Hazard and Operability Safety Analysis on Natural Gas Compressor Based on Signed Directed Graph

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Keywords: signed directed graph; hazard and operability analysis ; natural gas compressor ; combined analysis method

Abstract. SDG and HAZOP combination method is used for Safety analysis on natural gas compressor. Compares and analyzes deviation degree of results and the actual results with examples. Practice is proved that the combination method is superior to single safety analysis methods. And it is suitable for the safety analysis of natural gas compressor unit. It is of practical significance to the safety in production too.

Introduction

SDG (Signed Directed Graph) is composed of nodes and direction lines between nodes (nodes), which is also known as the branch network diagram. The method SDG can express complex causal relationships and inclusive massive potential information. Solving problems in complex systems, through the node with the problem domain mapped to the elements, the impact of the relationship between the various elements to correspond with the branch, SDG can describe a complex system of linkages between each of the components and their components of the system. However, this method generally only supports large or small two kinds of deviations which do not include device status information, and it often causes the wrong report of failures.

HAZOP (Hazard and Operability Analysis), which is the systematic review of methods to examine new designs or existing production process and engineering figure, which can evaluate device individual parts misuse or potential danger caused by mechanical failure, and its impact on the entire enterprise, but the method is the lack of quantitative analysis, depending on the level of team members, and likely caused by human factors errors.

In theory, these two characteristics of different analytical methods have complementary advantages, and in the actual safety analysis, the establishment of combined model has good application prospects.

Natural Gas Compressor SDG-HAZOP Modeling

A typical gas compressor system is divided into control systems, oil systems, fuel systems, air systems, gas turbines, gas booster compressor, booting the system, etc.. The entire system consists of many subsystems combination, each subsystem is an important part of the system running .In order to do the analysis of the entire natural gas compressor system, SDG-HAZOP model is established. It is necessary to clarify several important functions and workflow subsystem. Due to limited space, here only take the lubrication system for example, we establish SDG-HAZOP model.

When the system starts, the auxiliary (front / rear lubrication) pump extracts oil from the tank and fed to the filter and the regulator. Assisted by the oil pressure safety valves maintained at 20psig, the lubricating oil inflows into the engine and gas compressor lube oil system .through the manifolds. After the pre-lubricated (station valve process typically takes 4 minutes), the engine starts to rotate, the engine-driven main pump starts oil. As the engine speed increasing, the main engine-driven oil pump pressure goes up. When the oil pressure reaches the predetermined value (typically 35psig), the auxiliary pump shut down. Supplying the lubricating oil from the main oil pump, under the pressure regulator valve, hydraulic pressure 55psig is kept. If the oil temperature exceeds expected value (usually 140 ℉), the thermostat valve makes the lubricating oil flow to the cooler. The lubricating oil flows through the filter to reach the portal, through branch line inflows into the engine and the gas compressor lubrication points. The lubricating oil flows into accessories gear for gear and compressor rotor front bearing lubrication. The lubricating oil under the action of gravity flows back into the tank from the accessory box, and flows into compressor and turbine support box .The lubricating oil supplies compressor rotor and turbine rear bearing oil . The lubricating oil gathered inside the bearing support box , flows by gravity back to the tank, after the shutdown process lubricating goes by the auxiliary pump (through electronic control system automatically) to complete. During the latter lubrication process, the oil makes bearings and gears cool for 55 minutes.

SDG-HAZOP Modeling for Lubrication System

The lubricating oil system workflow can be seen, the main function of this system is to provide the lubricating oil for the appropriate mechanical compressor system to keep the suitable temperature. The lubricating oil for the mechanical mechanism is critical, and effective lubrication can protect mechanical mechanism from friction and wear, the cooling condition due to the movement of overheating is damaged, so mechanical efficiency is improved, the mechanical lifetime is extended. So the lubrication oil system for the compressor system has a pivotal role. For the entire system, the most important parameters of the lubricating system is the oil supply flow rate and its temperature.

