The Feature Pick-up Based on Bitmap Images and RGB

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Abstract

During the oil production, the recorder on recording charts prints the current curves and they indicate various working conditions of an electrical submersible pumping (ESP). Subtle malfunction or abnormal problems of the electrical submersible pumping can be detected and further analyzed from various features of these current curves on the recording charts. In this paper, a diagnosis expert system is presented for automatically analyzing these current recording charts and identifying work condition of an electrical submersible pumping. This expert system includes an open knowledge base, which can be updated or enriched according to the identified features of current curves on the recording charts, and a condition monitoring and failure pattern identification or recognition method, called “pick-up method of recording chart feature”, which can be correctly applied in most cases. It has been proved that the developed expert system can effectively improve the accuracy and efficiency of failure diagnosis and work condition monitoring of electrical submersible pumping.

Keyword: ESP, diagnosis, expert system, pattern recognition.

1 Introduction

The pick-up method of recording chart feature is a key technique by using a computer to automatically recognize the recording charts. Various features on the recording charts reflect lots of fault of an electrical submersible well system [1], [2]. Pick-up feature becomes one of the difficult tasks to build a pattern recognition system for automatically identifying the recording charts. Some of these important features cannot be easily found or identified because of being restricted by complicated environment and working conditions of ESP in the well. Therefore more and more people in the world are paying attention to pick-up feature problem.

Pick-up feature is essentially to identify the distinguish curves from the recording cards through using mathematic methods to describe some physical characteristics of a current curve. For different curves, feature distinction may be little in same kind but large in different kinds. Feature should never change along with parallel moving, rotating and scaling a curve.

There are many methods for feature pick-up, e.g. unchanged matrix, Fourier descriptor and time series model [3], [4], etc. The drawback of the unchanged matrix method is that it cannot reflect enough local information of a figure (or current curve) on a recording chart through limited invariable. Fourier descriptor has enough character number to reflect small change of local figure, but it needs a lot of work for further pattern recognition. Furthermore, by using the Fourier descriptor the character cannot be processed by parallel moving, rotation and scaling of the current curve. Both methods are sensitive to sound noise. In recent years, the technique of time series model has been applied in the field of pattern recognition.

More attentions have been paid to the development of the recording charts recognition, but little results have been achieved in concern with the confidence of the predictions of using the recording charts and the circumstances under which the predictions are valid. This statement can be further justified through the following literature review.

2 Feature Analysis

Traditionally, to monitor the work condition of an ESP, the electronic current of the driving motor of an ESP is measured. However, if only the electric current of motor is monitored, diagnosed and analyzed, very likely a number of aspects to affect system operation may be omitted. To improve effectiveness of the diagnosis and analysis, a new representation of the operating condition of ESP systems is required. This can be done by using relevant process variables to obtain an analogous to the well-known dynamic graph chart which is used by sucker rod pump operators [5]. The dynamic graph shows more information than the electric current. Following the same idea, this paper reports a pick-up feature method to fully analyze the electric current graph on a recording chart.

Figure 1 illustrates the feature base of recording charts, which includes 16 different kinds of electric current curves on the recording charts under standard working conditions. As shown in Figure 1, A1: ordinary recording chart, B1: recorder chart when power supply fluctuates; C1: recording chart when pump air slugs; D1: recording chart when pump takes out few oil; A2: recording chart when pump starts abnormally; B2: recording chart when pump runs continually and shuts periodically; C2: recording chart when pump runs in air-well; D2: recording chart when pump stops because current is low; A3: recording chart when pump’s protector does not work; B3: recording chart when pump’s delay time is short; C3: recording chart when pump stops because it is normal overloaded; D3: recording chart when pump runs in impurity well; A4: recording chart when pump starts compulsively; B4: recording chart when pump fluctuates because of overloaded; C4: recording chart when the pen in the recorder cannot draw a current curve; D4: recording chart when pressure safety value is not tested.

