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Integrated Fault Diagnostic Techniques on Marine Large-scaled High-pressure Reciprocating Gas Compressor Groups

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***Abstract*—The reciprocating gas compressor is the core equipment used to gather and transport offshore oil and gas. The BOP-X-2502A/B/C type compressor groups, which are marine large-scaled high-pressure reciprocating gas compressor groups on BZ28-2SBOP offshore platform of CNOOC (China) Ltd., are characterized by the complicated structures, various moving parts, numerous failure samples. Therefore, an integrated fault diagnostic technique is proposed to carry out the condition monitoring and the trend forecasting of compressor groups. The diagnostic technique also can be used to identify and locate the cause of faults, to determine the degree of fault type, to achieve the real-time network monitoring, and to share data resource using network, etc. Then the fault diagnostic software system is developed based on Lab Windows/CVI software. The safety of equipment and overall management level is improved significantly after using the diagnostic method.**

Keyword-reciprocating gas compressors; offshore platform; integrated fault diagnosis technology; fault diagnosis software; Lab Windows/CVI software.

I. INTRODUCTION

At present, there is not an absolute standard to follow for the diagnosis of natural gas reciprocating compressors. A primary method is to set the alarm value and stop instruction. Fault diagnosis technology has become one of the priorities for the international standardization organization (ISO)[1][2]. SH/T3143-2004 standard has been established in China, and its technical specification conforms to the standards of API STD 618.1995, API STD618 and GB/T12779-1991. The main parts of items and contents of SH/T143-2004 are generally just frame types. For example, such contents will be supplemented as different types and specifications of reciprocating machines, important parts, common locations of condition monitoring, measuring parameters, alarm values.

An integrated fault diagnostic technique for compressor groups of BZ28-2SBOP offshore platforn focused on condition monitoring, trend forecasting, de and type of fault, fault position, failure cause, real-t monitoring and data resources sharing. This research i important development direction for key equipm management and ocean platform development. It can als applied to the operation management of other impo

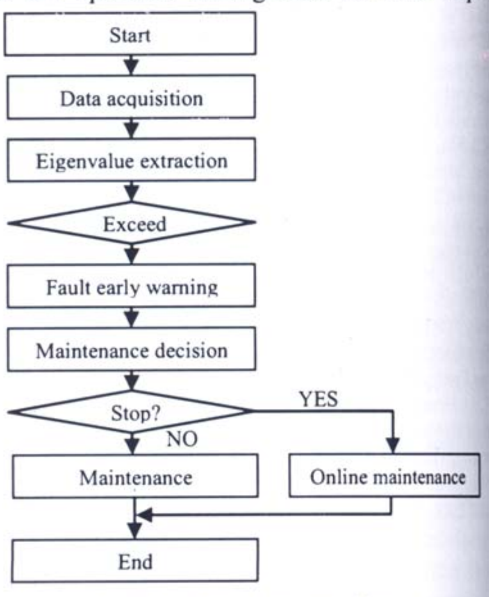

Figure 1. Basic flowchart of fault

equipments on the ocean platform at the same time, in o to maximize the equipments management efficiency [3].

II. BASIC THINKING ON INTEGRATED METHOD OF FAULT DIAGNOSIS.

The aim of mechanical fault diagnosis is to understand and master status of the machine running process, determine whether or not the partial part is normal, early detect failures, analyze the causes, and to forecast the development trend of technological failure.

Commonly used method of machinery fault testing and diagnosis contains vibration, noise, temperature, pressure, acoustic emission. It also contains lubricating oil analysis, metal content analysis, metallographic analysis, etc. Among the natural gas compressor fault diagnosis method, oil monitoring technology, vibration monitoring technology, noise monitoring technology, capability trend analysis and nondestructive testing have been adopted as a popular alternative[4][5][6]. The causes of natural gas compressor failure is complex, a single method is hard to meet the requirements. This paper addresses the problem by building a combined diagnosis model, exploring various composite structure and mechanisms.

Integrated diagnostic model contains the parameters diagnosis of performance, fault tree, vibration analysis, etc. It assumes the separate module carry on comprehensive diagnosis with a certain method. Fig1 shows the basic flowchart of fault diagnosis. Each individual diagnosis module can independently extract feature, diagnose, reason logically.

III. SYSTEM DESIGN

Temperature sensors, pressure sensors, flow sensors, level sensors, vibration sensors are decorated to collect the data. This is for the obtaining of the eigenvalue extraction.

