on-site operators to view and retrieve the required data in time. It helps the technicians to analyze the energy consumption of oil wells from a new view and find valuable information that can not be found by traditional research methods.
(2) It has defined three main factors affecting the system efficiency of oil wells which provides an analysis foundation for oil well conditions and parameters optimization.
(3) It is important to ensure the integrity and accuracy of data as much as possible which puts forward higher requirements for automatic acquisition technology. The establishment and application of energy consumption quota standard system provide a good reference for the application of big data analysis in oil field.

References

1. Zhu Zhiguo, Miao Yanping, Wang Jun, Ling Shuai, Xue Liqiang, Du Hang. The Application of Big Data Analysis Aiming at Reducing the Power Consumption of 100 Meters per ton of Pumping Well (2018). In: Energy Conservation in Petroleum & Petrochemical Industry, 8(10) :10–13.
2. Wang Huiping, Peng Jian, Liu Zhihai, Li Xiaomin, Zhang Junru, Ning Bi. Development and Application of Big Data Mining System for Oilfield Water Injection Production (2015). In: Petroleum Engineering Technology, 11:58–60.
3. Tan Chaodong, Li Xin, Geng Yuguang (2015) The application of big data system of oil production in Huabei Oilfield. In: Petroleum Engineering Technology,05:48-52.
4. Liu Jinguo. Overview of data analysis method and technology (2004). In: Science and Technology, 07:22–25.
5. Li Xin, Geng Yuguang, Yang Xiaoping, Huang Shaowei (2015).In: Research Institute of Oil Production Engineering in Huabei Oilfield Company. In: Oil Drilling & Production Technology, 07:76–79.
6. Zhang Yi; Guo Quan; Wang Jianyong. Big Data Analysis Using Neural Networks(2017). In: Advanced Engineering Sciences,1:10–18.
7. Miao Yanping, Zhu Zhiguo, Wang Jun, Ling Shuai, Deng Ming, Du hang. Energy Consumption Management of Oil Production Plant Based on Big Date Analysis (2018).In: Inner Mongolia Petrochemical Industry,08:32–33.