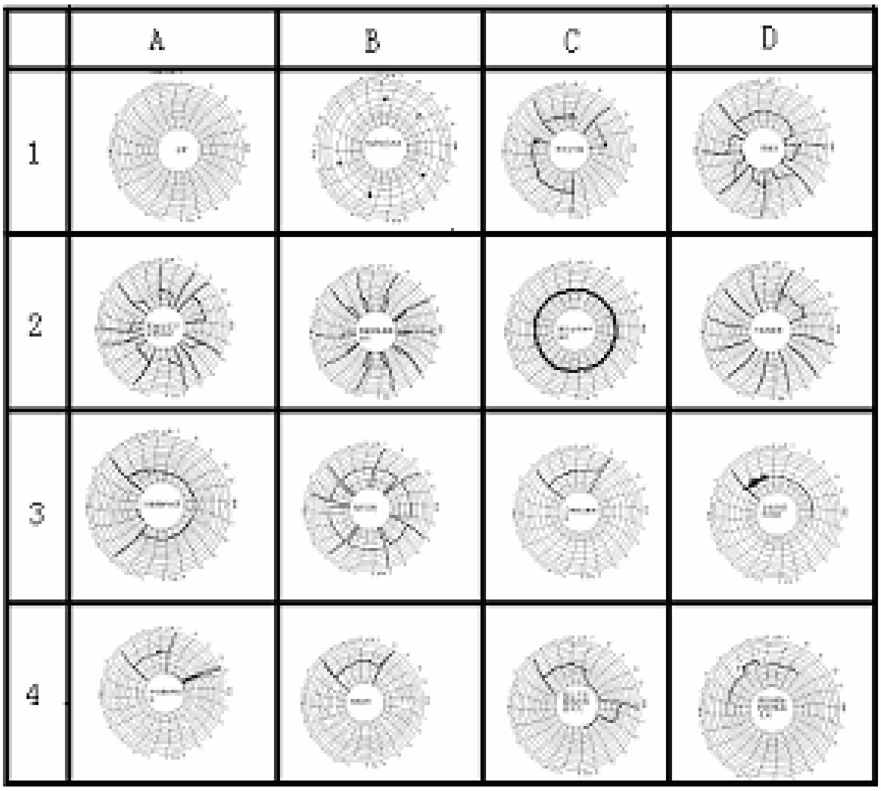

Fig. 1. The feature of recording chart

3 Establishing Coordinate

In the course of diagnosing electric submersible pump by using recording charts, pick-up feature of the electrical current curves on the recording chart decides the category of the faults and the accuracy of the diagnostic results.

The conclusion can be gained by discussing the pick-up method of standard recording charts. Under different working conditions, the value and fluctuation of electrical current are different. The coordinate is established firstly on a recording chart, and then a number of points on a current curve can be sampled according to a sample rate which is determined according to the pre-determined or required measuring precision. The total values of current on a recording chart reflect a different working condition of the driving motor in an ESP. Therefore, the sum (recorded as M) of square of current values or the area of a close loop current curve can be used to identify different geometric shapes of current curves or working conditions of an ESP. M value can be used for current curve pattern recognition, which can be calculated by equation 1 [6].

$$M = \sum I_i^2 \qquad (i = 1, \cdots, n) \qquad (1)$$

The current curve on a recording chart illustrates twenty-four hours working current of the driving motor of an ESP, which is normally a closed-loop circle as shown in figure 2. In the coordinate, a current value can be read easily along the circle. Every point on the circle corresponds to a current value, which is recorded as $I_i, i = 1,2,\cdots,n$.

4 Pick-up Feature of Recording Chart

The scanned recording chart can be kept in bitmap image format and stored in a computer. Then the computer system can process these bitmap images and automatically pick up features from the current curves on the stored bitmap images.