Fig.2 shows the cylinder combustion sensors and cylinder temperature sensor have been installed on the compressor.

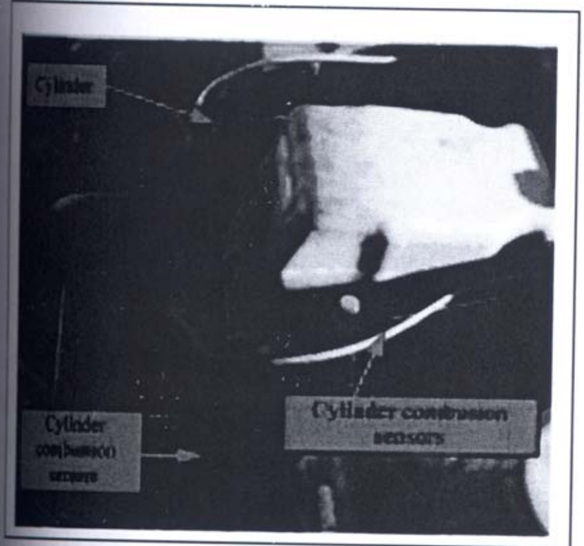

Figure 2. Sensors on the natural gas compressors

The data acquisition system of the reciprocating gas compressors is shown in Fig.3. Data transducers transmit different data to computer from different parts. Fig.4 shows waveform has been captured by the transducers.

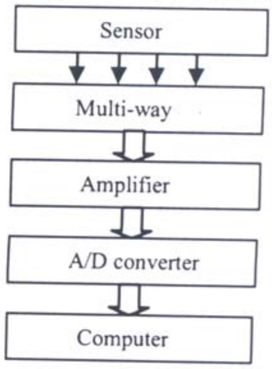

Figure 3. Data acquisition system

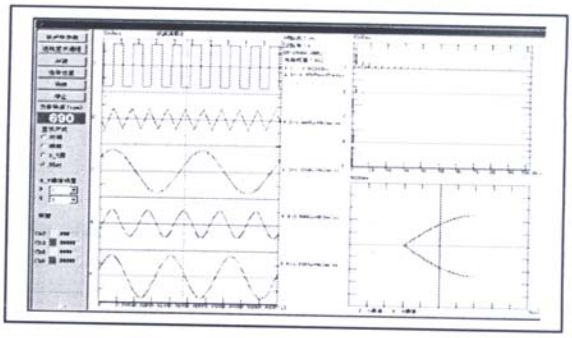

Figure 4. Waveform captured

Generally speaking, the distributed acquisition system of natural gas compressor often consists of three parts: surface acquisition system, telemetry data cable, as well as a central control station. The surface station acquisition is arranged by the direction of the measuring lines, which is responsible for collecting one or several geophysical data at the measurement position. The main task of the central control station is to complete the task of the data recording and quality monitoring [7]. The basic structure is shown in Fig.5.

In this system, the data processing method includes time domain method and frequency range method. Correlation analysis method should be taken in time domain, and frequency spectrum analysis method will be applied in frequency range. In addition, there are digital filter and window function designed in consideration of the need and significance of data analysis or processing. So that the signals can be truncated properly and it can processes and analyze signals easily.

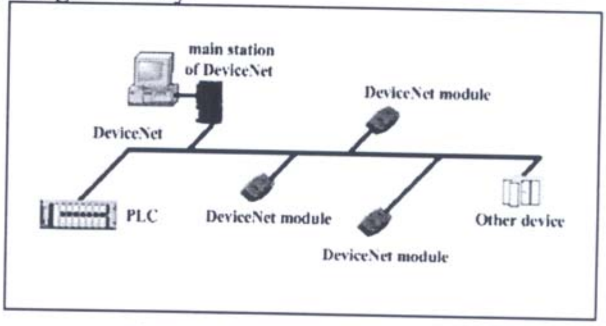

Figure 5. Distributed test system

The are many ways to identify the signal acquisition, commonly used identification methods are statistical methods, function identification, logical methods, fuzzy recognition method, the gray methods and neural network pattern recognition method. Regardless of this, each method consists of four stages: signal measuring, feature extracting, feature database establishing and comparing. The data preprocessing process is shown in Fig. 6.

