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CCC

SUCCESS STORY

CRACKED GAS COMPRESSOR CONTROL SYSTEM OPTIMIZATION (800K TPA ETHYLENE UNIT)

at Sinopec-SK (Wuhan) Petrochemical Co., Ltd

The ethylene plant's cracked gas compressor (tag:k-201) adopts a three-cylinder, five-section, fourteen-impeller compression structure.

The low-pressure cylinder is located in the first section and includes a double-intake structure with impellers in a back-back arrangement, as well as two stages with four impellers.

The medium-pressure cylinder spans the second and third sections, and has impellers in a back-to-back arrangement. The second section contains two impellers, while the third section contains three.

The high-pressure cylinder makes up the fourth and fifth sections with impellers back to back. The fourth section contains three impellers and the fifth section contains five.

The compressor is driven by ultra-high-pressure steam. In order to improve the operability and stability of the compressor unit, it utilizes a three-return-one, four-return-four and five-return-five (A/B cold reflux and hot reflux) design with a total of four anti-surge control valves. This process is shown in Figure 1.

Since system startup in 2013, it was found that the control margin between the operating point and the anti-surge control curve was too small (2 percent to 3 percent). Slightly fluctuations in the process will result in surge interlocking shutdown due to the small control

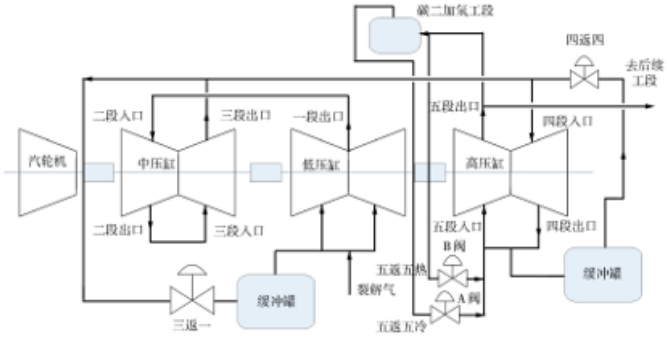


Figure 1.

margin. There was no decoupling control function between each anti-surge valve. When the three-return-one anti-surge valve was opened, the flow and pressure of the fourth inlet and outlet fluctuated drastically, which caused the four-return-four anti-surge valve to fully open. The fifth section had hot reflux and cold reflux. Hot return valve B participated in anti-surge control, while valve A was used for PID control only. When the surge occurred, valve B opened momentarily, causing the carbon dioxide hydrogenation unit to trip in the subsequent section. The one-time trip loss exceeded 20 million yuan.

Issues With the Existing ITCC Solution

1. There was no efficient coordinated control among the control loops. During operation, the four-return-four valve suddenly opened due to the opening of the three-return-one valve, resulting in over-standard vibration and subsequent shutdown.

2. There was no associated control applied to the cold and hot reflux of the fifth section anti-surge valves. PID control on the cold reflux valve could not open in time to make sure the fifth section had enough inlet flow, resulting in the opening of the hot reflux valve and then an increase of pressure and temperature of the fifth section, putting the machine at high risk of being tripped.

   The rotational speed was manually input and could not be fully automated, which was not conducive to achieving accurate inlet pressure control. This affected the yield of ethylene and propylene. TrainLink with CCC Vanguard controllers at Station A.

Control System Optimization Objects

1. A surge test should be conducted during the startup procedure to find the real surge line and performance curve. The test should not cause any damage to the machine and should avoid tripping.

2. Anti-surge control should be automatic. The anti-surge valve should fully close to ensure energy-savings, safe operation and protection of the unit.

3. Under low loading conditions, the compressor should run smoothly at the lowest energy consumption. When the cracking furnace is abnormally shut down within four furnaces, it should not cause the cracking gas compressor to stop. When the unit loading reaches 70 percent or more, the anti-surge valve should fully close.

4. Cascade control should be applied to compressor inlet pressure and speed controls. Stabilizing the inlet pressure control will reduce the inlet pressure fluctuation and achieve automatic control in case fewer than four cracking furnaces suddenly stop. The inlet pressure should be controlled at 25 kPa and the fluctuation deviation should not exceed 1 kPa in the circumstance of proper process conditions.

5. Decoupling control should be applied to the inlet pressure and three-return-one anti-surge valve controls, as well as the four-return-four and five-return-five anti-surge valve controls. The fourth section anti-surge valve should be properly controlled and should not cause high vibration and trip when it is opened from 0 percent to 100 percent.

6. Through the coordinated control of the A and B valves, the five-stage anti-surge should not only effectively prevent the machine from surge, but also should not cause the C2 hydrogenation system to have low airspeed that could result in a machine trip.