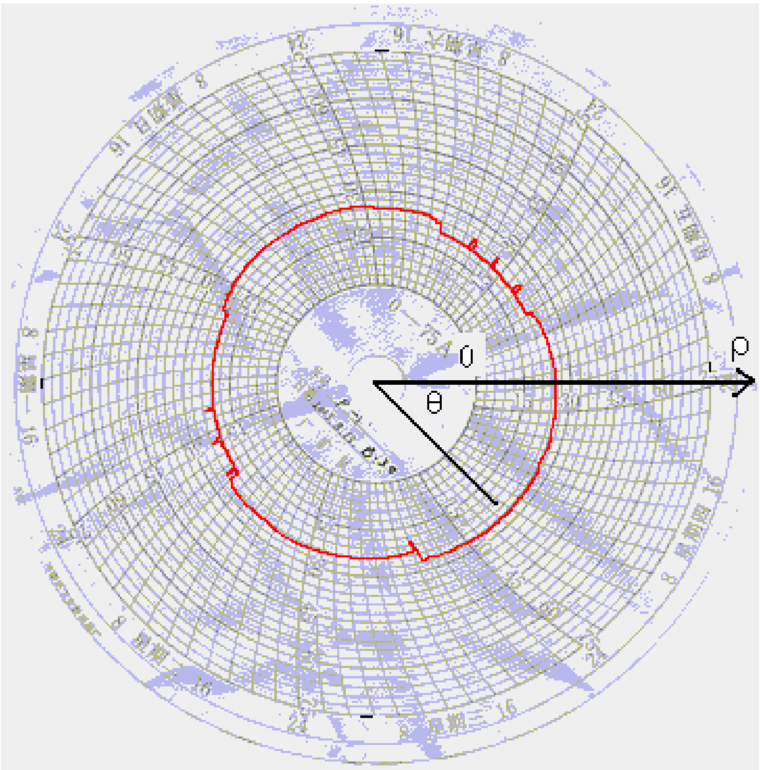

Fig. 2. Establishing the coordinate on a recording chart

To be processed by the computer, a continuous curve on a stored bitmap image must be converted into a set of discrete data. The digitalized process of a bitmap image is carried out through reading the different colors of pixels of the image on a computer screen. The different colors of pixel have different RGB (red, green and blue) values. As shown in Figure 2, the current curve is colorfully distinguished from its background on a bitmap image. Therefore, by selecting proper RGB value, a current curve can be automatically read by a computer system and recorded as a set of discrete data in the computer system.

The computer program for automatically picking up features from a recording chart is developed in Visual C++. The index value of pixel colors is from 0 to 255 for a 256-color bitmap. For example, the red color has an index value of 249. As shown in Figure 2, the current curve is plotted by red color. Therefore the computer system can pick up this current curve by setting the color index value as 249 from its background that consists of pixels with other colors. To erase the background, the computer system can simply set the index value of other pixels as 255, which means white color.

The value of recording chart cannot be directly read, because the value is serial. So the serial value must be sampled into discrete data. In order to ensure the required precision, the computer system reads 360 points from the circle as shown in Figure 2. It starts and reads points randomly from the circle. The sum of square of current values from these points is calculated according to equation 2, which is an M value to represent a working condition pattern of an ESP.

$$M = \sum_{i=1}^{360} Ii^2 \tag{2}$$

Figure 3 shows a bitmap image of a recording chart before the computer system processes it and Figure 4 shows the bitmap image after the processing. The pix-map coordinate corresponding current curve is recorded in the computer system. According to equation 2, the chart feature M is got as follows in terms of the feature base as shown in Figure 1: A1: M_1=12960; B1: M_2=13039; C1: M_3=8740; D1:, M_4=6513; A2: M_5=3268; B2: M_6=1750; C2: M_7=10890; D2: M_8=1429; A3: M_9=6435; B3: M_{10}=11448; C3: M_{11}=3187; D3: M_{12}=5703; A4: M_{13}=2232; B4: M_{14}=3135; C4: M_{15}=3359; D4: M_{16}=5412.