Impact equations are as follows:

$$RH1 \leftarrow RH2 + RH5 + RH7 \tag{1}$$

$$RH3 \leftarrow RH6 \tag{2}$$

$$RH4 \leftarrow RH8 \tag{3}$$

$$RH8 \leftarrow RH3 - RH1 \tag{4}$$

According to the emulation analysis of the data of a compressor unit. It's important for the note that, in this period of time, there are three operation parameters deviation from the normal value, lubricating oil tank of liquid level, oil pressure and gas turbine bearing temperature. The curves of values and time have been drawn in Figure 1, Figure 2 and Figure 3.

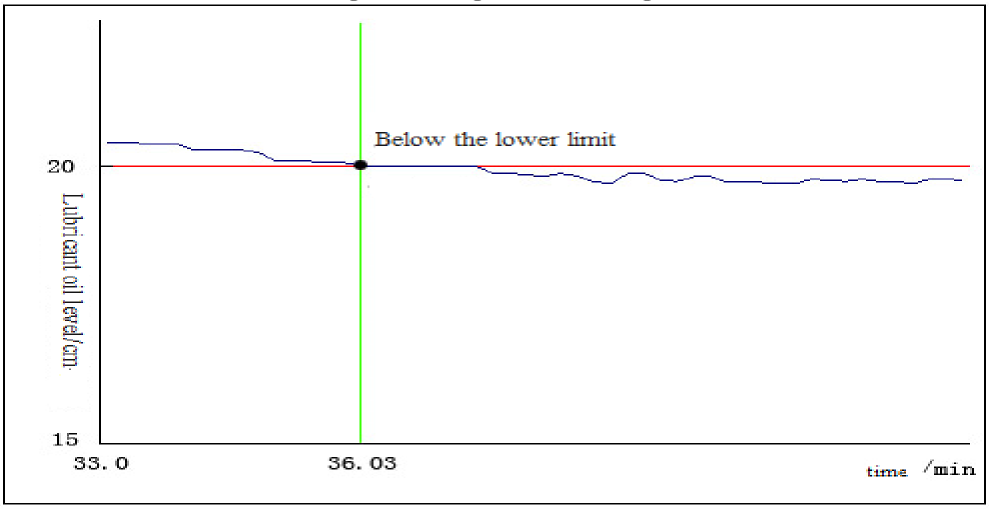

Fig. 1 Oil level curve of lubricating oil tank

From Figure 1, we know that Lubricating oil tank of liquid level has trended downward over time, and below the threshold limit at 36.03 points.

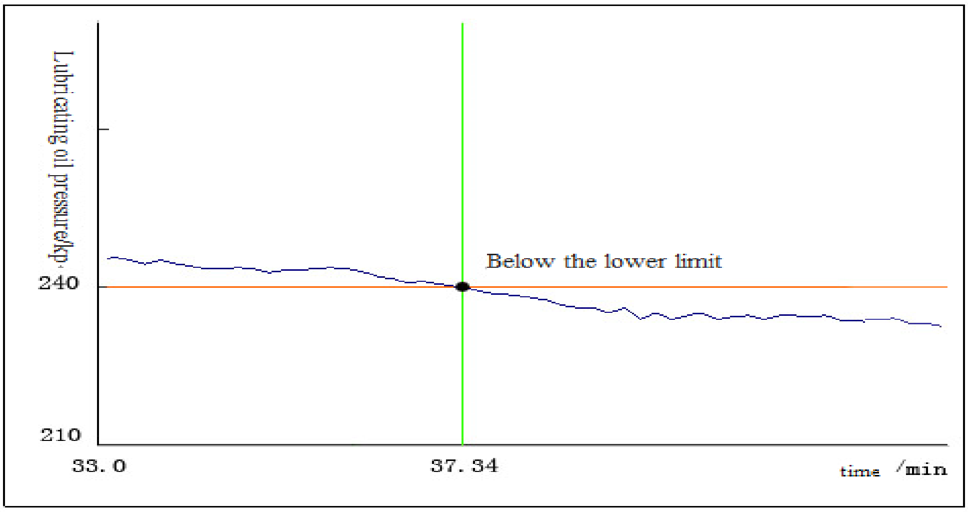

Fig. 2 Oil pressure curve of lubricating oil tank

From Figure 2, we know that lubricating oil pressure has trended downward over time, the lubricating oil level is below the lower limit at 37.34 min, lubricating oil pressure drops to the threshold limit.