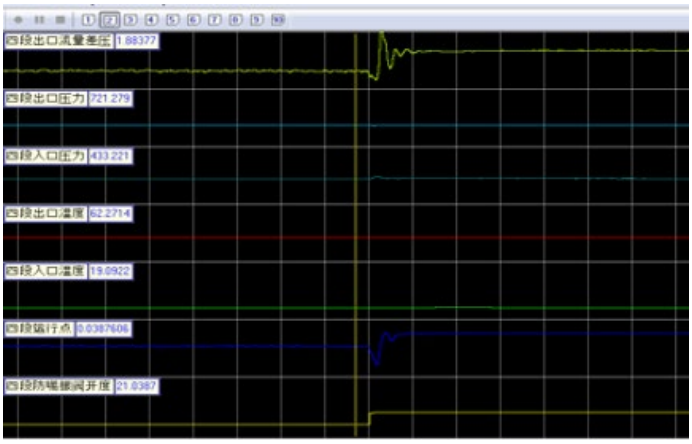
7. Automatic control should be achieved for turbine speed and extraction control at the same time. Decoupling control should be applied to the speed and extraction controllers to ensure extraction control is automatic, thus providing stability to turbine speed. According to the steam turbine intake/extraction power curve, efficiency of the steam turbine should be optimized and the steam pipe network should be stabilized.

8. Fallback control strategy should be implemented for instrument failure to ensure automatic control when the instrument fails abnormally. An instrument abnormal fault alarm should be provided.

9. The cracker gas compressor control system should be synchronized with the GPS clock.

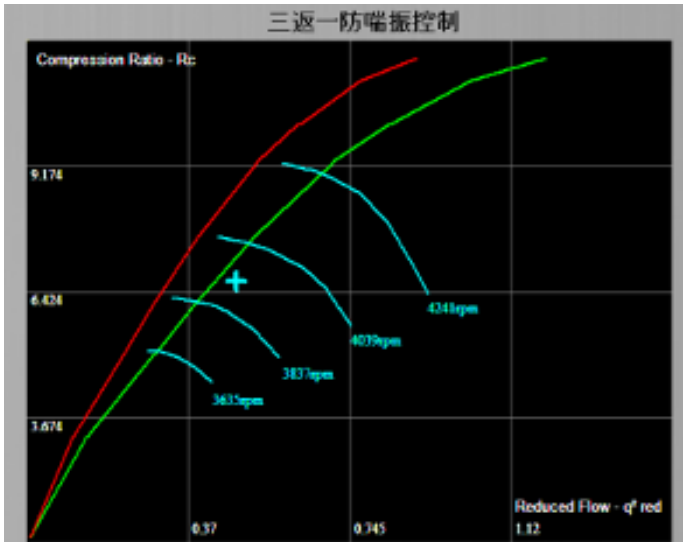
Execution

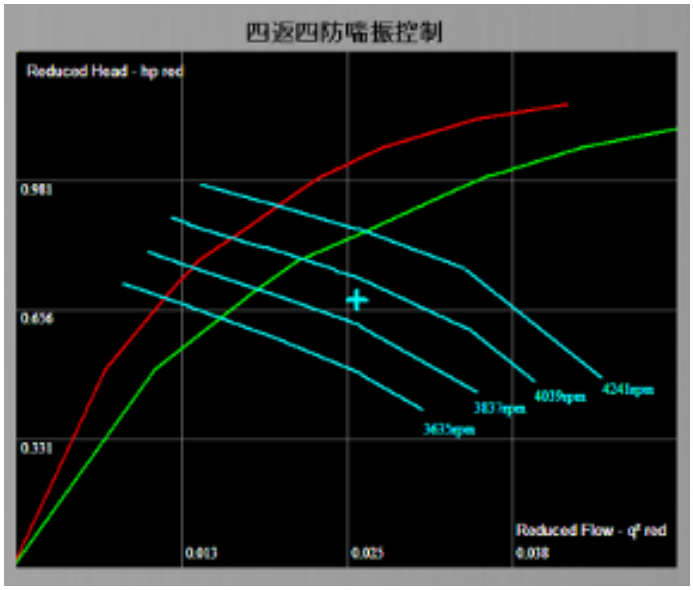
1. Remove surge control and speed control function from the existing controller and use the CCC Series 5 Vanguard to control anti-surge, performance, speed and extraction.
2. CCC S5 Vanguard Applications:
   - Anti-Surge Control
   - Performance Control
   - Speed Control
   - Extraction Control
3. Real-time surge test during startup



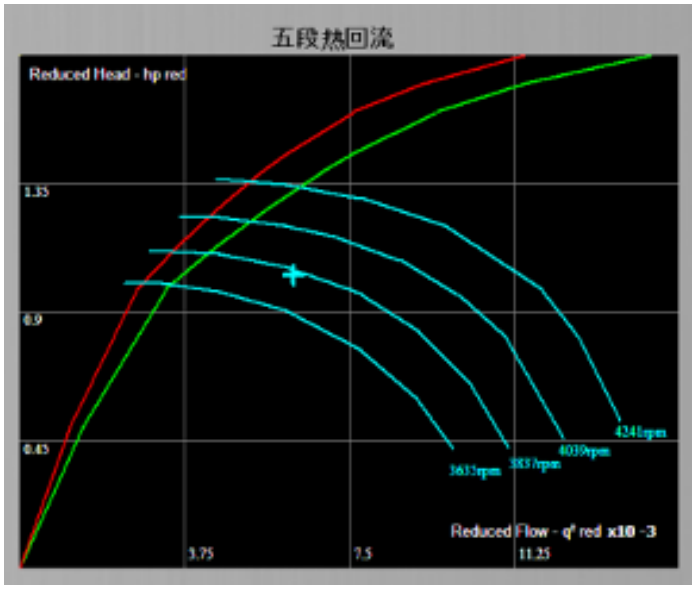
Comparison between real surge line and estimated surge line