From the M values as listed above, it can be seen that some M values are very close. To further take the statistic errors into consideration, it would be difficult to distinguish some working conditions simply by M values. In our work, a standard statistic error is set as $4 \times I_0^2=144$ and I_0 is current value in ordinary working status, which normally has a value of 6 in the polar coordinate. In terms of the discussions made above, the working conditions are classified as follows in terms of M values:

A1 or B1, when $M_{1,}$ M_2>12204
B3, when $12204 \geq M_{10} > 11169$
C2, when $11169 \geq M_7 > 9815$
C1, when $9815 \geq M_3 > 7642$
D1 or A3, when $7642 \geq M_4$、$M_9 > 6069$
D3, when $6069 \geq M_{12} > 5558$

D4, when $5558 \geq M_{16} > 4520$
A2, when $4520 \geq M_5 > 3494$
C4, when $3494 \geq M_{15} > 3273$
C3 or B4, when $3273 \geq M_{11}$、 $M_{14} > 2684$
B2 or D2 or A4, when $2684 \geq M_6, M_8, M_{13}$

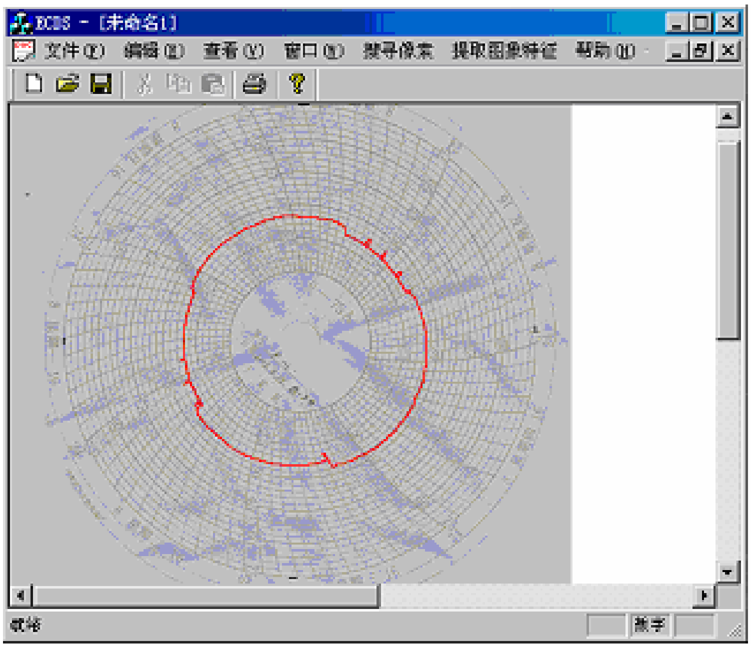

Fig. 3. The recording chart before the computer system processes

It is obvious from the working conditions as classified above, some of the working conditions, such as A1 and B1, or C3 and B4, need to be further distinguished by using other pattern recognition methods, such as supplementary method as proposed in Section 7. According to the implementation results in several oil fields, the working condition identification method by using M values as presented in this paper has a relatively high accuracy, which is up to 97% correct recognition rate. In practice, most M values that are calculated from equation 2 are allocated in the middle domain of the values as listed above.

5 About I_0

In polar coordinate, I_0 equals to 6 for a normal ESP (electric submersible pump), which is a current value on the recording chart. However different pumps have different I_0 values. In order to make a standardization of formulae, the current value of different pumps under ordinary motor working conditions can be unified by multiplying a ratio α , which can be calculated by equation 3.

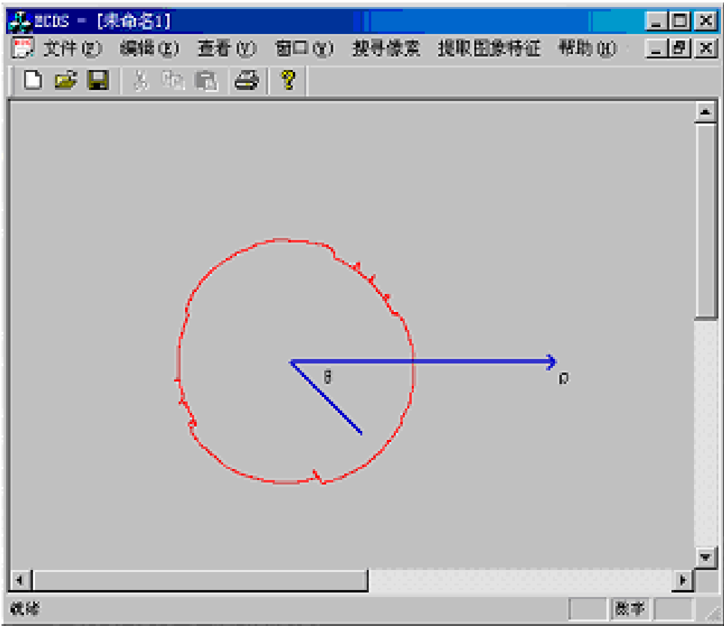

Fig. 4. The recording chart after the processing

$$\alpha = {}^{6}\!/\!_{I_0'} \qquad (3)$$

Where I_0' is a current value of the driving motor in an ESP under an ordinary working condition.