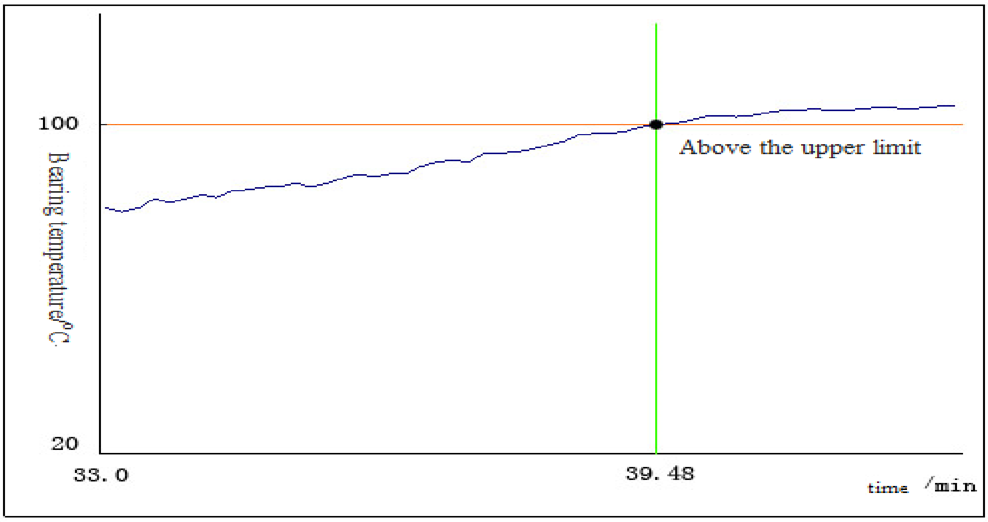

Fig. 3 Temperature curve of Gas turbine bearing

From Figure 3, we know that gas turbine bearing temperature has trended upward over time, temperature continues to rise after it is higher than the upper limit at 39.48min.

In this period of time, through the analysis, we found that: the lubricating oil tank of liquid level is low—> lubricating oil pressure is low - >bearing temperature is high. The results are shown in Table 1 below.

Table 1 SDG-HAZOP report list

System fault propagation paths：RH2—>RH1—>RJ4				
Deviation Node	Deviation	Node Number	Possible Reasons	Adverse Consequences
Gas turbine bearings temperature	High	RJ4	(1)Lubricating oil supplying quantity is not enough/ oil leak/ Lubricating oil tank of liquid level is low (2)Lubricating oil pressure is low (3)Bearing installation	Speed up the bearing wear/ Lubricating oil deterioration

			seat wear/ Oil pipe is blocked/Bearing itself is flawed	
Lubricating oil pressure	Low	RH1	Lubricating oil supplying quantity is not enough/ Oil leak/ Lubricating oil tank of liquid level is low	Gas turbine bearing temperature is high
Lubricating oil tank liquid level	Low	RH2	Lubricating oil supplying quantity is not enough / Oil leak	(1)Lubricating oil pressure is low (2)Gas turbine bearing temperature is high / Speed up the bearing wear/Lubricating oil deterioration

The results show that, in this period of time, lubricating oil system of natural gas compressor is likely to appear abnormal, leak or lack of enough oil in the lubricating oil tank. It is resulted in the lack of lubricating oil pressure, and gas turbine bearing temperature rises finally. Maybe cause the bearing wear and lubricating oil deterioration. Obviously, keep it going would cause problems of machine. According to the confirmed of field staff and the information about the data, at the scene of the day, Lack of lubricating oil caused parameters deviate from the normal values, and then Lead to abnormal. Thus, analysis results and the actual situation of the system are consistent.

Conclusion

Natural gas compressor is a key device for Natural gas pipeline transportation, which has the complex mechanical structure. The safe operation of the device is directly related to the work of the entire pipeline transportation safety. In this paper, Signed directed graph-Hazard and Operability Analysis (SDG-HAZOP) combining method is used for natural gas compressor safety analysis, and the SDG-HAZOP model for the safe operation of natural gas compressors provides a strong support for the work in future.

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