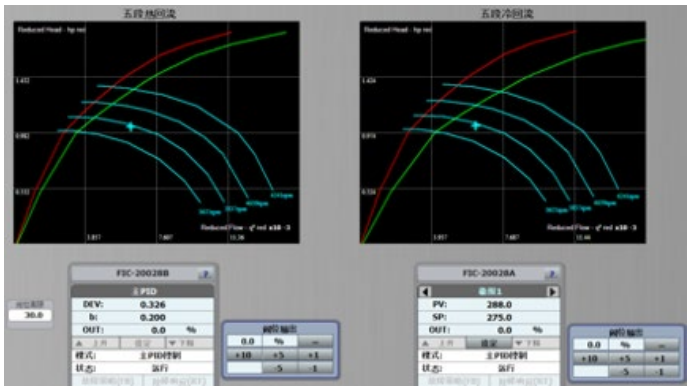
Three-return-one surge line moved 5 percent toward left; four-return-four surge line moved 15 percent toward right.





Five-return Five surge line moved 7% towards right.





As can be seen from the above figure, the surge lines of the hot and cold reflux are the same, but different anti-surge lines were set. When the operating point was close to the surge line, the cold reflux valve opened first. When the operating point was away from the surge line, the hot reflux valve closed first. At the same time, the minimal flow control from the fifth-stage outlet to C2 hydrogenation unit was set on the cold reflux controller to prevent the C2 hydrogenation unit from tripping after the opening of the hot reflux valve.

4. Retrofit on Performance Control

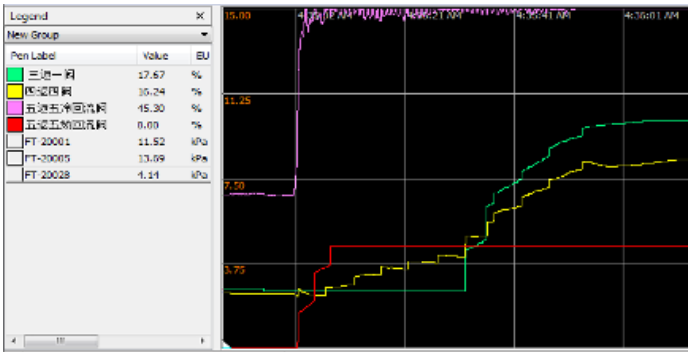
   After the retrofit, the cascade control was put into the speed controller and the speed was automatically adjusted according to the set value of the inlet pressure.

Results

1. The recycle valves fully closed.

2. All the controllers operated automatically and the inlet pressure control was stable.

3. During startup at 2:20 a.m. on June 1, the fifth-stage inlet flow was severely degraded due to blockage on the inlet filter by mechanical impurities. The fourth-stage outlet was operating under pressure. The low between the fourth and fifth sections were interrupted and the sections were cycled. Under this major fluctuation, the operator did not do anything to the control system. The CCC controller opened each recycle valve to a certain degree automatically, ensuring that the compressor was away from the surge in time and avoiding a trip when the vibration on fourth stage was over high (the highest vibration value of the fourth stage was detected as 63um and the interlock value is 89um).



4. After the retrofit, steam consumption was reduced by 10t/hour. At the time of publication, the price of steam was approximately CNY180.00/t, making the cost-savings value approximately CNY1,800/hour. If the machine runs 8,000h/year, it will save CNY14.4M/year.

Conclusion

Through the control system retrofitting on the cracking gas compressor, a step-response anti-surge strategy was added to the control system, improving the decoupling function of the anti-surge valve and achieving a fully closed anti-surge valve. Through the actual anti-surge test during start-up, the true surge curve was measured and the operating area of the compressor was adjusted according to the measured curve. When surge occurs, the operating point can be safely pulled back to the safe area. This reduces material backflow; saves 10t in ultra-high-pressure steam consumption per hour while running 7 furnaces; and effectively reduces fluctuations in or unplanned shutdowns of key units. The economic benefits and environmental benefits are obvious.

CCC Retrofit Services

From the proposal stage all the way through commissioning, CCC's retrofit services deliver high-performance, fully optimized turbomachinery controls. Regardless of who manufactured the original equipment, our expert teams will implement ultra reliable, field-proven control solutions that result in improved plant efficiency and uptime.

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