6 Supplementary Method

Most of recording charts can be distinguished through the method as presented in previous sections. However, some recording charts may not be distinguished by using the method as presented above. The method as presented above mainly identifies the recording charts by the area of a close loop current curve on a recording chart, i.e. sum of square of current values. If two current curves look similar, the method will fail to identify the current curve pattern. The current curve as shown in Figure 5, which denotes a pump stops due to a normal overload, looks similar to the current curve as shown in Figure 6, which denotes a pump stops due to a fluctuated overload.

These two current curves cannot be distinguished by simply using M values. Hence a supplementary method needs to be further introduced to identify similar current curves.

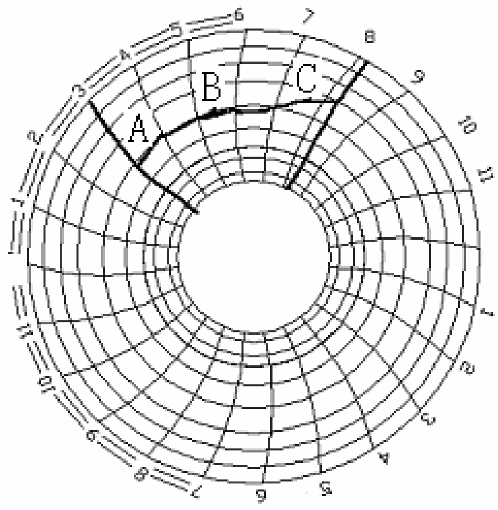

Fig. 5. Recording chart of normal overload

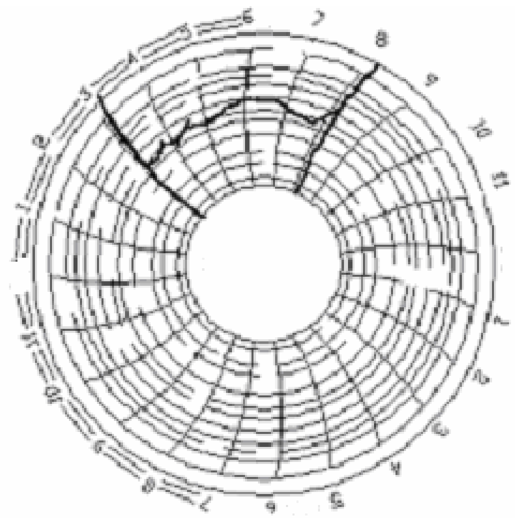

Fig. 6. Recording chart of fluctuate overload

The current curve as shown in Figure 5 can be divided into three parts, A, B and C. Part A shows that the motor starts when current is lower than an ordinary current value, i.e. I_0=6, and then it comes back to the ordinary current value. Part B shows that pump is running ordinarily at the current value I_0. Finally Part C shows the current raises gradually along the time and finally reaches to the overload protection value to result in pump stops. This means the current curve as shown in Figure 5 has a certain pattern of current change. On the other hand, the current curve as shown on Figure 6 illustrates a random fluctuation of current value without a clear current change pattern, which indicates a fluctuated overload of an ESP. The fluctuated overload of an ESP is caused by the change of well fluid density and high backpressure.

As shown in Figures 5 and 6, the pump stops due to normal overload shows a stead increase pattern of current, whereas the pump stops due to fluctuated overload illustrates a random fluctuation of current. This difference of current pattern between these two working conditions can be identified by the following supplementary method.