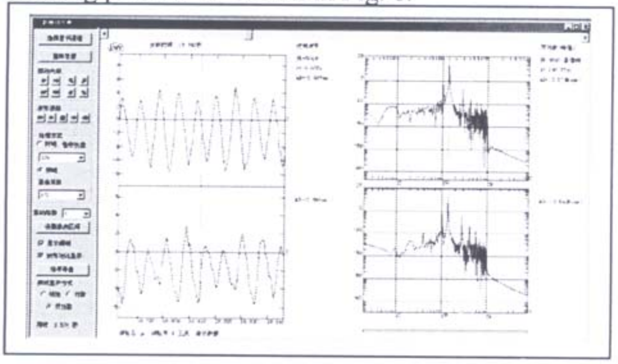

Figure 6. Data preprocessing

Correlation Analysis on the data gathered by sensors at one time is good for judging whether or not there are some disorders of the machine. So that it is easier to find out the source of trouble precisely, and a lot of time is saved for trouble maintenance. Method of correlation analysis of signals includes the study of correlation coefficient, autocorrelation coefficient and cross-correlation coefficient. The fault diagnostic techniques can evaluate the quality of the data and the general state of machines by some analysis. And then the limit warning will be determined according to the average value at the moment.

In order to diagnose the malfunction of compressors, we should analyze the characteristic spectrum of the related signals. A drawing of spectrum consists of some spectral lines (such as 200, 400, 800). And the diagnosis information can be obtained from these spectral lines. Fig.7 shows the method of utilizing spectral analysis method to analyse the spectrum.

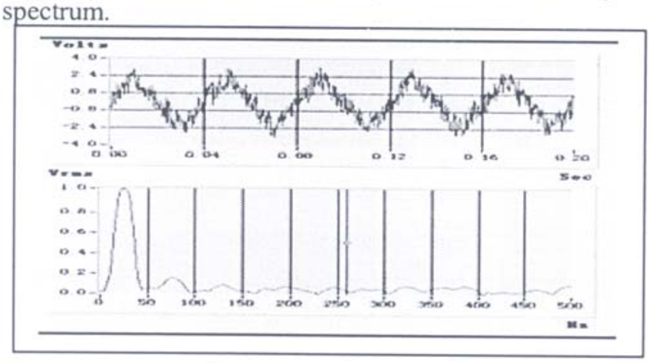

Figure 7. Spectrum analysis

The basic management of spectral analysis is as follows:

A. To Choose The Peak Frequency and Corresponding Spectral Values

This is one of the most widely used methods applied to identify faults from the spectrogram. It only needs to get the peak frequency and its value of spectrum. The rel background information shows that the fault con characteristic frequency. And it will help us to diagno we observe the dynamic change in the spectrogram. [8][

B. To Set the Frequency Window

To set some frequency windows in the frequency of certain spectrum, and to make the average heig window or spectra area (power) to be the charact parameter. This method is used in practice commonly.

C. To Fit the Curves or Set the Reference Lines

Make use of the polynomial to fit certain spectral cu and make the polynomials coefficient to be charact parameters. Besides, it also can set a reference line (li parabola used commonly). Then add the deviation v exceeded the reference line or add the values after squa deviations. Make the result to be the characte parameters.

D. To Analyze the Frequency Spectrum

To set a frequency as the reference wave, then to ga ratio between its high and fundamental harmonic power.

E. To Acknowledge the Alarm Value

To get a complete range of vibration data from machine, then estimate the quality of the data and the s the machine. At last it can determine the limit of the value according to the current level.

IV. OBTAINING OF CHARACTERISTIC VALUE

The dynamic signal of natural gas compressor co wealth of information of the various components compressor, including fault messages in the actual ru Therefore, the time domain characteristic features used to reveal the compressor failure. Commonly us domain characteristics features are: Kullback indicators of K, Bhattacharrya distance of B and the index V.

$$K = \ln(\frac{\sigma_T}{\sigma_R})^2 + (\frac{\sigma_{RT}}{\sigma_T})^2 - 1$$

$$B = \frac{1}{4}\frac{(U_R - U_T)}{\sigma_R^2 + \sigma_T^2} + \frac{1}{2}\ln(\sigma_R^2 + \frac{\sigma_T^2}{2\sigma_R\sigma_T})$$

$$V = \frac{\sigma^2{}_{RT}}{\sigma^2{}_T} - 1$$

Where σ_R^2 responds the residual of X_{T} responds the residual of X_{Rt}; U_R responds value of X_{Rt}; U_T responds the mean value of X

K, B, V can be used to diagnose a variety of c failure. TABLE 1 shows the values of K unde conditions, and the status to be tested is determi status of the valve impact mostly.