First of all, a set of data is read from each current curve respectively, which is written down in the following two data sets. The set on the left is taken from the current curve as shown in Figure 5 and the data set on the right is taken from the current curve as shown in Figure 6.

$$\begin{bmatrix} 5.8,5.8,5.8,5.8,5.8,5.8,5.8,6.0,6.0 \\ 6.0,6.0,6.0,6.0,6.0,6.0,6.0,6.0,6.0 \\ 6.0,6.0,6.0,6.0,6.0,6.0,6.0,6.0,6.0 \\ 6.0,6.0,6.0,6.0,6.0,6.0,6.0,6.0,6.0 \\ 6.0,6.0,6.0,6.0,6.0,6.0,6.0,6.0,5.6 \\ 5.6,5.6,5.6,5.6,5.6,5.6,5.6,5.6,5.6 \\ 5.6,5.6,5.6,5.6,6.0,6.0,6.0,6.1,6.2 \\ 6.2,6.3,6.3,6.4,6.4,6.5,6.5,6.6,6.6 \\ 6.7,6.7,6.8,6.8,6.8,6.9,6.9,7.0 \end{bmatrix} \qquad \begin{bmatrix} 6.0,6.0,6.0,5.8,5.8,5.8,5.9,5.9,5.9 \\ 6.0,6.0,6.0,6.0,5.9,5.9,5.8,5.8,5.8 \\ 5.9,5.9,6.0,6.1,6.2,6.2,6.2,6.1,6.1 \\ 5.9,5.9,5.8,5.8,5.8,5.9,5.9,5.9,6.2 \\ 6.2,6.3,6.3,6.4,6.4,6.5,6.5,6.6,6.7 \\ 6.9,7.0,7.0,7.0,6.9,6.9,7.0,7.0,7.0 \\ 7.0,7.0,7.0,7.0,7.0,6.8,6.7,6.7,6.5 \\ 6.5,7.4,6.3,6.1,6.1,5.9,5.8,5.5,5.5 \\ 5.7,5.9,6.0,6.3,6.7,7.0,7.2 \end{bmatrix}$$

Secondly, by using equation 4, the sum (recorded as D) of square difference for each set of data can be calculated. For the left data set, D equals to 9.85 and for the right data set, D equals to 21.88.

$$D = \sum (I - I_0)^2 \tag{4}$$

D can be used as another pick-up feature value in addition to M value to further distinguish closing working conditions. When D≥（9.85+21.88）/2=15.87, it indicates that the pump stops due to a fluctuated overload. Otherwise, it indicates the pump stops due to a normal overload.

7 Conclusion

Based on the discussions made in this paper, the following conclusions can be achieved:

1. In the research work as presented in this paper, the physical characteristics of recording charts have been described and identified by simple mathematic models. By using these mathematic models, sixteen typical types of recording charts can be automatically classified or identified by the computer expert system as presented in this paper. To automatically classify the recording charts is a key technology to solve the monitoring and diagnosis problem of the ESP.

2. Through adopting image processing technique in combination with pattern recognition technique, this research project finds an effective method to automatically monitor and diagnose the ESP's working condition under a well.

References

[1] Huang Xing, Shi Puqin: Introduction of Diagnosis Technology in Electric Submerge Pump Well. Oil Gas Test. Vol. 9 (2000), pp. 59-61.
[2] Coben, D. J.: Captain Field Electric Submersible Pump, Condition Monitoring and Completion System. J. of Petroleum Technology. Vol. 67 (1997), pp. 201-208.
[3] Bian Shaoqi: Pattern Recognition. Tsinghua University, Beijing (1988).
[4] Xiong Shenshu: Nonlinear Time Serial Model for Shape Recognition Using Neural Networks. Automatic. Vol. 31 (1999), pp. 47-51.
[5] Feng Ding: Neural Network Expert System for Rod Pumping Diagnosis. China Petroleum Machinery. Vol. 30 (1996), pp. 1-4.
[6] Putra Koesnihadi, J. B., Lea, J. F.: Hybrid Lift Technology: A Design Technique of Combining Electrical Submersible Pumping with Liquid-jet Gas Pump. In Proc. of SPE Annual Technical Conference and Exhibition. (2002) SPE77731.

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