TABLE I. K VALUES FOR DIFFERENT STATES

	Normal working	Links hitting	Valve impact	Quarantine status
Normal working	0. 000	0.176	0. 212	0. 182
Links hitting	0. 087	0.000	0.020	0.026
Valve impact	0.084	0. 019	0.000	0.005
Thrombus status	0.079	0.024	0.005	0.000

The compressor is issued by various components of the energy spectrum in the frequency response range actually. It may distinguish whether or not that the parts of the band is in an abnormal state when there is an exception of the energy spectrum belongs to the frequency range.

After computing the energy spectral density or power spectral density, it can obtain various of fault features.

It is available to take the absolute energy values and relative energy value T_f as the fault features related to the frequency bands.

$$E_j = \sum_{i=1}^{N} ESD(i)\Delta f \tag{4}$$

$$T_f = \frac{E_j}{E} \tag{5}$$

Where Δf responds frequency resolution; *ESD(i)* responds the spectral line of power spectrum density values, corresponding to i; E is the total energy; N is the number of spectral lines within a specific frequency band. What is more, it will get the conclusion below:

- Detection objects will be defined based on different faults accordingly.
- According to the frequency of occurrence of all the effect factors and the severity of consequence caused by them, certain values can be assigned to the effect factors. Meanwhile, the detection order is depended on the sizes of the values.
- When some of the effect factors have the comparative values, the detection order should be determined by the difficulty level of the detection.

By contrast, the fault tree method is based on the probability of the event. and the structure function of fault tree diagnostic method is as follows:

$$\varphi(X) = \max(X_1, X_2, \ldots\ldots, X_n) \tag{6}$$

Where φ is the condition of top event; X_i (i =1, 2, ...) is the condition of bottom event, φ is decided by X_i (a total number of the 2^n states). It gets a lot of unpredictability of the location and the principle about the fault and can not prevent the beginning of the tiny fault timely. Fig.8 shows the fault of natural gas compressors.

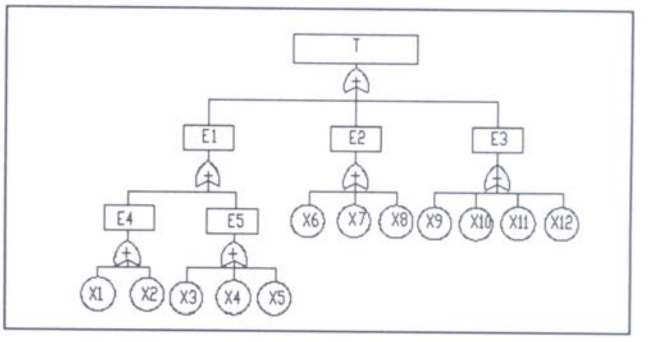

Figure 8. Fault trees of natural gas compressors

V. THE SOFTWARE DESIGN FOR FONTS DIAGNOSIS

Combining the purpose of fault diagnosis analysis, part of the operation can be debugged based on the usage of the software driver program. Lab Windows/CVI [10][11], a kind of virtual instrument software from NI company, boasts a sort of software development environment which has the functions of signal acquisition , measure analysis and data presentation. Compared with traditional instruments, Lab Windows/CVI has more advantages which go as follow:

- Lab Windows/CVI has abundant function libraries with powerful functions.
- Instrument library, a special resource of Lab Windows/CVI, contains GPIB, VXI and the drivers of RS-232 like oscilloscope, multimeter, function generator, etc.
- The establishment and edit of the graphical user interface (GUI) can be realized with the application of UI editors. What's more, GUI can be built and controlled in the process of programming based on the use of Lab Windows/CVI library functions. This makes the usage of the software more flexible.

VI. SUMMARY

In terms of the natural gas compressor, this paper has conducted researches on fault diagnosis methods and put forward technical protocols for the combination diagnosis system. This combination diagnosis system mainly contains three parts: data acquisition, data analysis and fault diagnosis. It has helped to realize the fulfillment of the overall process of online monitoring, fault diagnosis, fault prediction and so on and also carried out software design and development based on Lab Windows/CVI. According to the performance test and the fault diagnosis methods mentioned in the above paper, the whole life cycle of the equipment can be further studied and the management of the equipment can be greatly improved.

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